IF 4061
Visualisasi Data dan Informasi

Interactive Visualization

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Sekolah Teknik Elektro & Informatika

Contents

- Data manipulation loop
- Exploration and navigation loop

Acknowledgement

Most of the contents of the slides were taken from:

Colin Ware. Information Visualization : Perception for Design 2ed. Morgan Kaufmann. 2004 Chapter 10

Interactive Visualization Mantra

"Overview first,

zoom and filter,

then details on demand"

(Shneidermann, 1998)

Good Visualization

- <u>One of its parameter:</u>

  Allows users to drill down and find more data that seems important
- Examples:
  - To see an interesting detail (by zooming in)
  - To get an overview (by zooming out)
  - To find some related information in a lateral segue
    - Displaying information needed and disappearing when not needed

Interactive Visualization

→ A process made up a number of interlocking feedback loops

Criteria for Interactive Visualization

1. **Human input**:
   - *Availability of control* of some aspect of the visual representation of information
   - Examples of input devices for interactive operations: trackball, mouse, joystick

2. **Response time**:

   Changes made by the human must be *incorporated* into the visualization in *a timely manner*

Three Broad Classes

1. Data manipulation loop
   – Objects are selected and moved using basic skill of eye-hand coordination
2. Exploration and navigation loop
   – Users find his/her way in a large visual data space
3. Problem solving loop
   – Users form hypothesis about the data
   – Refine them through an augmented visualization process
   – May be repeated through multiple visualization cycles

1. DATA MANIPULATION LOOP

Data Selection and Manipulation Loop

- Main Issue:

  Delays (even a fraction of a second) can seriously disrupt the performance

- Related to:

  1. Choice of reaction time
  2. 2D positioning and selection
  3. Hover queries
  4. Path tracing
  5. Two-handed interactions
  6. Learning
  7. Control compatibility
  8. Vigilance

1. Reaction Time in Optimal Readiness (Kohlberg, 1971)

- A person can react to a simple visual signal in about 130 msec given an optimal state of readiness
- Sometimes, before someone can react to a signal, he/she must make a choice

Hick-Hyman law (1953)

- Hick-Hyman law for choice of reaction time:

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

  - C : the number of choices
  - a and b : empirically determined constants (depends on the device/app)
  - $\log_2(C)$: the amount of information processed by a human operator (bits of information)

Factors affecting choice reaction time

- The distinctness of the signal
- The amount of visual noise
- Stimulus-response compatibility
- Degree of accuracy required

   people respond faster if they are allowed to make mistakes occasionally (speed accuracy trade-off)

- etc *(For a useful overview of factors involved in determining reaction time, see Card et al, 1983)*

Reaction Time on Optimal conditions

- Under optimal conditions, the response time per bit of information processed is about 160 msec plus the time to set up the response

2. Two-D Positioning and Selection

- In interactive visualization application, graphical object functions has two main functions:
  - for presenting data (output)
  - As a way of finding out more about data (input)

Fitt's law (Paul Fitts, 1954)

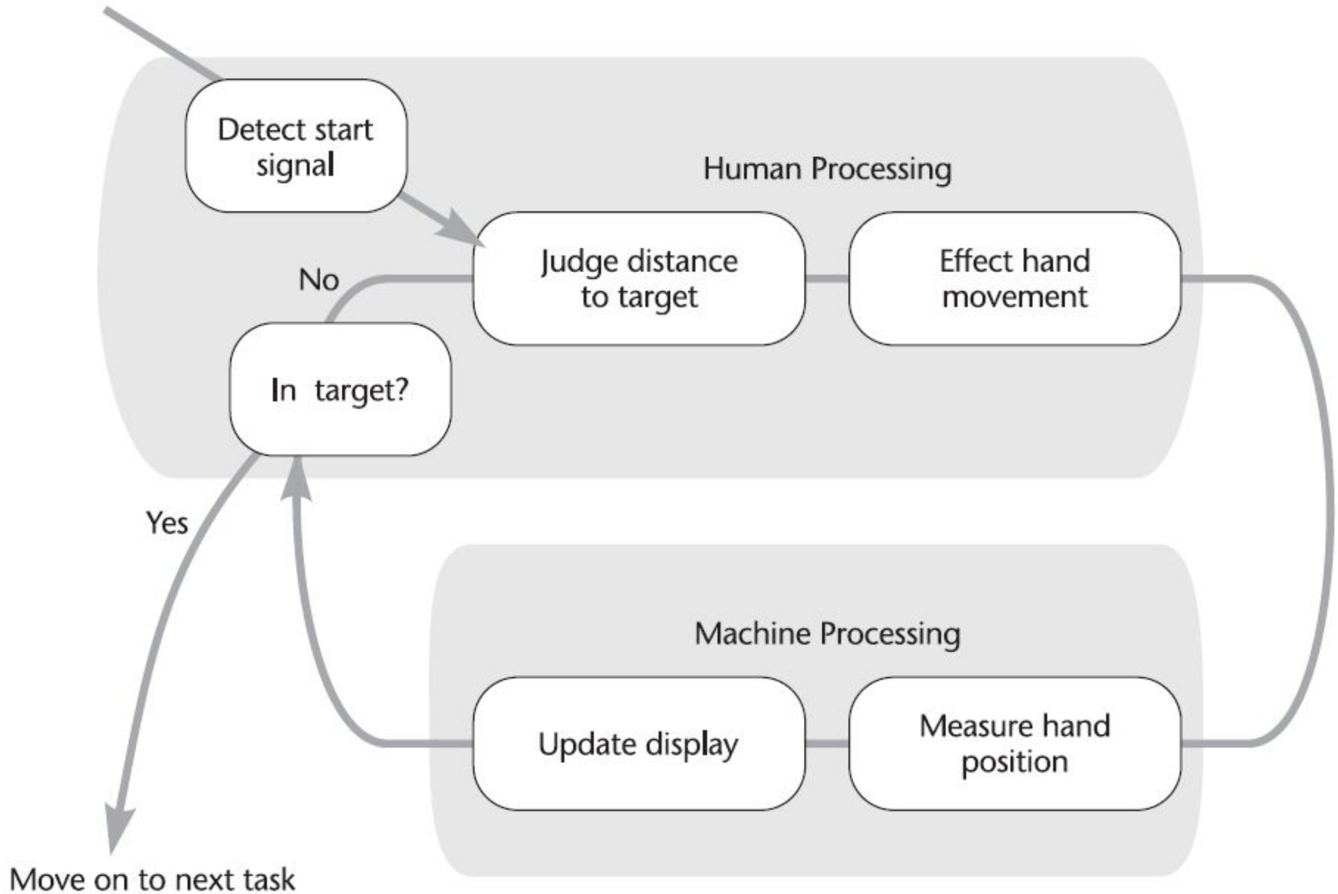
- To estimate the time taken to select a target that has particular position and size:

$$\text{Selection time} = a + b \log_2(D/W+1.0)$$

  - D: distance to the center of the target
  - W: the width of the target
  - a and b: empirically determined constants
  - $\log_2(D/W+1.0)$ is called *index-of-difficulty*

Fitt's law (Cont.)

- Also describing an iterative process of eye-hand coordination



Fitt's law (Cont.)

- There is a significant lag between a hand movement and the visual feedback provided on the display
  - Especially In more complex data visualization systems such as 3D VR technologies
- Fitt's law modified to include machine-lag

$$\text{Mean Time} = a + b\,(\text{Human Time} + \text{MachineLag})\text{Log}^2(D/W+1.0)$$

3. Hover Queries

- Extra information is revealed about an object when the mouse cursor passes over it
- Implementation:
  - with a delay
    - the function of an icon is shown by a brief text message after hovering for a second or two
  - without a delay
    - the mouse cursor to be dragged over a set of data objects, rapidly revealing the data contents and perhaps allowing an interactive query rate of several per second in special circumstances

4. Path Tracing

- On tasks e.g. tracing a curve or steering a car, involve continuous ongoing control

 continually making a series of corrections based on visual feedback of the recent actions

- Accot & Zhai (1997) derive a prediction about continuous steering tasks (based on Fitt's law):

$$v = W/\tau$$

  - v: velocity
  - W: path width
  - τ: constant (depending on the motor control system)

5. Two-Handed Interaction

- Interaction using both of our hands
- Guiard's *kinematic chain theory* (Guiard, 1987):
  - the left hand and the right hand form a kinematic chain
    - the left hand providing a frame of reference for movements with the right (in right-handed individuals)

Example: Two-Handed Interaction

- Computer-based drawing package [Kurtenbach et al., 1997; Bier et al. 1993]
  - Move templates with left hand, paint around the shapes with right hand
  - Position tool palettes with left hand, normal draw with right hand

6. Learning

- The *power law of practice* describes the way task performance speeds up over time:

$$\log(T_n) = C - \alpha \log(n)$$

  - C = log(T1): based on the time to perform the task on the first trial
  - T_n : time required to perform the n^{th} trial
  - a: constant (the steepness of the learning curve)
- Skill learning is characterized by more and more of the task becoming automated and encapsulated.
- The computer system should provide rapid and clear feedback of the consequences of user actions (Hammond, 1987)

7. Control Compatibility

- Stimulus–response (S–R) compatibility
- It will be easier to execute tasks in computer interfaces if they are designed based on previously learned ways of doing things, e.g.:
  - Easier to learn: move a computer mouse to the right, causing an object on the screen to move to the right
  - The opposite will be more difficult to learn
- Skill learning factors:
  - Consistency with real-world actions
  - Simple physical affordances

8. Vigilance

- A need to understand how people can maintain *vigilance* while performing monotonous tasks
  - e.g.
    - monitoring radar screens for long hours
    - airport baggage X-ray
    - industrial quality-control inspection
    - large power grids

Wickens (1992): Vigilance

- To perform a difficult vigilance task effectively requires a high level of sustained attention, using significant cognitive resources

- Vigilance performance falls:
  - substantially over the first hour
  - because of fatigue
  - by Irrelevant signals

