Part V Views

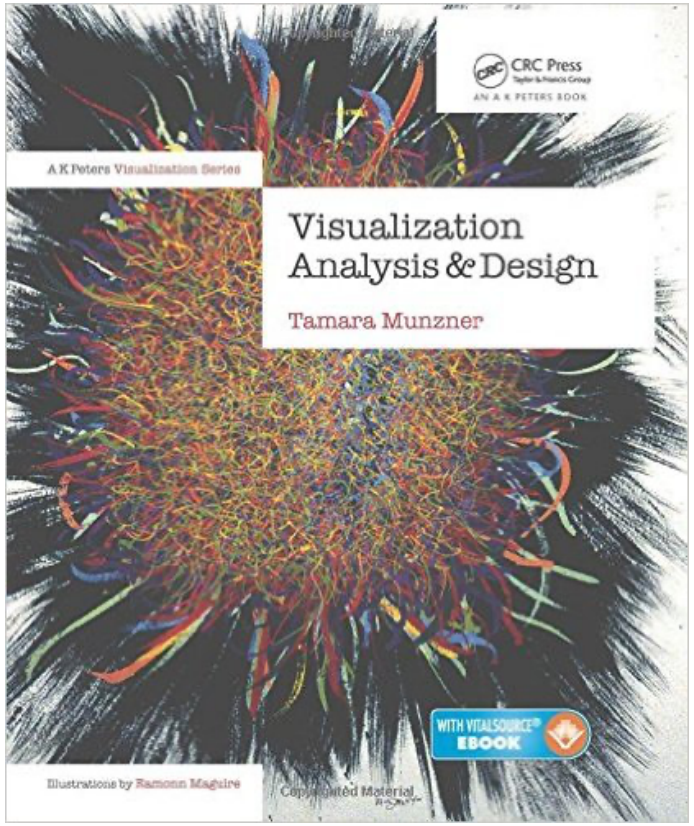
View Manipulation

The most important property of a program is whether it accomplishes the intention of its user.

C. A. R. Hoare

Source of This Unit

- **Material of this unit is based on Chapter 11 of Tamara Munzner, *Visualization Analysis and Design*, AK Peters/CRC Press, 2014.**



Some Initial Notes: 1/3

- **The way to change a view covers the full set of all other design choices for idioms.**
- **Any aspect of visual encoding can be changed, including ordering, any other choice pertaining to spatial arrangement, and the use of other visual channels such as color.**
- **Changes could be made concerning what elements are filtered, the level of detail of aggregation, and how the data is partitioned into multiple views.**

Some Initial Notes: 2/3

- A change often requires a set of items or attributes within the visualization as input.
- There are several choices about how a user can select elements:
  A. What kind of elements can be targets?
  B. How many selection types are supported?
  C. How many elements can be in the selected set?
  D. How to highlight the elements?

Some Initial Notes: 3/3

- **Navigation** is a change of viewpoint: changing what is shown in a view based on the metaphor of a camera looking at the scene from a movable point of view.
- **Zooming in** to see fewer items in more detail can be done geometrically, matching the semantics of real world motion.
- With semantic zooming, the way to draw items adapts on the fly based on the number of available pixels, so appearance may change dramatically.

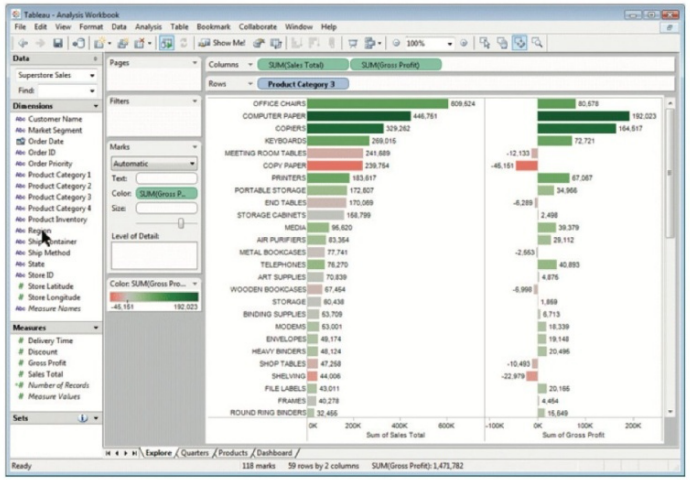
Change View over Time: 1/4

- **The possibility for how the view changes can be based on any of the other design choices of *how to* construct an idiom:**
  - **A. change the encoding,**
  - **B. change the arrangement,**
  - **C. change the color,**
  - **D. change the viewpoint,**
  - **E. change which attribute are filtered,**
  - **F. change the aggregation level,**
  - **G. etc.**

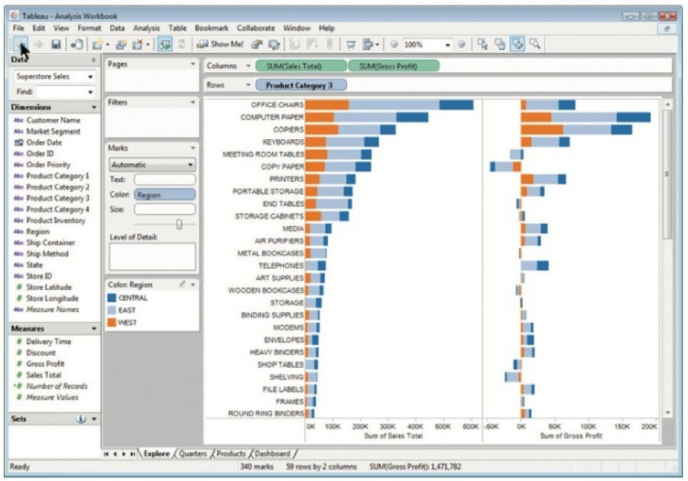
Change View over Time: 2/4

- The visual encoding could be changed to a completely different idiom.
- Some visualization tools allow the user to manually change between several different idioms, such as switching from a node-link layout to a matrix layout of a network.
- Giving the user control of the encoding is particularly common in general-purpose systems designed to flexibly accommodate a large range of possible datasets.

Change View over Time: 3/4

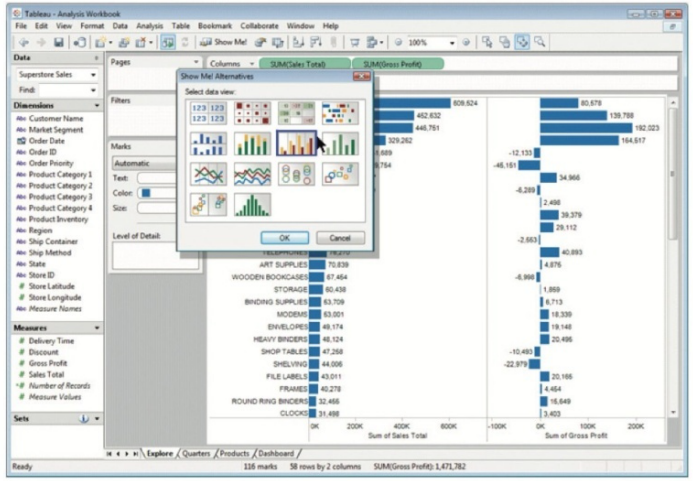


Bar chart

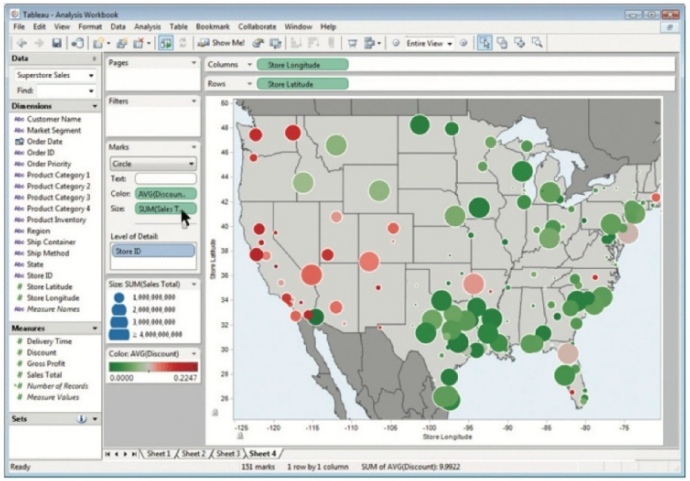


Stacked bar chart

Tableau supports changes between visual encoding idioms with drag and drop interaction.