Improve Vigilance

- Provide reminders at frequent intervals about what the targets will look like
- Take advantage of the visual system’s sensitivity to motion
- Make the signal perceptually different or distinct (in color, motion, texture, etc.) from irrelevant information

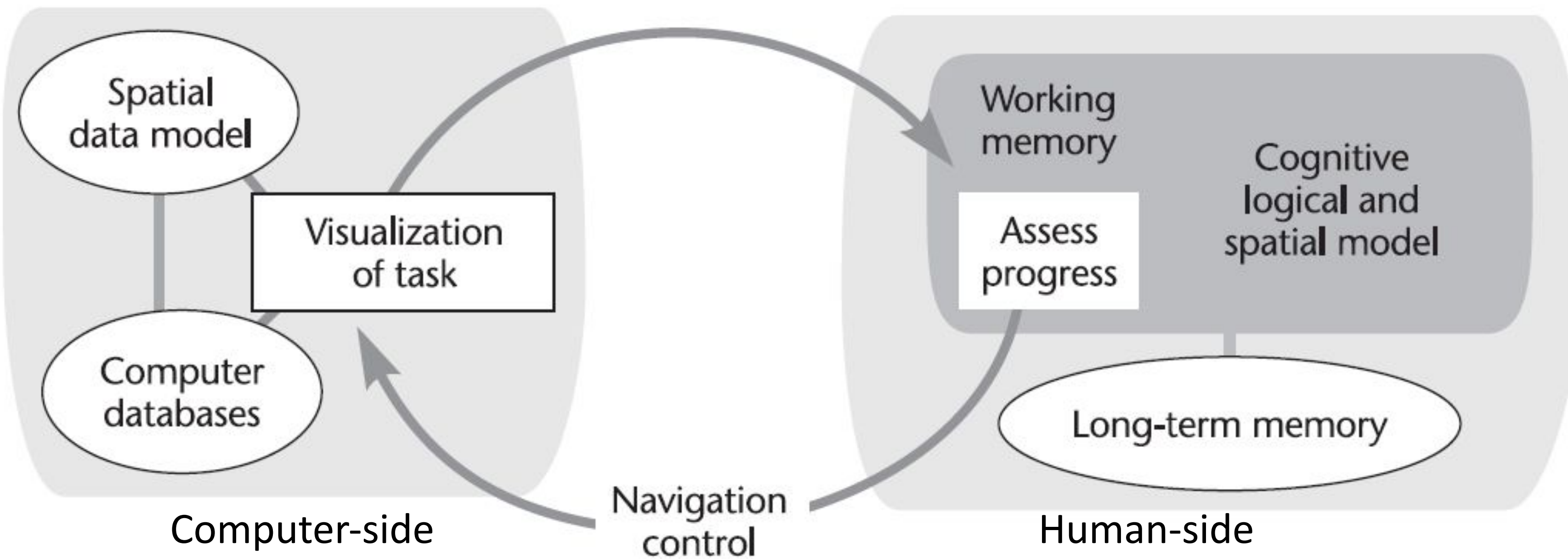
2. EXPLORATION AND NAVIGATION LOOP

Exploration and Navigation Loop (1)

- View navigation mapping the data into an extended and detailed visual space
- Issues:
  - complex, encompassing theories of path-finding and map use,
  - cognitive spatial metaphors
  - direct manipulation and visual feedback
- Problems:
  - Locomotion and viewpoint control
  - Frames of reference
  - Map orientation
  - Focus, context, and scale
  - Rapid interaction with data

Exploration and Navigation Loop (2)

- The basic navigation control loop



Locomotion and Viewpoint Control (1)

- Some data visualization environments show information in such a way that it looks like a 3D landscape, not just a flat map
- We should find it easy to navigate through data
- Locomotion is largely about:
  - perceiving and using the affordances offered for navigation by the environment [Gibson, 1986]

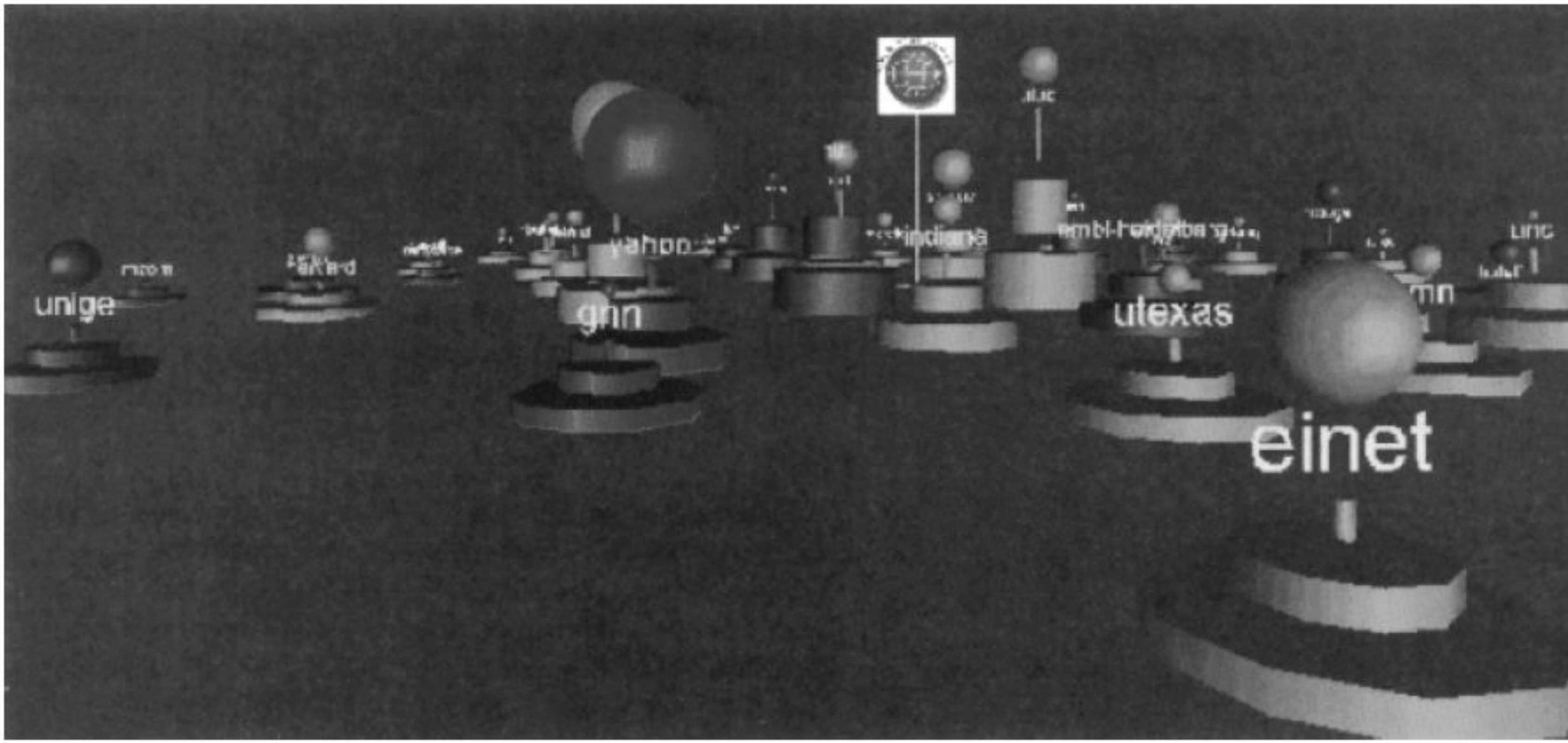


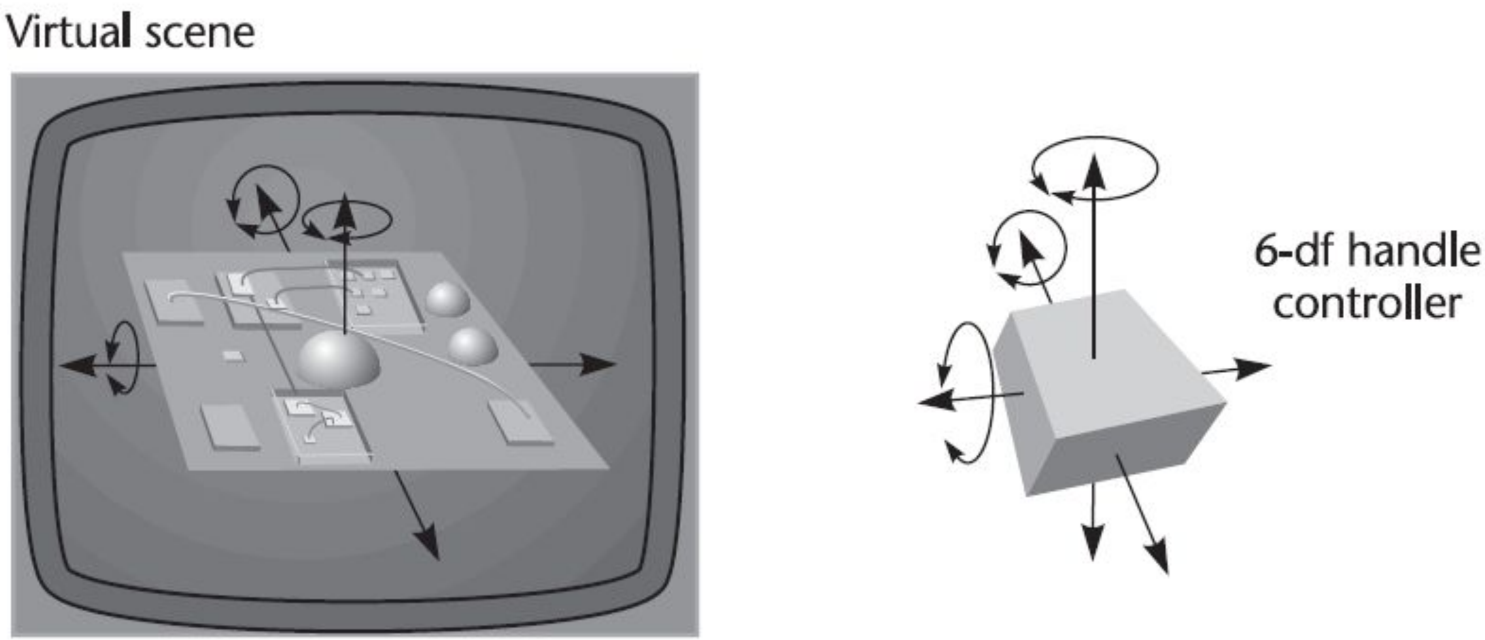
Figure 10.3 Web sites arranged as a data landscape (T. Bray, 1996).

Locomotion and Viewpoint Control (2)

- *Spatial navigation metaphors/interaction metaphors*:
  Cognitive models for interaction that can profoundly influence the design of interfaces to data spaces.
- 4 main classes of metaphors of controlling the viewpoint in virtual 3D spaces:
  - World in hand
  - Eye-ball in hand
  - Walking
  - Flying

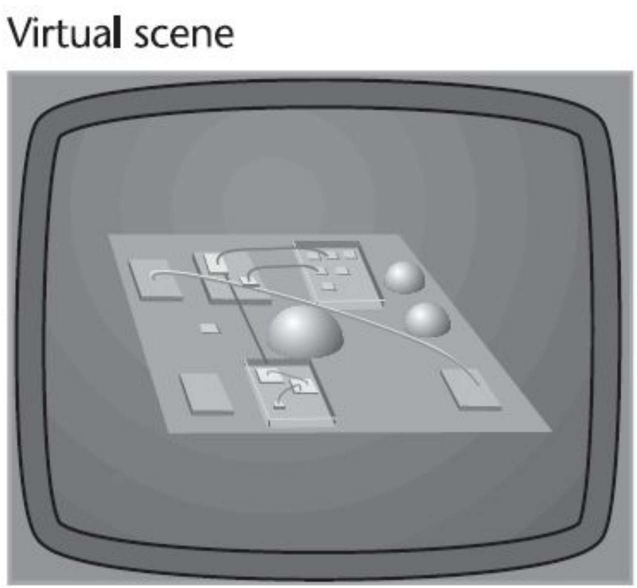
Locomotion and Viewpoint Control (3)

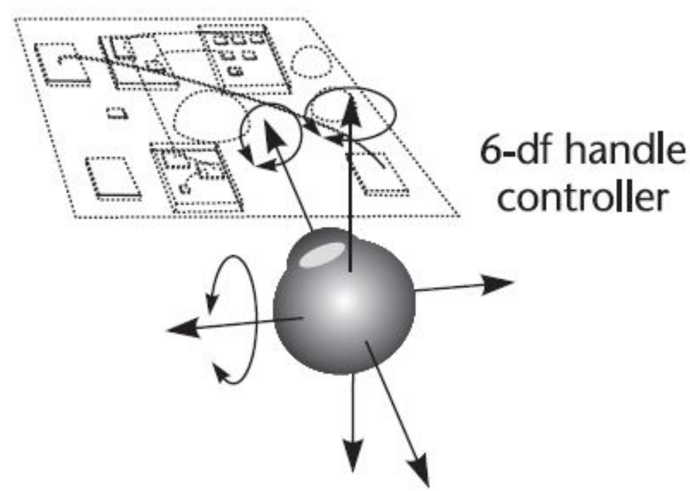
- World in hand
  - The user metaphorically grabs some part of the 3D environment and moves it



Locomotion and Viewpoint Control (4)

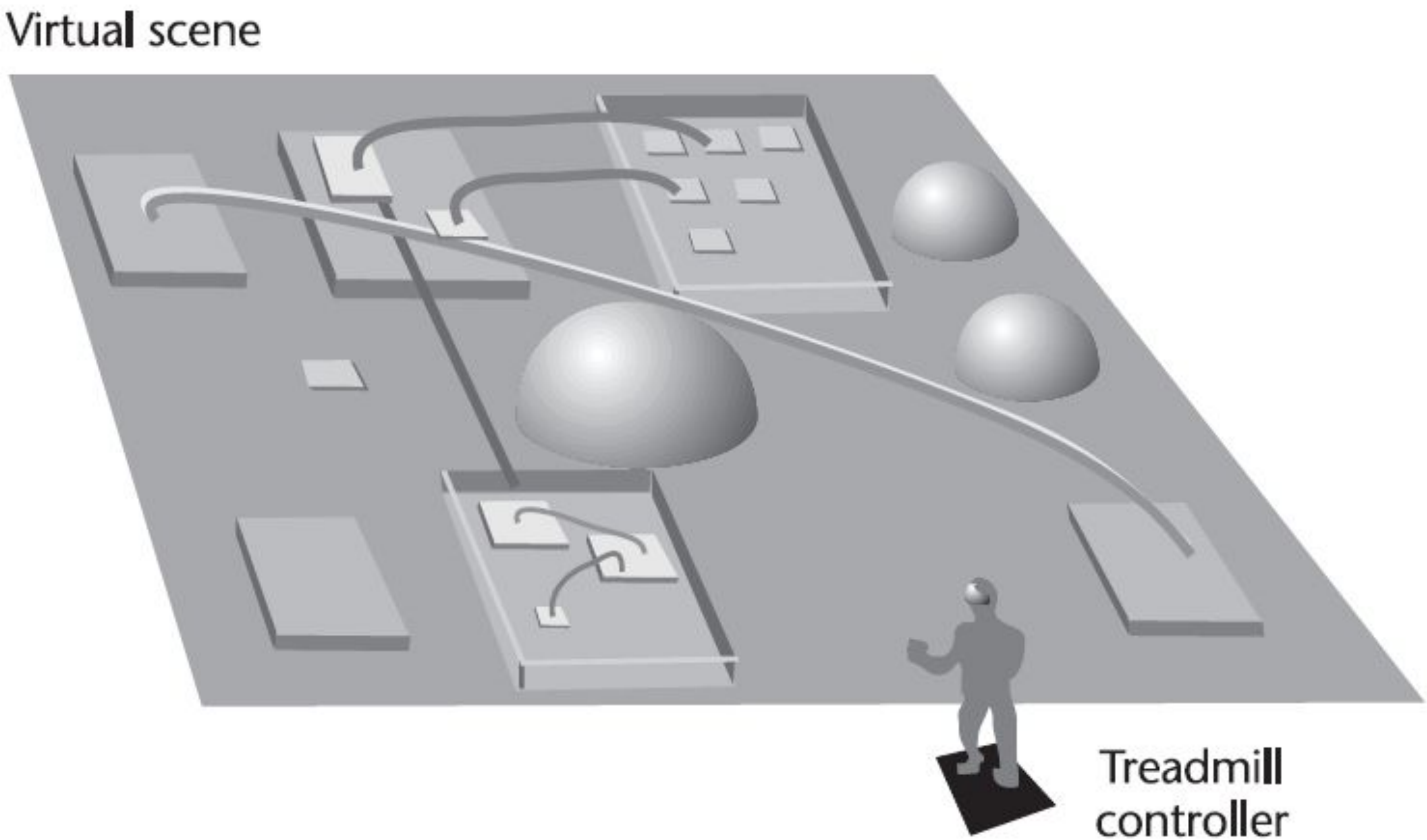
- Eyeball in hand
  - the user imagines that he/she is directly manipulating her viewpoint, much as she might control a camera by pointing it and positioning it with respect to an imaginary landscape





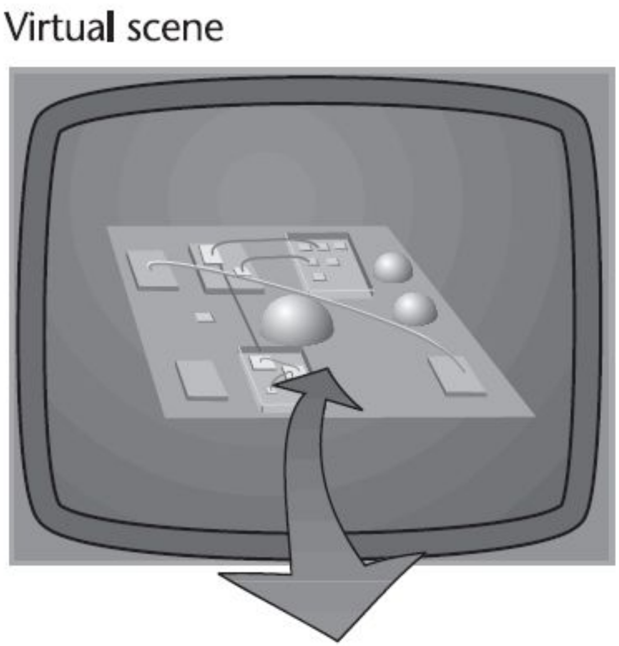
Locomotion and Viewpoint Control (5)

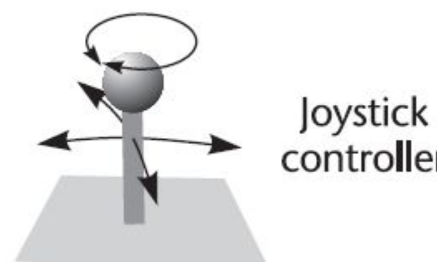
- Walking



Locomotion and Viewpoint Control (6)

- Flying
  - fly-through interfaces that enable users to smoothly create an animated sequence of views





Locomotion and Viewpoint Control (7)

- Wayfinding:
  - encompasses both the way in which people build mental models of extended spatial environments and the way they use physical maps as aids to navigation
- Siegel & White (1975) 3 stages to form wayfinding knowledge:
  - **Declarative knowledge**: information about key landmarks is learned
  - **Procedural knowledge**: routes from one location to another, landmarks as decision points, connecting links between locations (topological knowledge)
  - **Cognitive spatial maps** :a representation of space that is two-dimensional, includes quantitative information about the distances between the different locations