Selecting a different encoding



Encoded using geographic positions

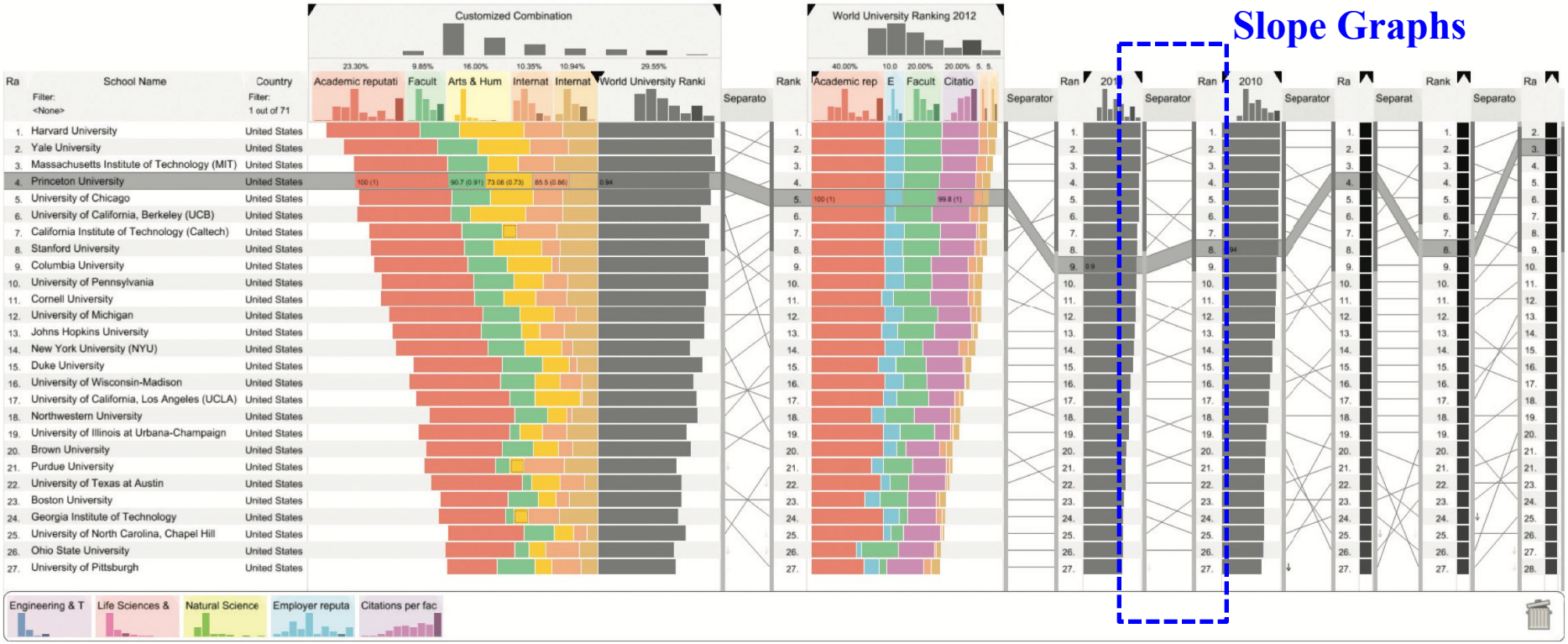
Change View over Time: 4/4

- A view change is to alter some parameters of the existing encoding (e.g., range of mark size).
- Many kinds of change involve rearrangement of some or all of the items in the view.
- **Reordering** (i.e., sorting) is a powerful choice for finding patterns in a dataset by interactively changing attribute that is used to order the data.
- Reordering data spatially allows us to invoke the pattern-finding parts of our visual system to quickly check whether the new configuration conveys new information.

Example: LineUp 1/4

- A **LineUp** system is designed to support exploration of tables with many attributes through interactive reordering and realigning.
- In addition to sorting by any attribute, the user can sort by complex weighted combinations of multiple attributes.
- LineUp is explicitly designed do support the comparison of multiple rankings.

Example: LineUp 2/4

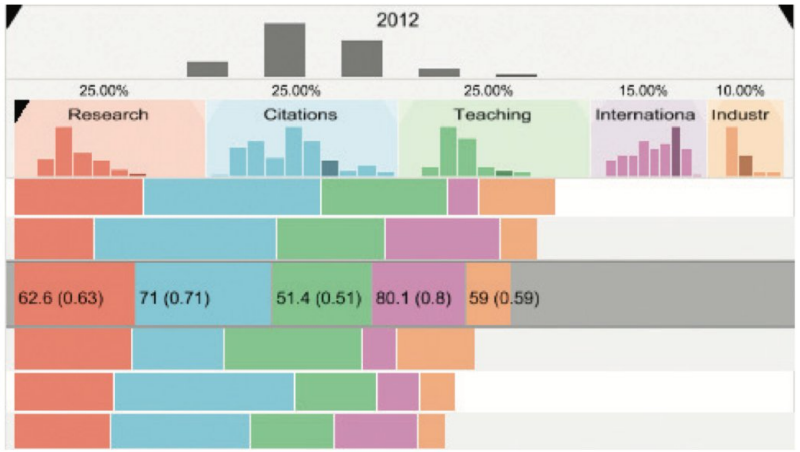


Customized Ranging (2012 Data)

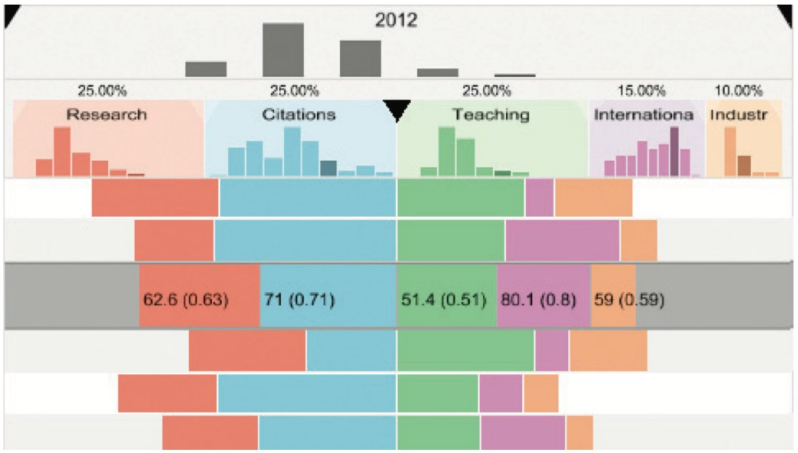
World Ranging (2012 Data)

Compressed View with a Single Summary Bar for 2 More Rankings (2011 & 2010 Data)