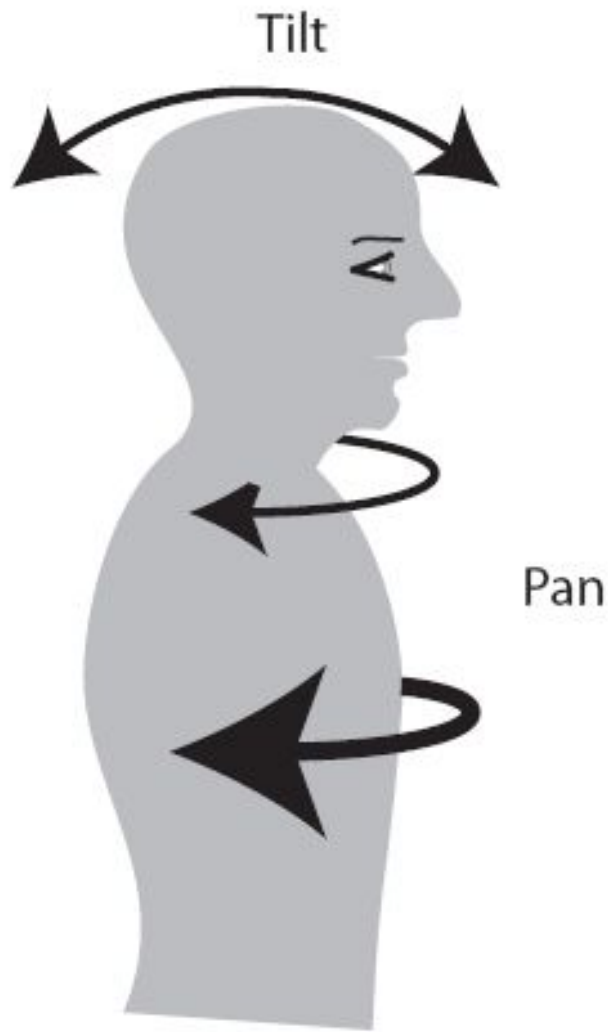
Lynch's Types	Examples	Functions
Paths	Street, canal, transit line	Channel for navigator movement
Edges	Fence, riverbank	Indicates district limits
Districts	Neighborhood	Reference region
Nodes	Town square, public building	Focal point for travel
Landmarks	Statue	Reference point into which we cannot enter

Figure 10.5 The functions of different kinds of landmarks in a virtual environment. *Adapted from Vinson (1999).*

Frames of Reference (1)

- The ability to generate and use something cognitively analogous to a map can be thought of as applying another perspective or *frame of reference* to the world
  - **Egocentric**: subjective view to the world
  - **Exocentric**: external view to the world
    - E.g. monitoring avatars in video games, controlling virtual cameras in cinematography, monitoring the activities of remote or autonomous vehicles

Primary Rotation Axes of Egocentric Coordinates



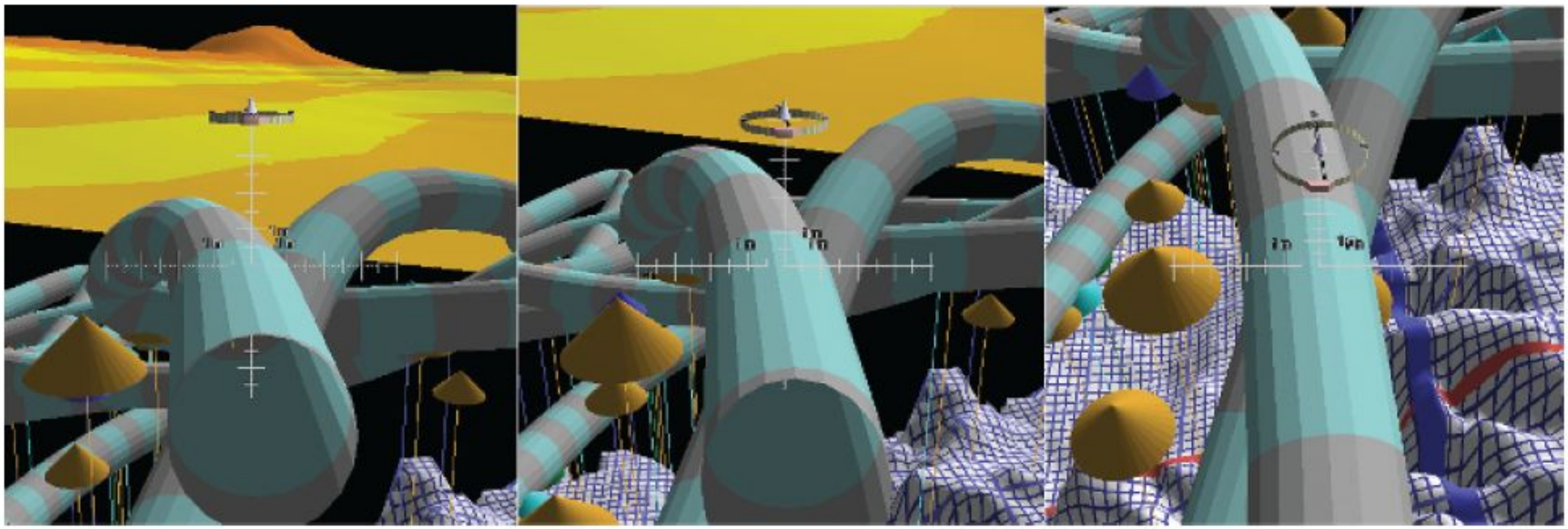
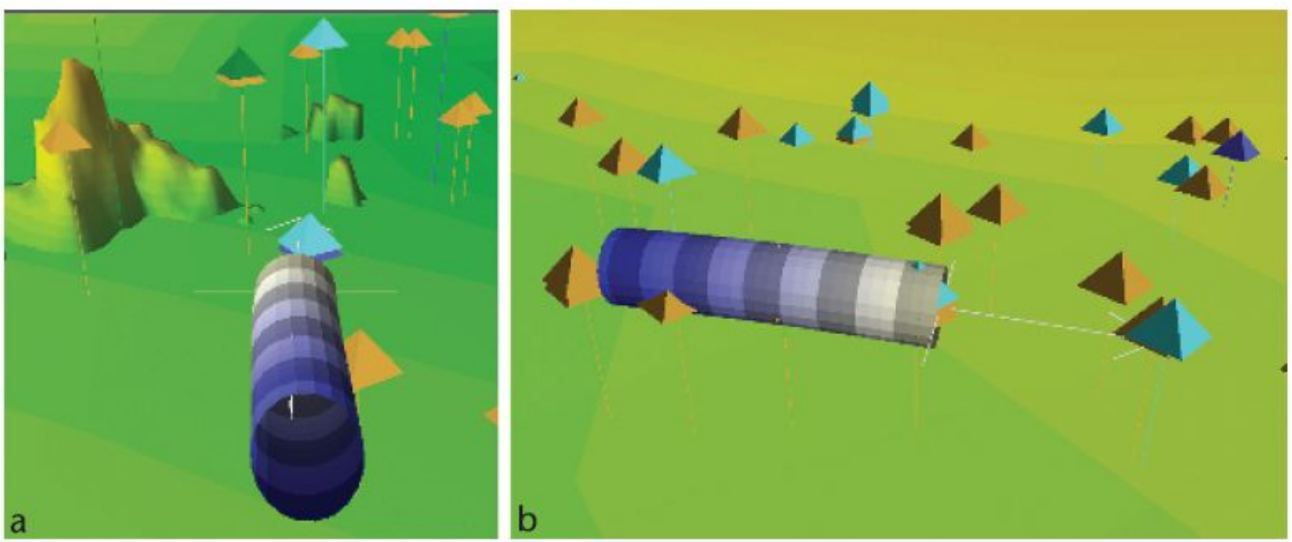


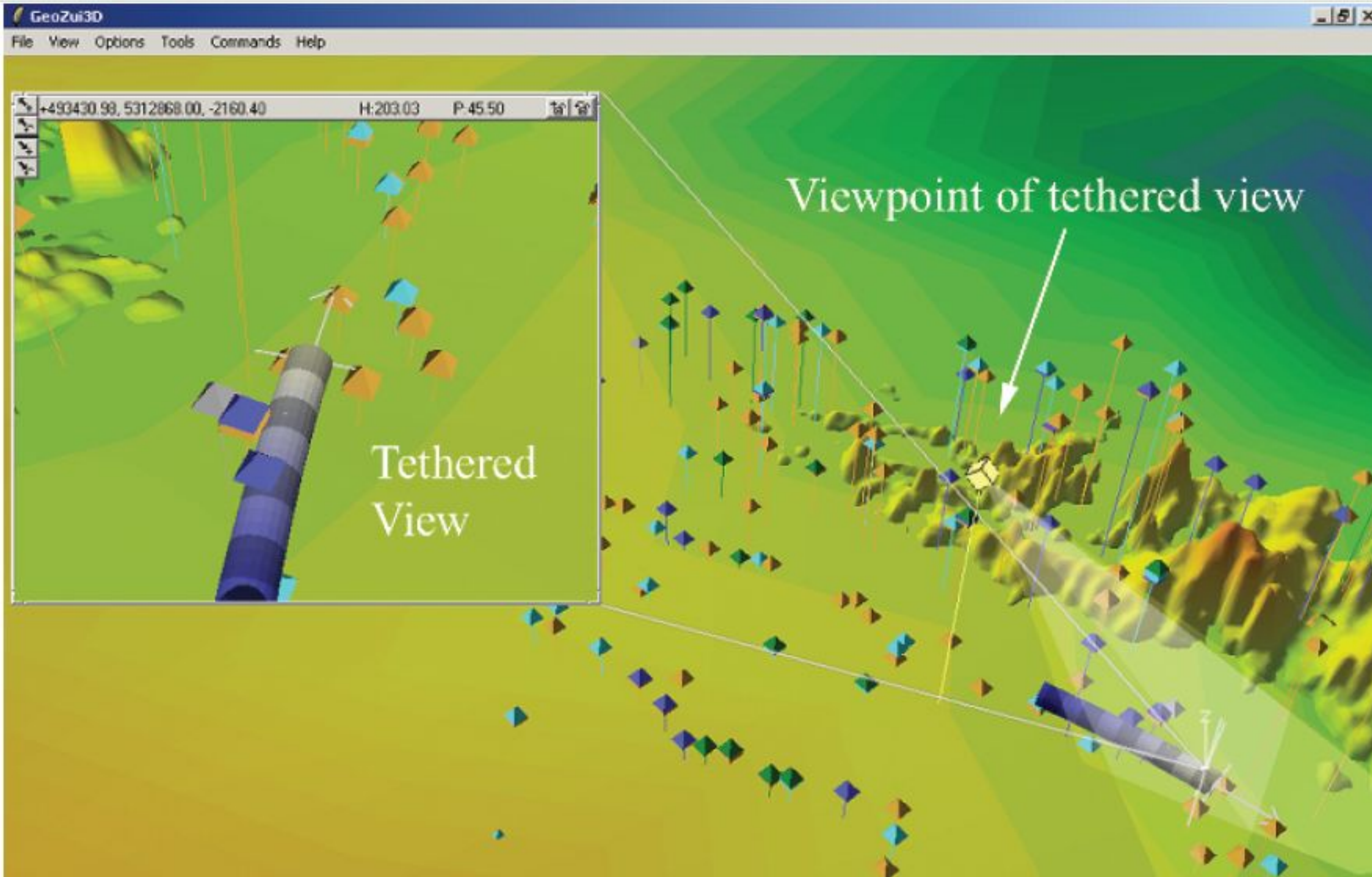
Figure 10.8 View-control widgets for examining geographic data. Note that the rotational degrees of freedom match the rotational degrees of freedom of egocentric coordinates. The three views show different amounts of tilt. The handle on the top widgets can be dragged left and right around the ring to change the view heading.