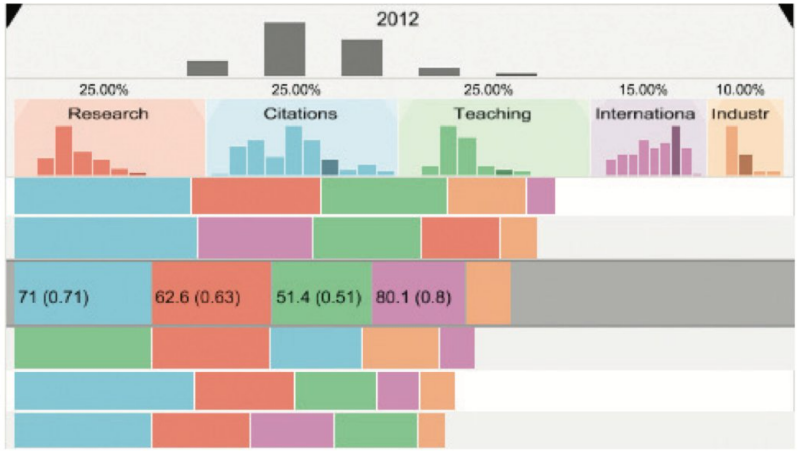
Example: LineUp 3/4



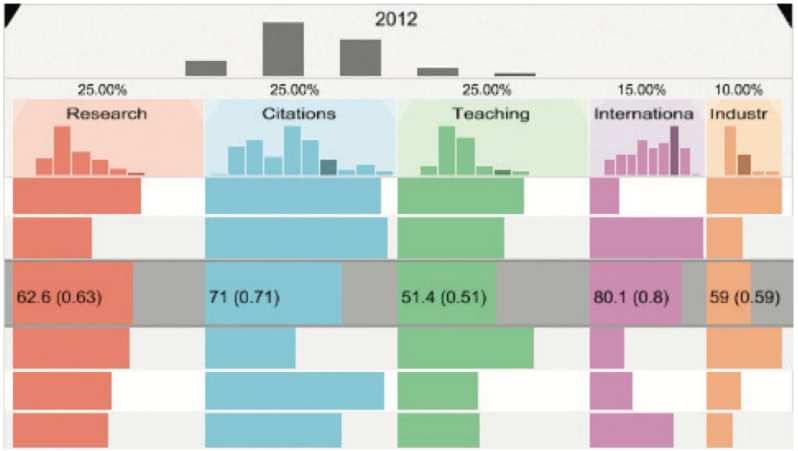
Classical stacked bars



An attribute is selected as a baseline



Bars sorted by decreasing size separately in each row to emphasize the most contributing attribute



Each attribute aligned to its own baseline

Example: LineUp 4/4

Idiom	LineUp
Data Type	Table.
Derived Data Type	Ordered attribute: weighted combination of selected attributes.
Encoding	Stacked bar charts, slope graphs
Task (Manipulate)	Reorder, realign, animated transitions.
Task	Compare rankings, distributions.

Animation

- **Many kinds of change involve reducing or increasing the amount of data that is shown: changes to *aggregation* and *filtering* are at the heart of interactive data reduction idioms.**
- **Many kinds of changes to a view over time fall into the general category of animation, including changes to the spatial layout.**
- **While animation has intuitive appeal to many beginning designers, it is valuable to think carefully about cognitive load and other trade-offs.**

Example: Animated Transitions 1/4

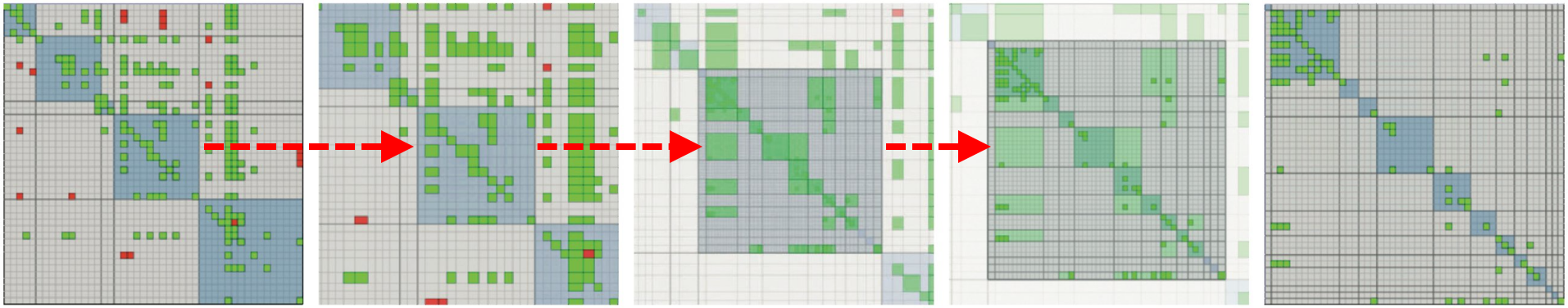
- One of the best-justified uses of animation is the idiom of **animated transition**, where a series of frames is generated to smoothly transition from one state to another.
- Animated transitions are an alternative to a **jump cut**, where the display simply changes abruptly from one state to the next.
- The benefit of animated transitions is that they help users maintain a sense of context between the two states by explicitly showing how an item moves to its next position.

Example: Animated Transitions 2/4

- These transitions are most useful when the amount of change is limited, because people cannot track everything that occurs if many items change in different ways all of the time.
- They work well when a small number of objects change while the rest stay the same, or when groups of objects move together in similar ways.
- Transitions can also be broken down into a small number of states.

Example: Animated Transitions 3/4

Five frames from an animated transition of a network shown as an adjacency matrix



The data type is a compound network, where there is a cluster hierarchy associated with the base network.

The transition shows a change from one level of hierarchical aggregation to the next, providing more detail.

Initially, only a subset of what is visible.

The middle block gradually stretches out to fill all of the available space, and additional structure appears within it; the other blocks gradually squish down to nothing, with their structure gradually becoming more aggregated as the amount of available screen space decreases.

Example: Animated Transitions 4/4

Idiom	Animated Transitions
Data Type	Compound network.
Manipulation	Change with animated transition. Navigate between aggregation levels.

Select Elements

- **Allowing users to select one or more elements of interest in a visualization is a fundamental action that supports nearly every interactive idiom.**
- **The output of a selection operation is often the input to a subsequent operation.**
- **In particular, the *change* choice is usually dependent on a previous *select* result.**
- **We will talk about the following: selection design choices, highlighting, selection outcomes.**

Selection Design Choices: 1/2

- **What can be selected**: data items, links or nodes of network data, levels within an attribute (i.e., all items that share a unique value for that attribute), a view of multiple views, etc.
- **The number of independent selection types**: single selection (i.e., elements either selected or not selected), two selections (i.e., mouse click for one kind and mouse hover for the other), multiple selections (i.e., multiple kinds of clicks – left, middle, right mouse button).

Selection Design Choices: 2/2

- **How many elements can be in the selection set**: If multiple elements can be selected, can the selection only support spatially contiguous group of items, or allow the user to add and remove items from the selection set in multiple passes or views?
- For example, a visualization tool might allow the user to interactively assign items into any of many groups, change the name of a group, and change the color of items in the group.

Highlighting: 1/6

- **Selection is very closely related to highlighting, where the elements that were chosen are indicated by changing their visual appearance.**
- **Selection should trigger highlighting in order to provide users with immediate visual feedback, to confirm that the results of their operations match up with their intentions.**
- **Two different choices can be independently varied*: the interaction idiom of how the user selects elements* and *the visual encoding idiom of how the selected elements are highlighted*.**

Highlighting: 2/6

- **For data items, nearly any change of visual encoding strategy can be used for highlighting (i.e., changing its color). But note that *the highlight color should be sufficiently different from the other colors that a visual popout effect is achieved with sufficient hue, luminance, or saturation contrast*.**
- **A fundamental limitation of highlighting by color change is that the existing color coding is temporarily hidden.**