Frames of Reference (2)

- Important **exocentric** views
  - Another person's view
  - Over-the-shoulder view
  - God's eye view
  - Wingman's view
  - Map view



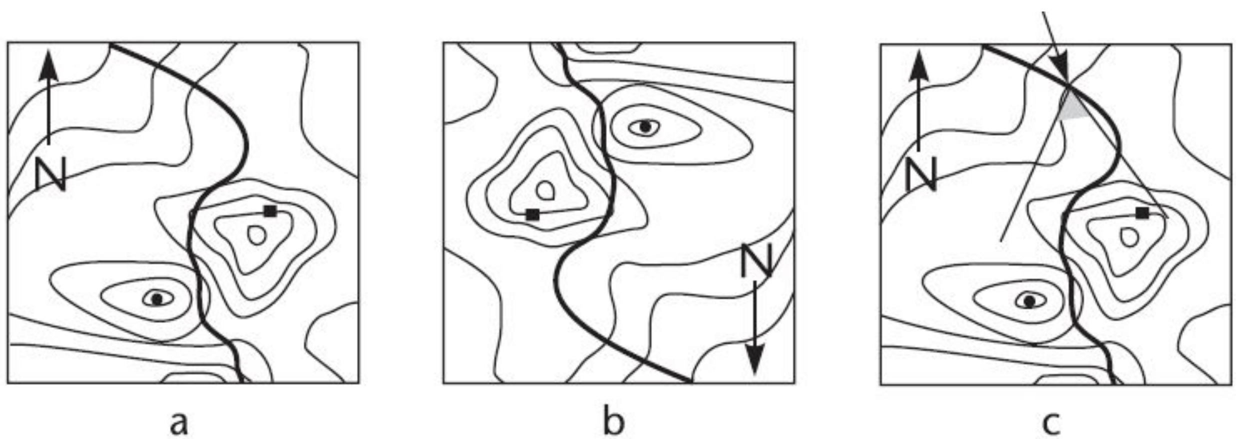
(a) God's-eye view of a moving vehicle shown by the tube object in the foreground. (b) Wingman's view of the same vehicle.



The subwindow in the upper left corner provides a tethered view. The overview contains a number of graphical devices to make the tethering explicit (Plumlee and Ware, 2003).

Map Orientation (1)

- To display map:
  - the track-up display
  - the north-up display



(a) North-up map. (b) Track-up map. (c) North-up map with user view explicitly displayed.

Map Orientation (2)

- Supporting visualizations with maps:
  - Overview maps should be provided when an information space is large
  - User location and direction of view within the map should be indicated “You are here” arrow
  - Imagery of key landmarks should be provided

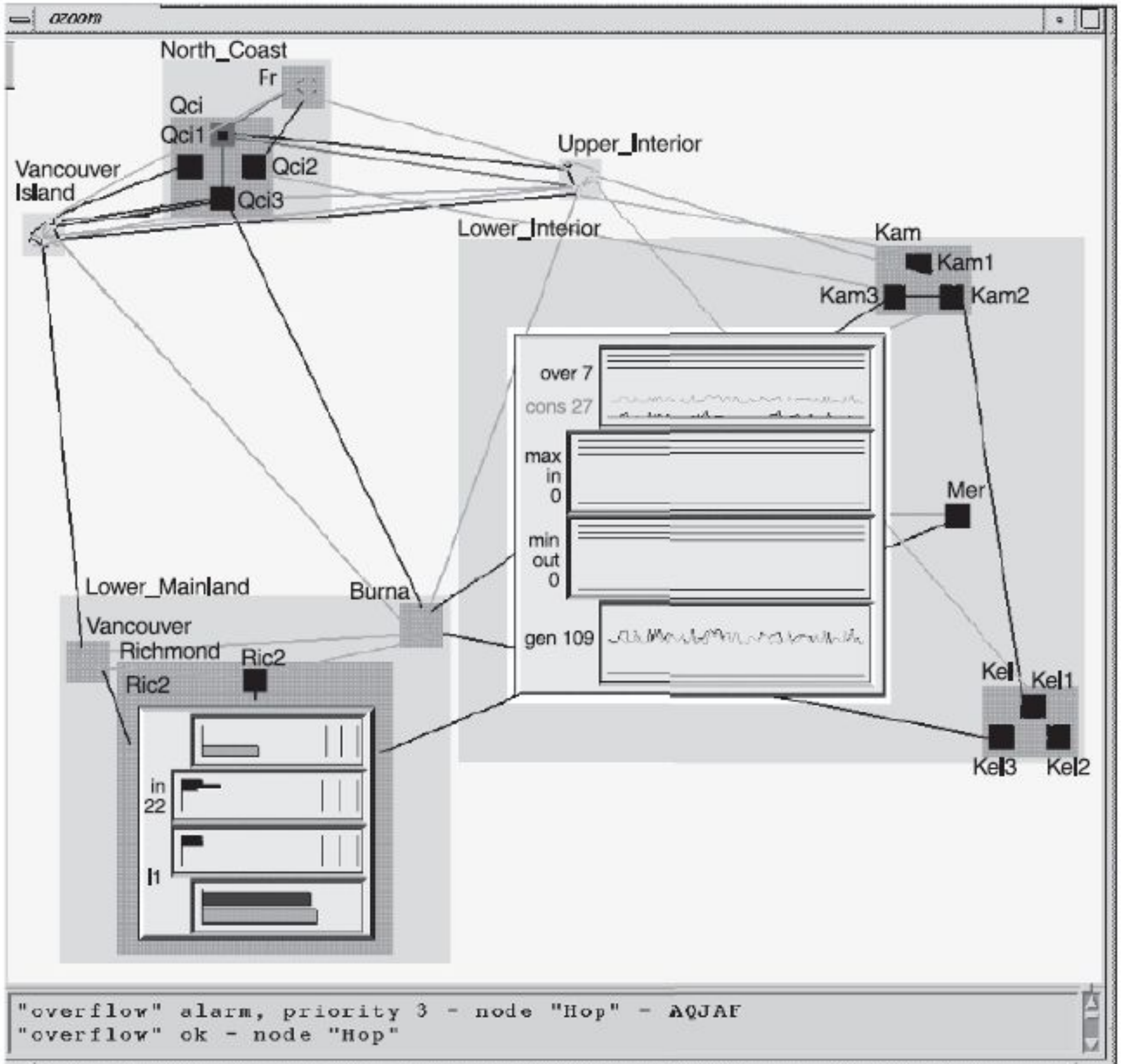
Focus, Context, and Scale (1)

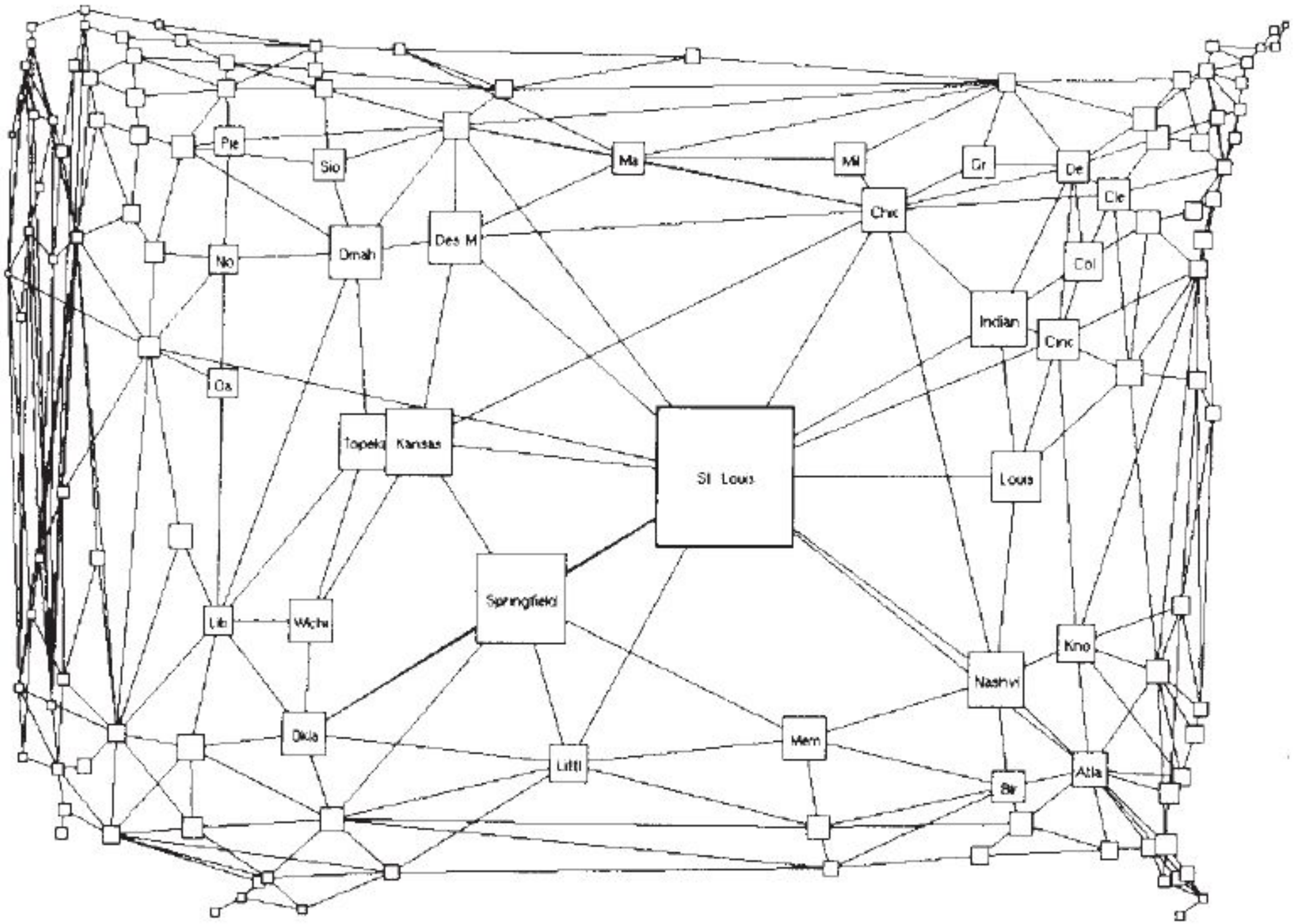
4 different visualization techniques:

1. Distortion
2. Rapid zooming
3. Elision
4. Multiple windows

Focus, Context, and Scale (2) : 1. Distortion

- Distort a data representation:
  - giving more room to designated points of interest
  - decreasing the space given to regions away from those points

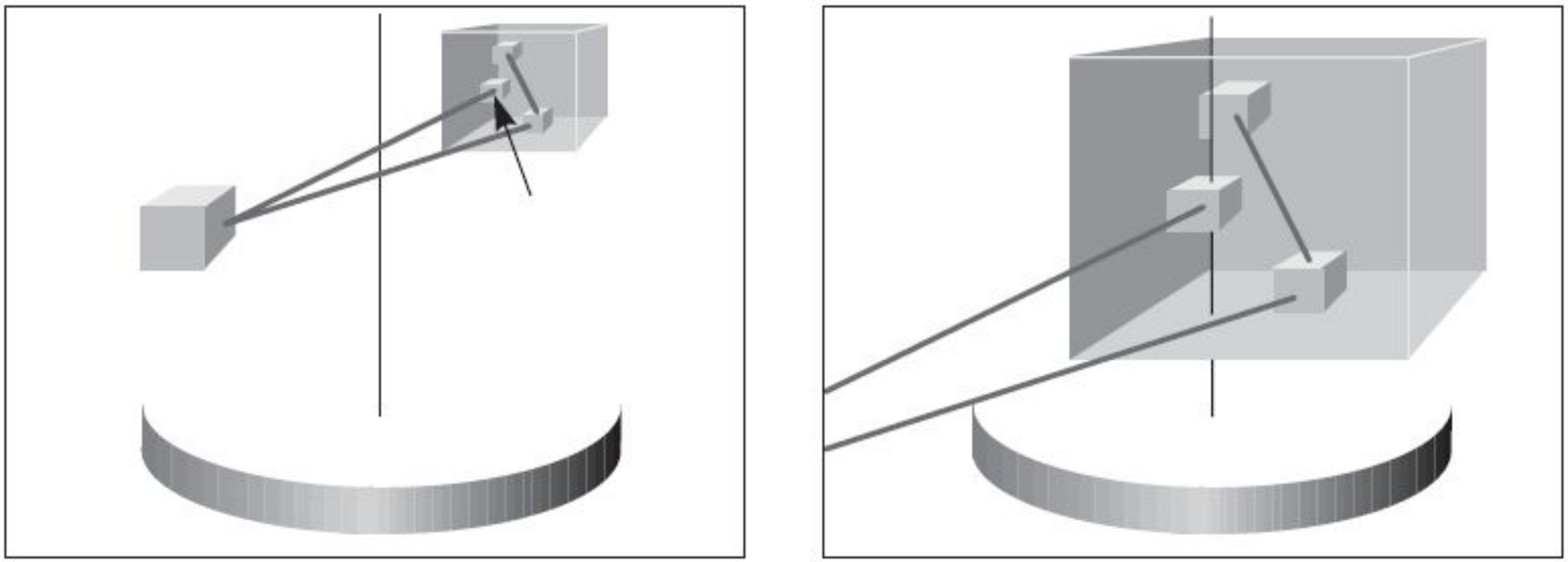

ozoom
North_Coast
Fr
Qci
Qci1
Qci2
Qci3
Vancouver Island
Upper_Interior
Lower_Interior
Kam
Kam1
Kam2
Kam3
over 7
cons 27
max in 0
min out 0
gen 109
Mer
Kel
Kel1
Kel2
Kel3
Lower_Mainland
Burna
Vancouver
Richmond
Ric2
Ric2
in 22
l1
"overflow" alarm, priority 3 - node "Hop" - AQJAF
"overflow" ok - node "Hop"



Fish-eye view of links between major American cities. The focus is on St. Louis (Sarkar and Brown 1994).

Focus, Context, and Scale (3): 2. Rapid Zooming Techniques

- A large information landscape is provided, although only a part of it is visible in the viewing window at any instant



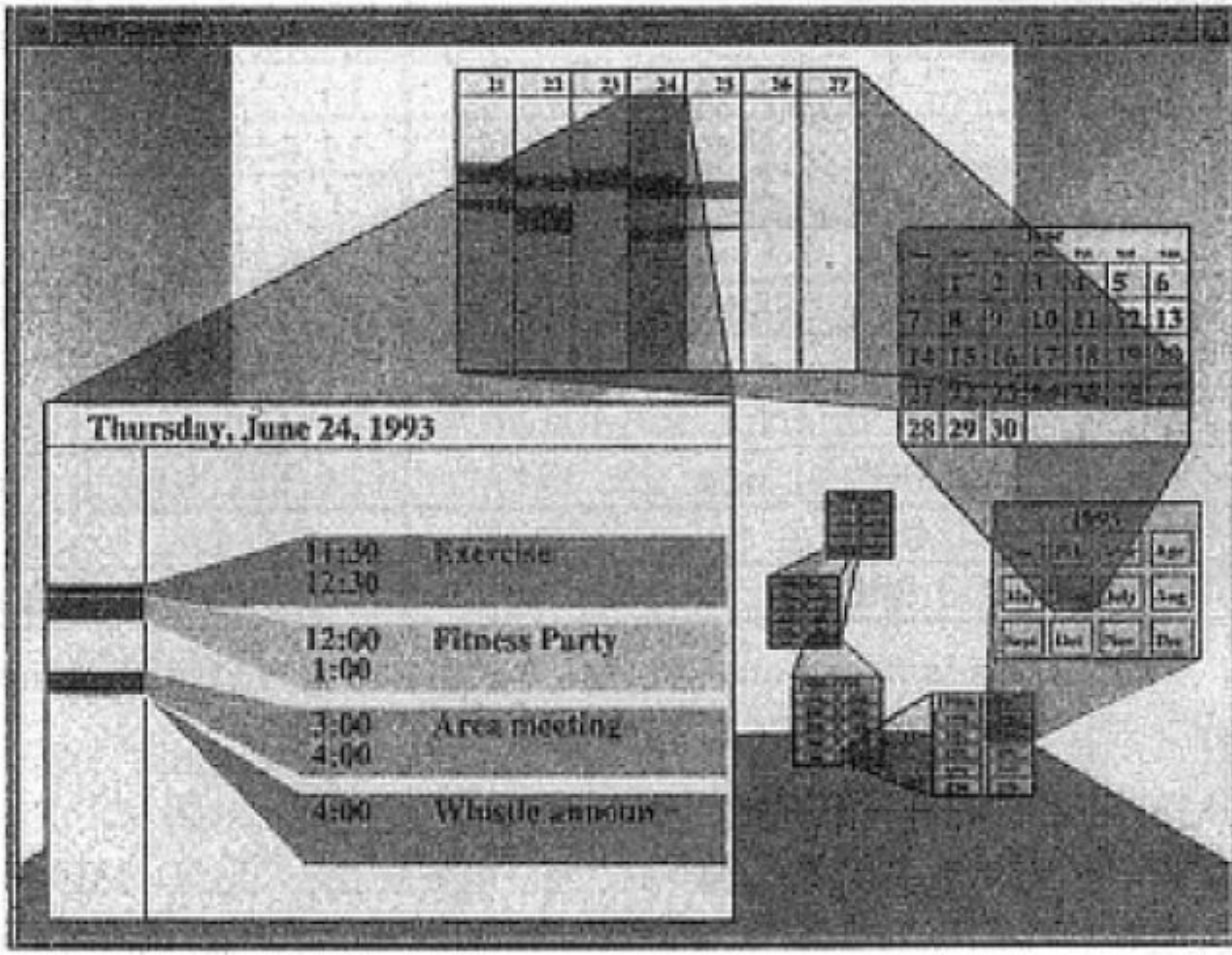
In the NV3D systems (Parker et al., 1998), clicking and holding down the mouse causes the environment to be smoothly scaled as the selected point is moved to the center of the 3D workspace.