Highlighting: 3/6

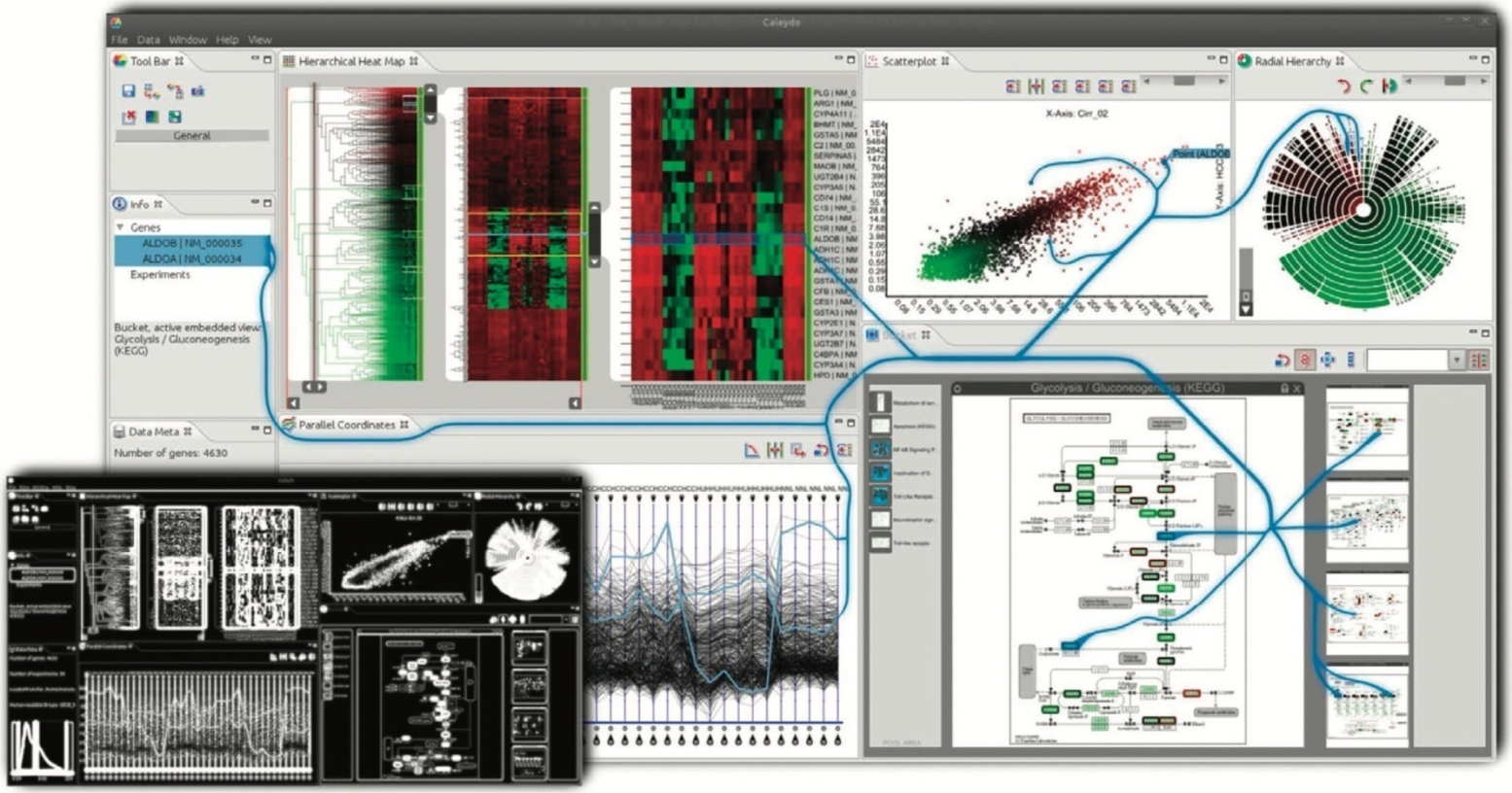
- One way to overcome this problem is to highlight with an outline (i.e., adding an outline mark around the selected object or changing the color of an existing outline mark to the highlight color).
- For large marks, this works effectively, but when marks are small, this may not provide enough visual salience.
- Another solution is to use the size channel (e.g., increasing an item's size or linewidth of a link).
- It is also common to highlight with the shape channel (i.e., changing a solid line to a dash one).

Highlighting: 4/6

- Another design choice is to use motion coding:
  - Moving all selected points in small circular orbits oscillating around their usual location,
  - Moving all selected items slightly back and forth relative to their original position,
  - Having a dash pattern crawl along selected links.
- Although this choice looks unusual, experiments have shown that motion coding often outperformed more traditional highlighting approaches of coloring, outlining, size changes)

Highlighting: 5/6

- Yet another choice for highlighting is to add connection marks (i.e., context-preserving visual links) between the objects in the selection set.



Highlighting: 6/6

Idiom	Context-Preserving Visual Links
Data Type	Any Data.
Encoding	Any encoding. Highlight with link marks connecting items across views.
Task (Manipulate)	Select any element.
Task (Coordinate)	Juxtaposed multiple views.

Selection Outcomes

- Sometimes the outcome of selection is additional actions, beyond simply highlighting.
- Selection is usually the first step in a multistage sequence, allowing the user to indicate specific elements that are the target of the next action.
  - Selected items might be filtered or aggregated, or their visual encoding could be changed.
  - A selected set of regions or items might be reordered with a view.
  - A navigation trajectory could be constructed of an animated transition.

Navigate: Changing Viewpoint

- Large and complex datasets often cannot be understood from only a single point of view.
- **Navigation** means to changing the point of view from which things are drawn.
- When the camera viewpoint is changed, the set of items visible in the camera frame also changes.
- Navigation can be broken down into three components: **zooming**, **panning** (2D) and **translating** (3D), and **rotating**.

Geometric Zooming

- **Geometric zooming** corresponds almost exactly with our real-world experience of walking close to objects, or grasping objects with our hands and moving them closer to our eyes.
- In the 2D case, it is moving a piece of paper closer or farther from our eyes, while keeping it parallel to our face.
- With geometric zooming, the fundamental appearance of objects is fixed, and moving the view point simply changes the size and perspective at which they are drawn.

Semantic Zooming: 1/5

- **With semantic zooming, the representation of the object adapts to the number of pixels available in the region occupied by the object.**
- **The visual appearance of an object can change subtly or dramatically at different scales.**
- **Example: A visual representation of a text file may always be rectangular, but its contents could change considerably. If the box is *small*, it would contain a short text label. A *medium-size* box could contain the full file title. A *large* box could accommodate a multi-line summary.**