Focus, Context, and Scale (4) : 3. Elision Technique

- Parts of a structure are hidden until they are needed

Focus, Context, and Scale (5)

- Multiple Windows
  - one window that shows an overview and several others that show expanded details

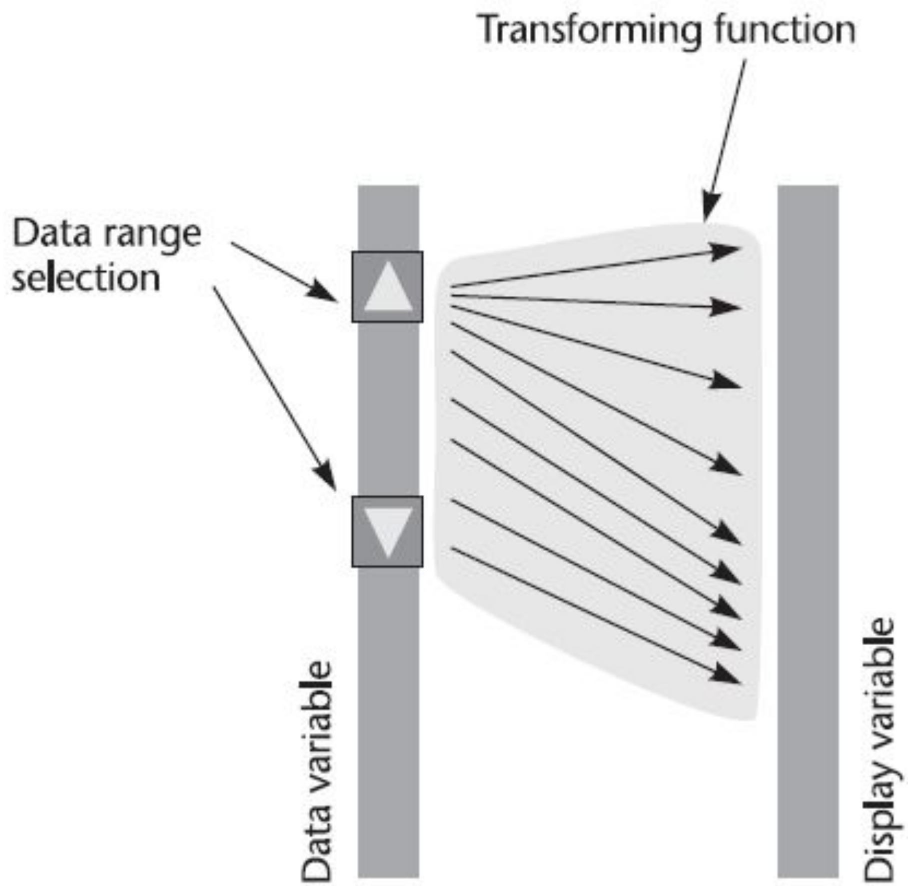


The spiral calendar (Card et al., 1994). The problem with multiple-window interfaces is that information becomes visually fragmented. In this application, information in one window is linked to its context within another by a connecting transparent overlay.

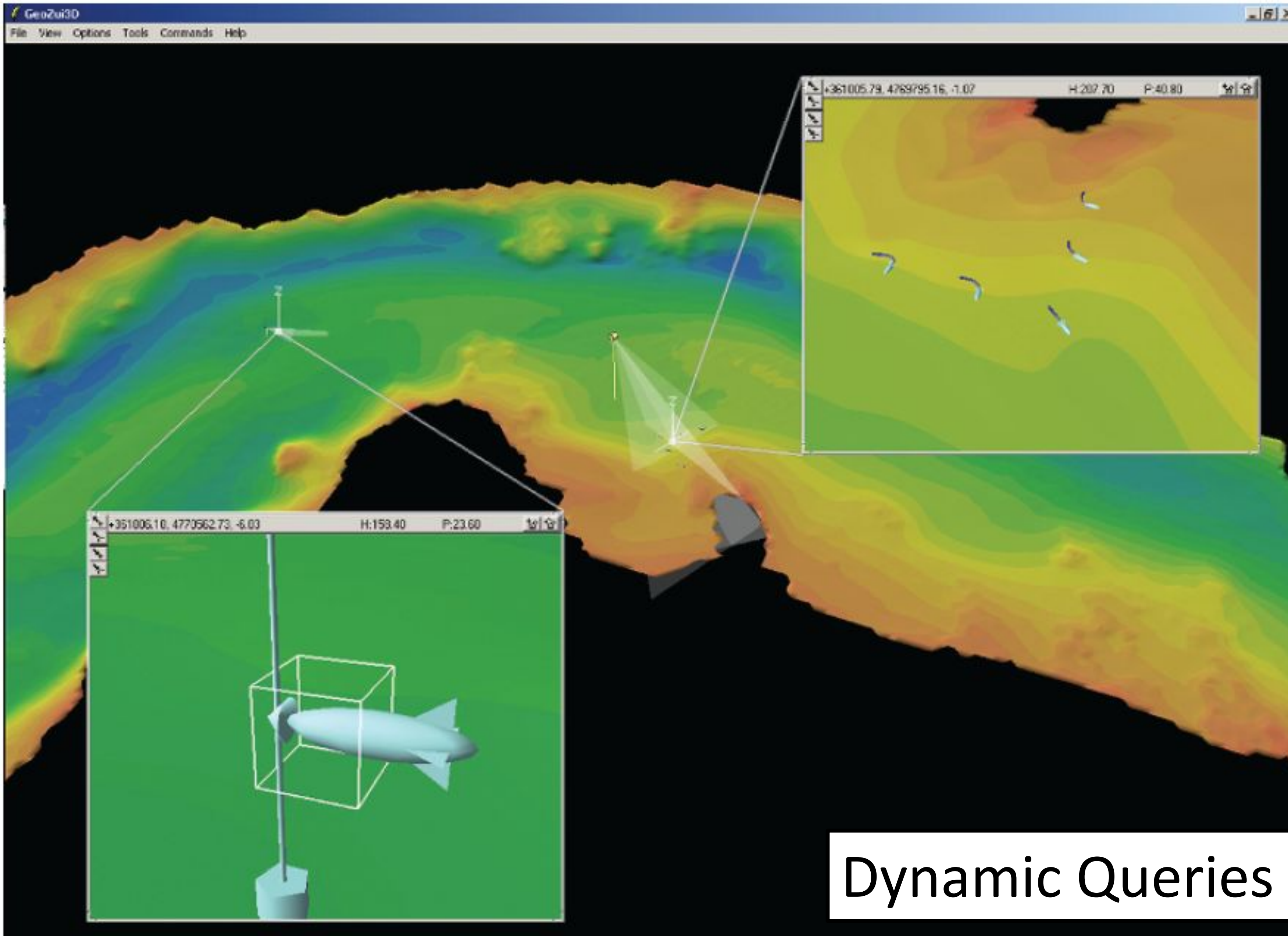
Rapid Interaction with Data

- The mapping between the data and its visual representation must be fluid and dynamic
- Interactive data display technique:
  - Dynamic queries
  - Brushing
  - Map different data attributes to a wide variety of visual variable: position, color, texture, motion, and so on

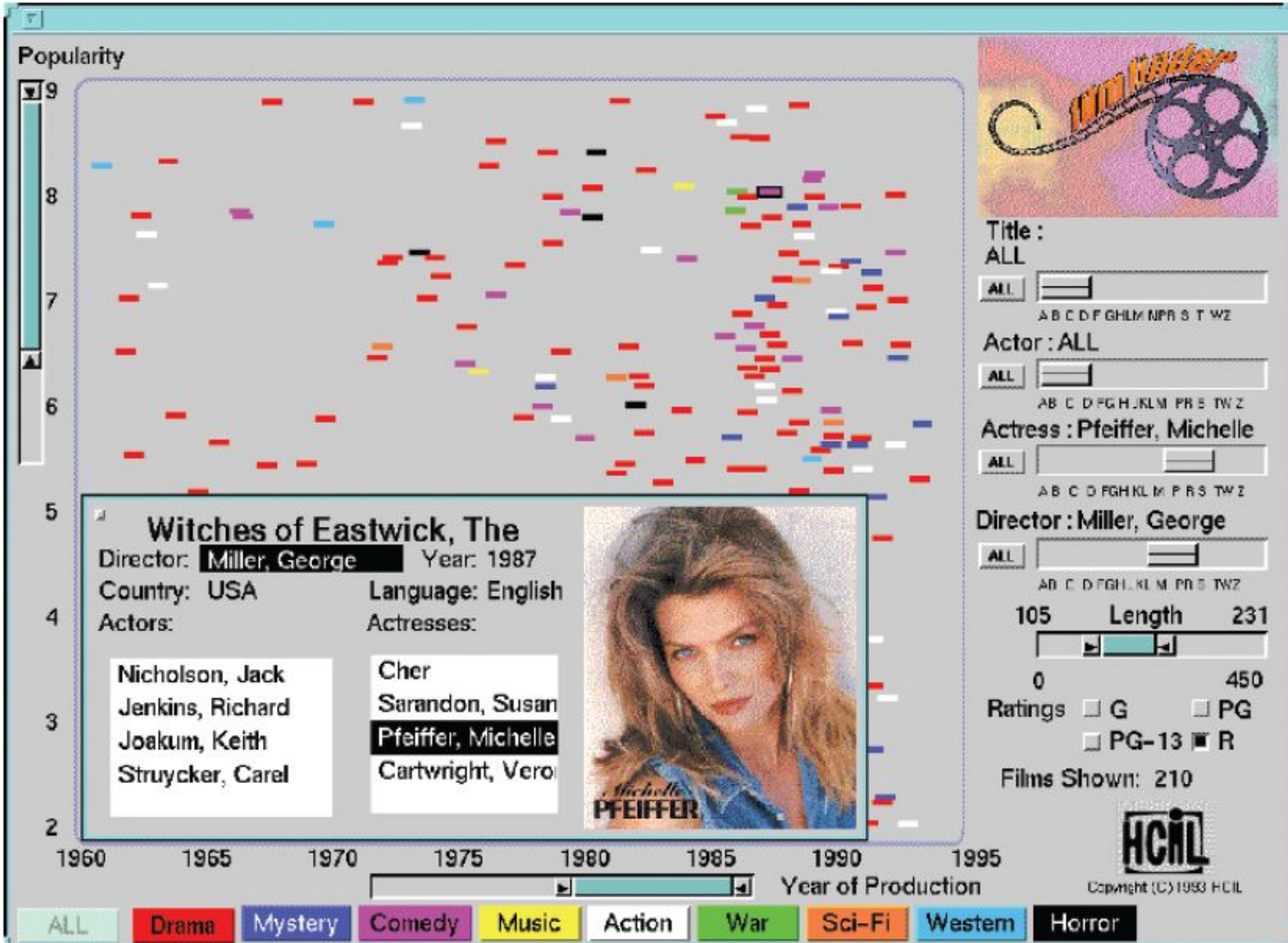
Dynamic Queries



In a visualization system, it is often useful to change interactively the function that maps data values to a display variable.