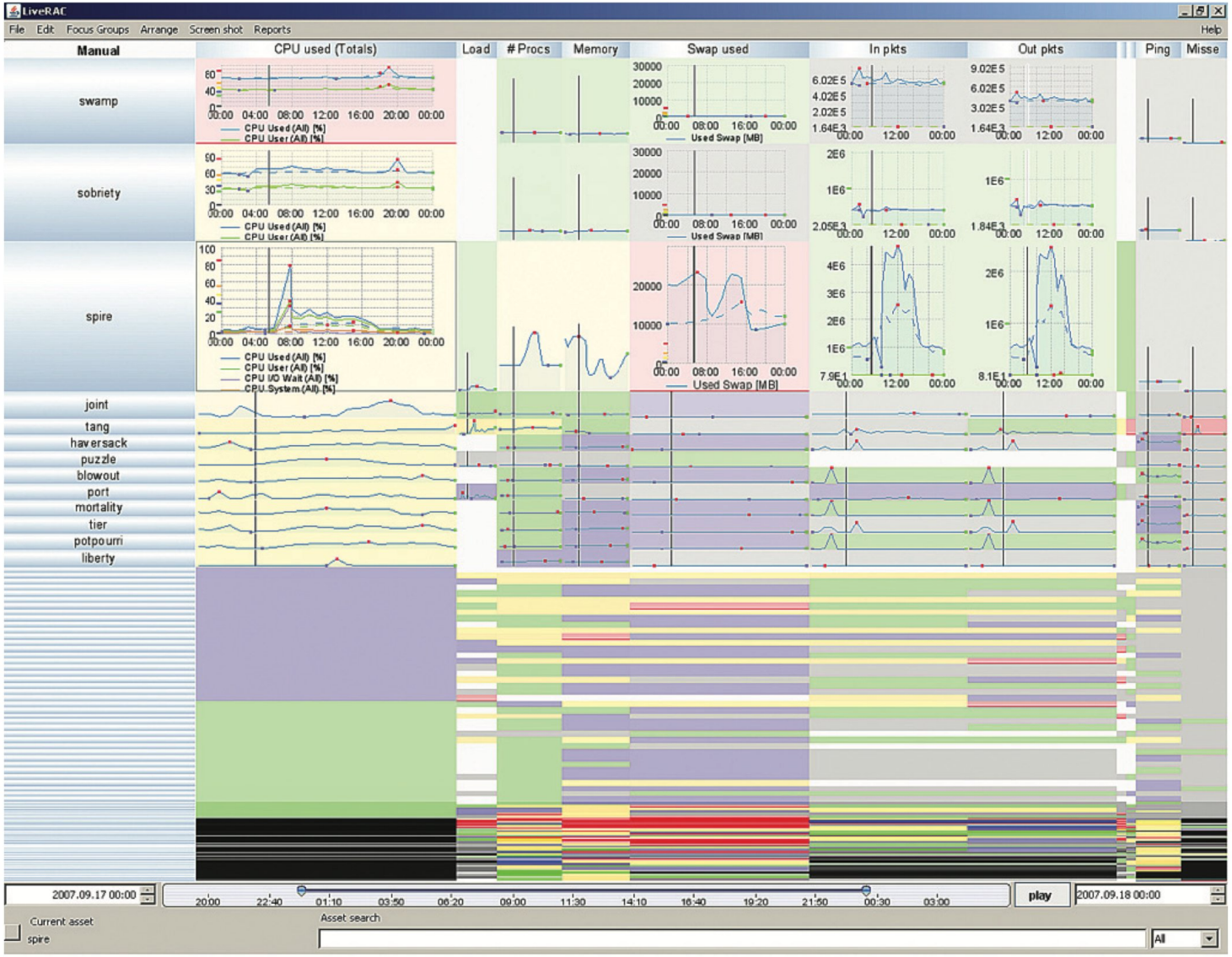
Semantic Zooming: 2/5

- **LiveRAC is a visualization system for analyzing large collections of time-series data.**
- **Line charts in a very large grid use semantic zooming, automatically adapting to the amount of space available as rows and columns are stretched and squished.**

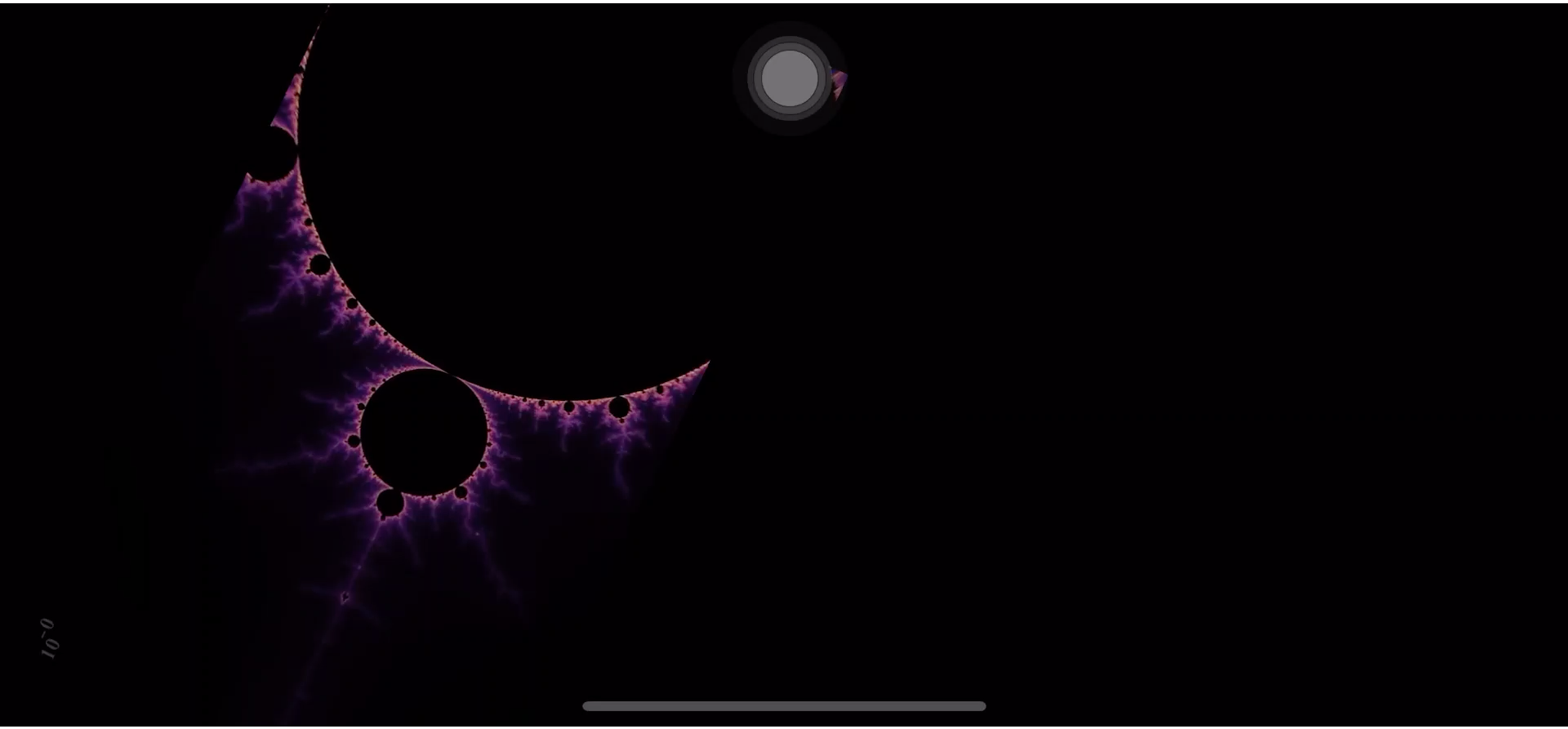
Semantic Zooming: 3/5

- When the available box is tiny, only a single categorical variable is shown with color coding.
- Slightly larger boxes also use **sparklines**, very concise line charts with dots marking the minimum and maximum for that time period.
- As the box size passes thresholds, axes are drawn and multiple line charts are superimposed.
- This stretch-and-squish navigation idiom is an example of a **focus+context** approach.

Semantic Zooming: 4/5



Semantic Zooming: 5/5



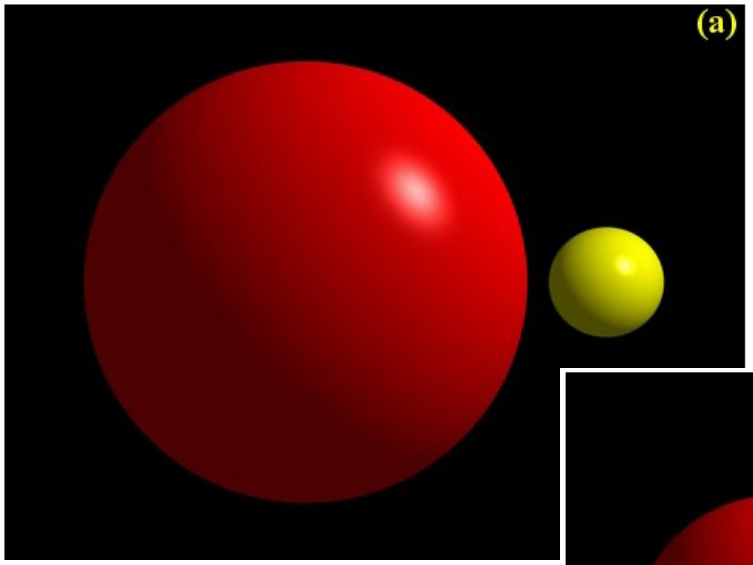
The **Mandelbrot set** is defined as follows: For each number c in the complex plane let $z_0 = 0$ and $z_{n+1} = z_n^2 + c$. As long as $|z| <= 2$ and $n <$ **Max-Iterations**, continue this iteration. Otherwise, color c in some color.

Constrained Navigation: 1/5

- With **unconstrained navigation**, the camera can move anywhere. However, users often have difficulty figuring out how to achieve a desired viewpoint with completely free navigation, especially in 3D.
- It is easy to inadvertently move the view point inside objects that are intended to be solid.
- It is also possible that the camera may pointed at nothing at all.

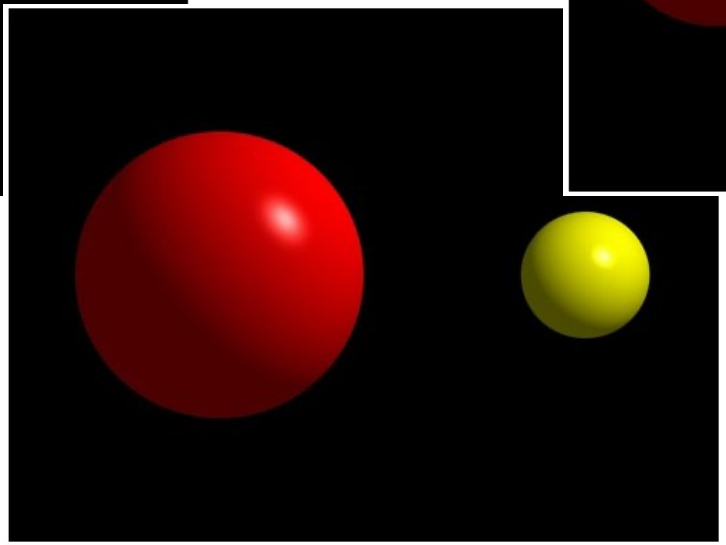
Constrained Navigation: 2/5

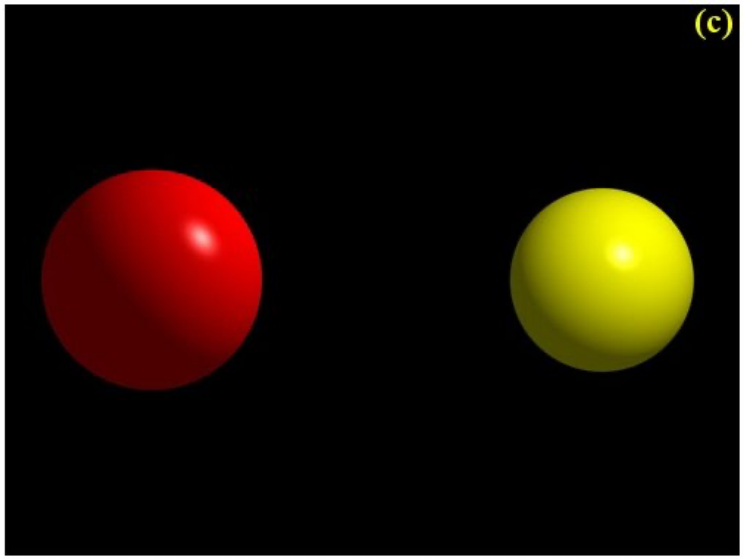
- Be aware of perspective distortion in 3D. **Moving camera closer exaggerates near objects.**



Two balls of equal size with the red one closer to the camera

Camera moved away from the red ball



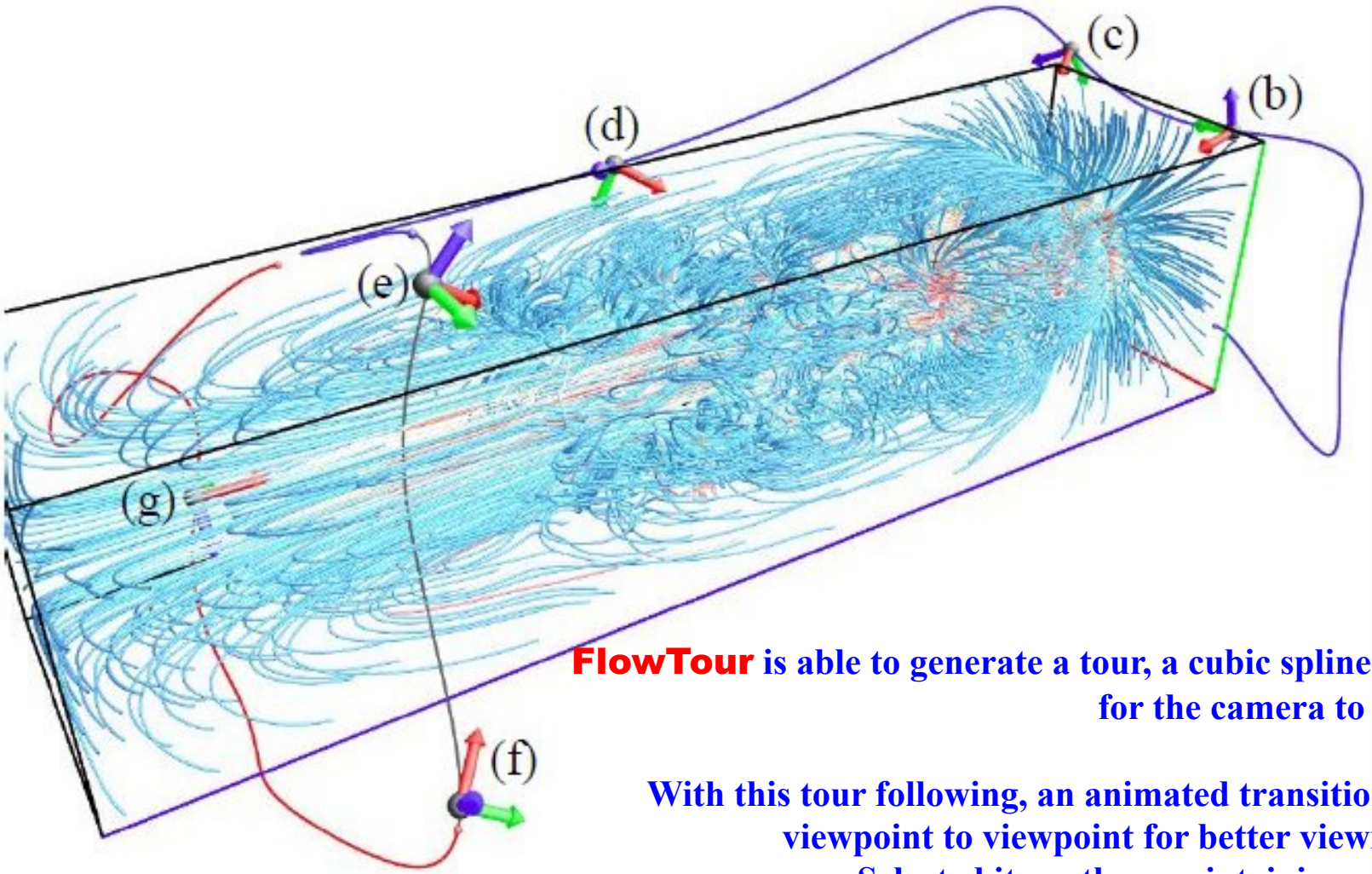


Camera very far from both balls

Constrained Navigation: 3/5

- With **constrained navigation**, the movement of camera has some limit on the motion (e.g., can only be moved in certain region, zoom can only be applied to certain range, etc.)
- Camera may also be restricted to a selected path along which the scene can be viewed in the best way (e.g., less clutter and occlusion).
- Constrained navigation is particularly powerful when linked navigation between multiple views (e.g., a tabular or list view being sorted by some attributes).

Constrained Navigation: 4/5

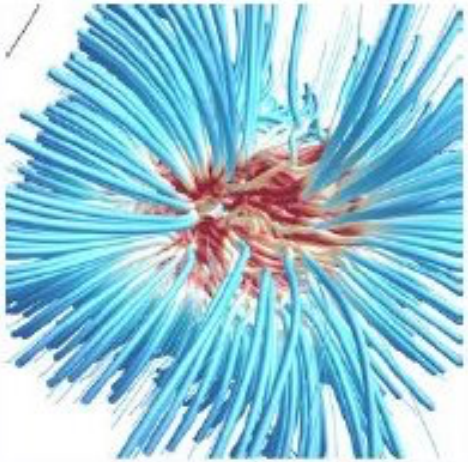


FlowTour is able to generate a tour, a cubic spline curve, for the camera to follow.

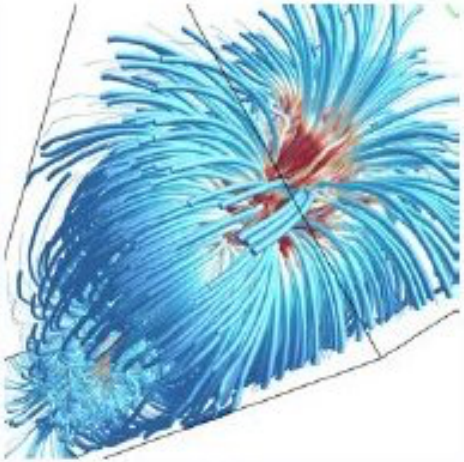
With this tour following, an animated transition from viewpoint to viewpoint for better viewing the Selected item, thus maintaining context.