Dynamic Queries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Title : ALL
Actor : ALL
Actress : Pfeiffer, Michelle
Director : Miller, George
105 Length 231
0 450
Ratings G PG PG-13 R
Films Shown: 210
Witches of Eastwick, The
Director: Miller, George
Year: 1987
Country: USA
Language: English
Actors:
Nicholson, Jack
Jenkins, Richard
Joakum, Keith
Struycker, Carel
Actresses:
Cher
Sarandon, Susan
Pfeiffer, Michelle
Cartwright, Vero
1960 1965 1970 1975 1980 1985 1990 1995
Year of Production
ALL Drama Mystery Comedy Music Action War Sci-Fi Western Horror
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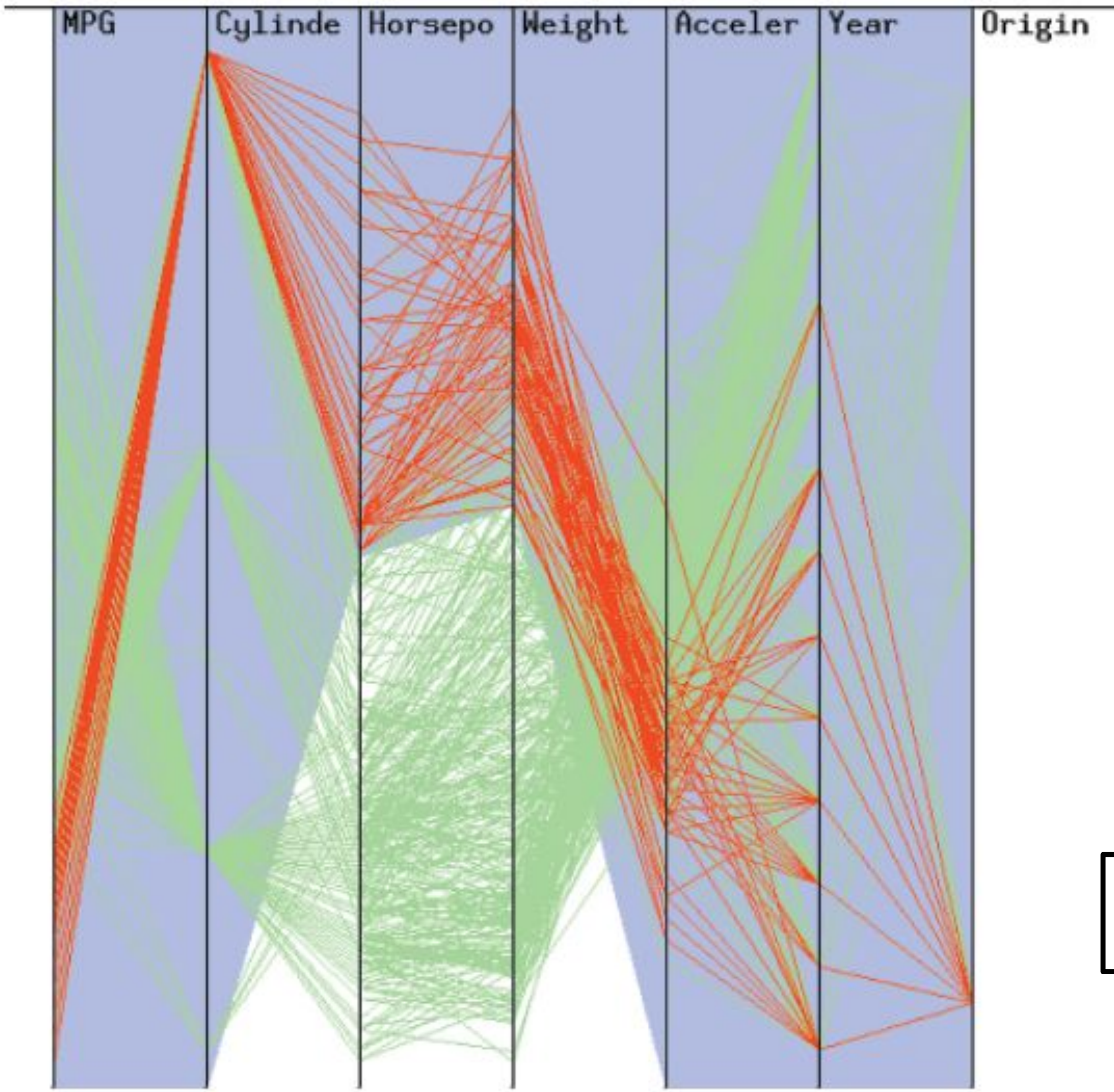
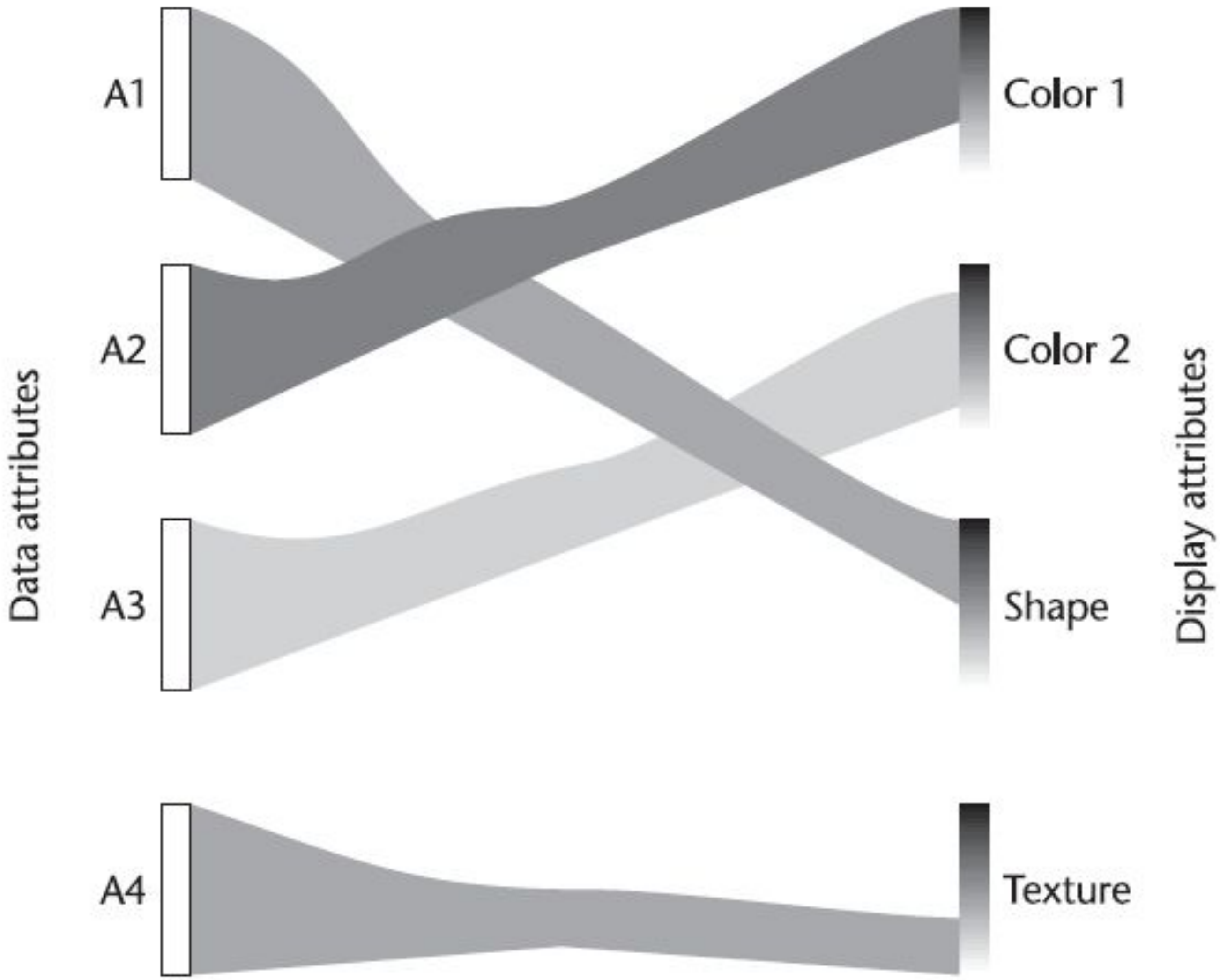
Copyright (C) 1993 HCIL



BRUSHING

In a parallel-coordinates plot, each data dimension is represented by a vertical line. This example illustrates brushing. The user can interactively select a set of objects by dragging the cursor across them. *From: XmdvTool (http://davis.wpi.edu/~xmdv). Courtesy of Matthew Ward (1990).*



In some interactive visualization systems, it is possible to change the mapping between data attributes and the visual representation.

Challenges

- How to make the graphic interface as fluid and transparent as possible
- Goal of cognitive system designs:
  - to tighten the loop between human and computer, making it easier for the human to obtain important information from the computer via the display

Friendly Reminder

Group Project Assignment II

- Create a dashboard or interactive visualization works by following six steps discussed on these slides.
  - The topic of your works can be taken from the last project
- Deliverables : A zipped file containing
  - A documentation
  - A dashboard
- Submission date: Sunday, April 24th 2017, 23.55 p.m.
- Presentation date : April 25th and 26th 2017