Jun Ma, et. al.

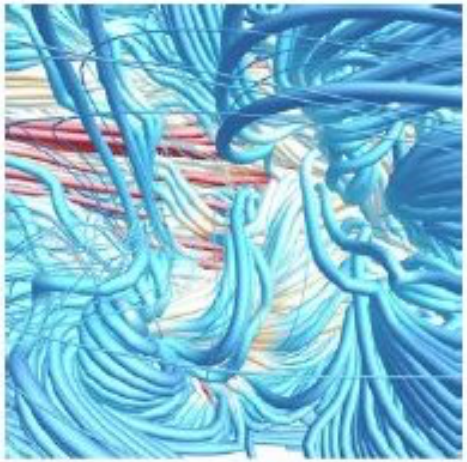
Constrained Navigation: 5/5



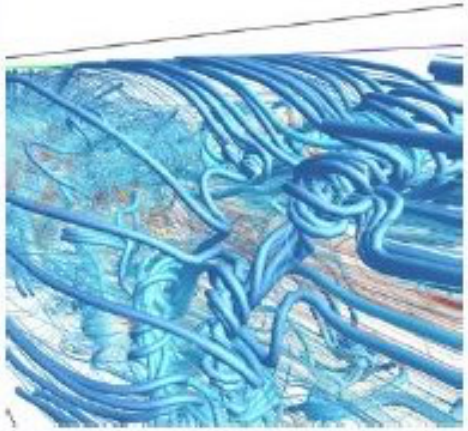
From viewpoint (b)



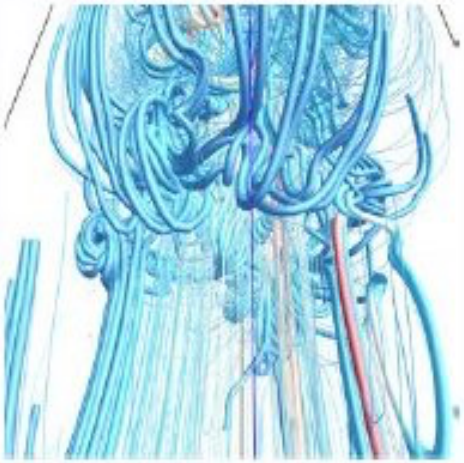
From viewpoint (c)



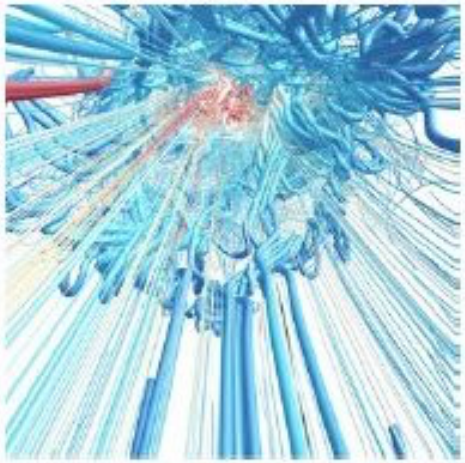
From viewpoint (d)



From viewpoint (e)



From viewpoint (f)



From viewpoint (g)

Navigate: Reducing Attributes

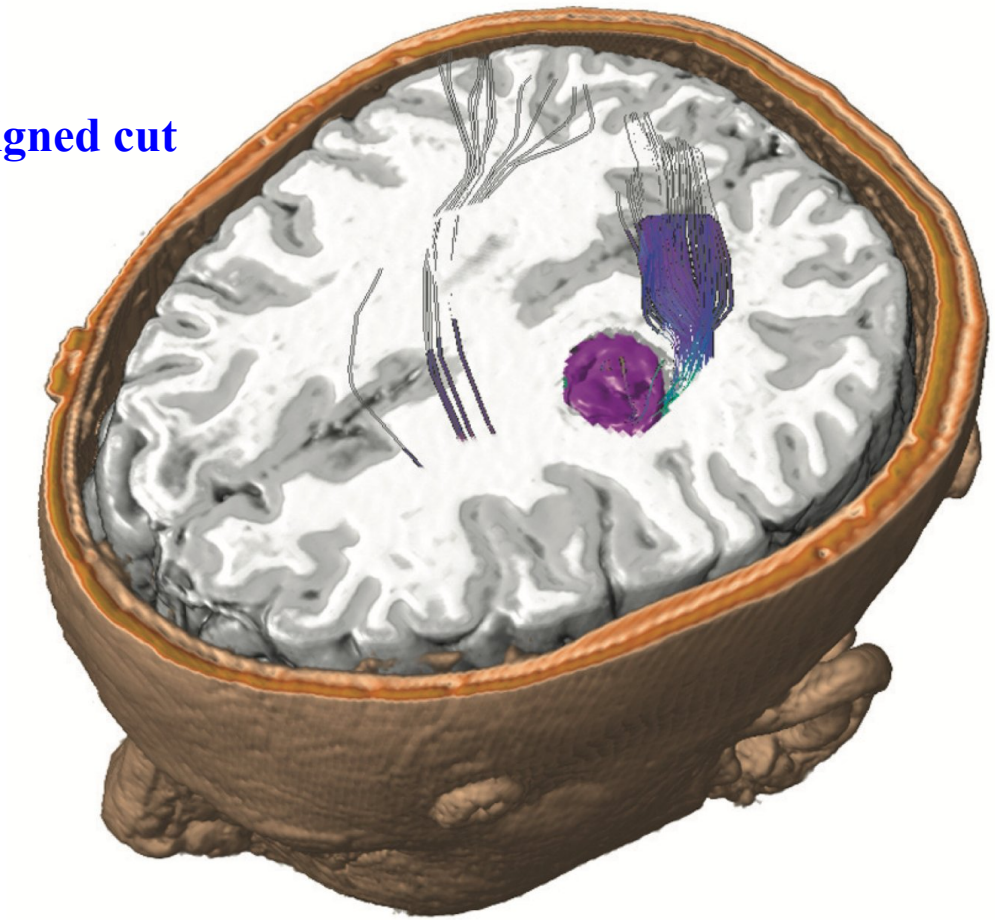
- **The geometric intuitions that underlie the metaphor of navigation with a camera also lead to a set of design choices for reducing the number of attributes: slice, cut and project.**
- **Although these idioms are inspired by ways to manipulate a camera in a 3D scene, they also generalize to higher-dimensional spaces.**
- **In what follows, we shall use *dimensions* instead of the synonym *attributes*.**

Reducing Attributes: Slice 1/3

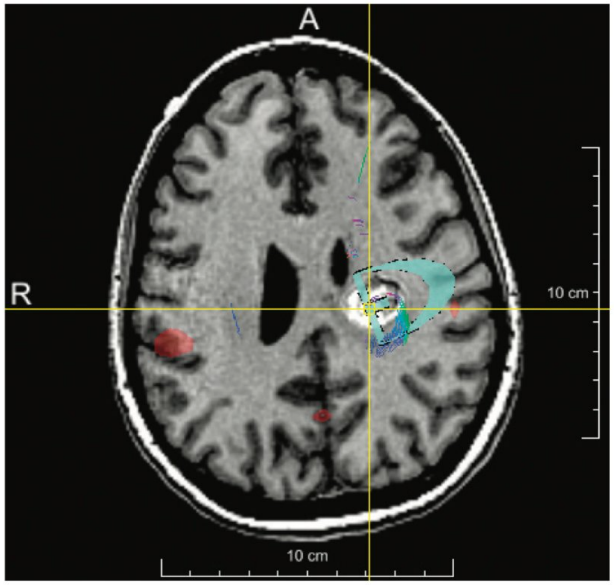
- **With the slice design choice, a single value is chosen from the dimension to eliminate, and only the items matching that value for the dimension are extracted to include in the lower-dimensional slice.**
- **Slicing is a very intuitive metaphor when reducing spatial data from 3D to 2D.**

Reducing Attributes: Slice 2/3

Axis-aligned cut



Axis-aligned slice



The slice choice eliminates a dimension/attribute by extracting only the items with a chosen value in that dimension.

Reducing Attributes: Slice 3/3

- **Slices do not have to be axial. But, one benefit of axis-aligned slices is that they may correspond to views that are familiar to the viewer.**
- **It is possible to slice along a plane at an arbitrary orientation that does not match the original axis.**
- **Slicing is not restricted to a change from 3D to 2D. The slicing plane could be a hyperplane, the higher-dimensional version of a plane.**

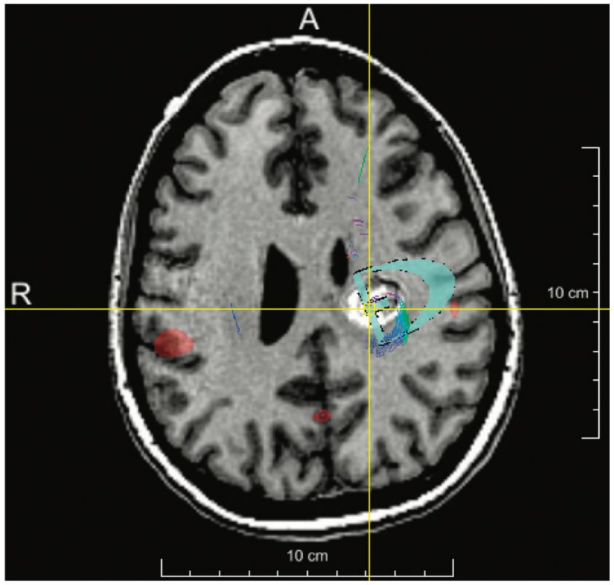
Reducing Attributes: Cut 1/3

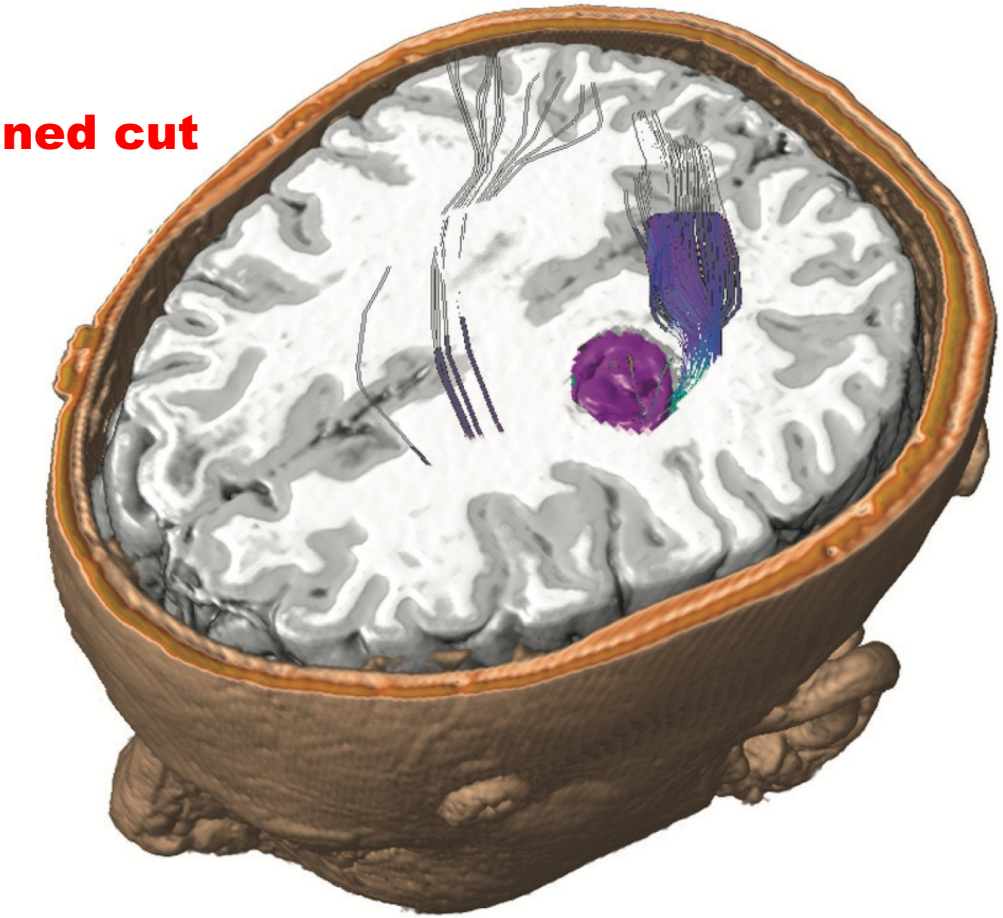
- The interaction idiom of **cut** allows the user to position a plane that divides the viewing volume into two, and everything on the side that contains the camera will not be shown.
- This **cutting plane** can either be axis-aligned or arbitrarily oriented just like the **slices**.
- The cut design choice shows more information than just the 2D slice alone, because the surrounding 3D context behind the cutting plane is also visible.

Reducing Attributes: Cut 2/3

Axis-aligned cut

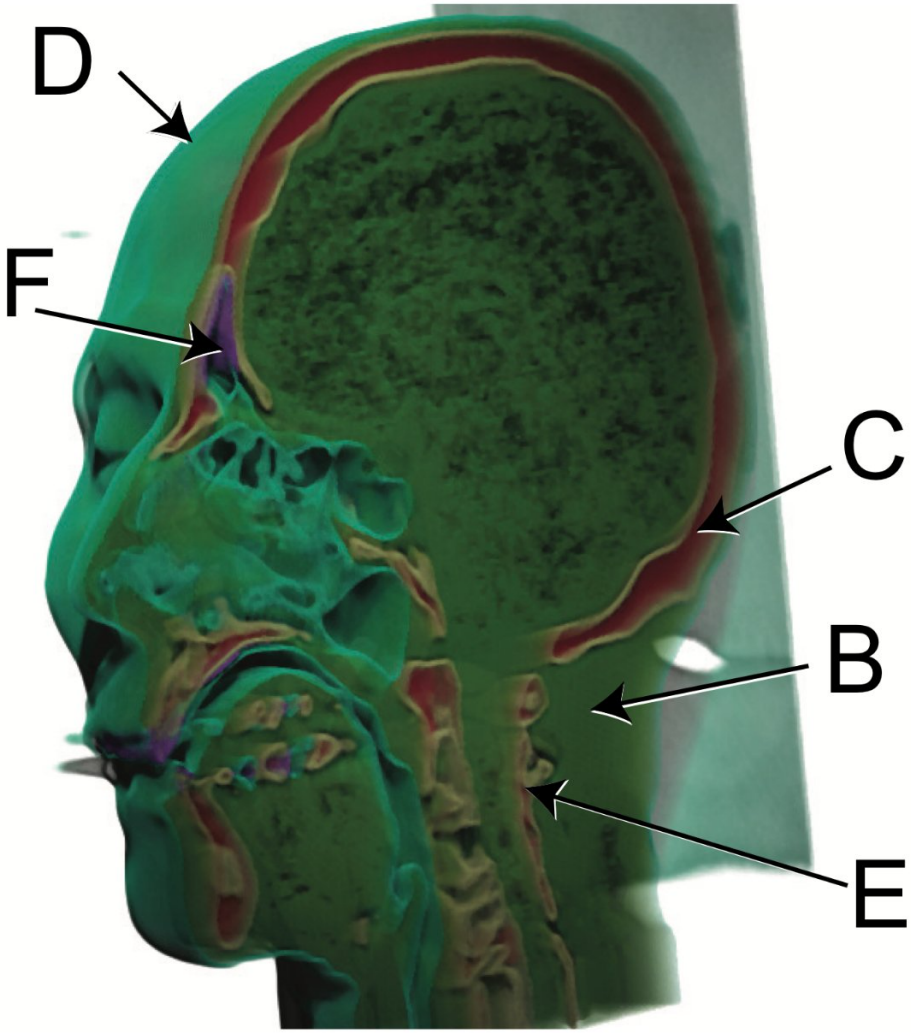
Axis-aligned slice





With cut, the surrounding 3D context is visible.

Reducing Attributes: Cut 3/3



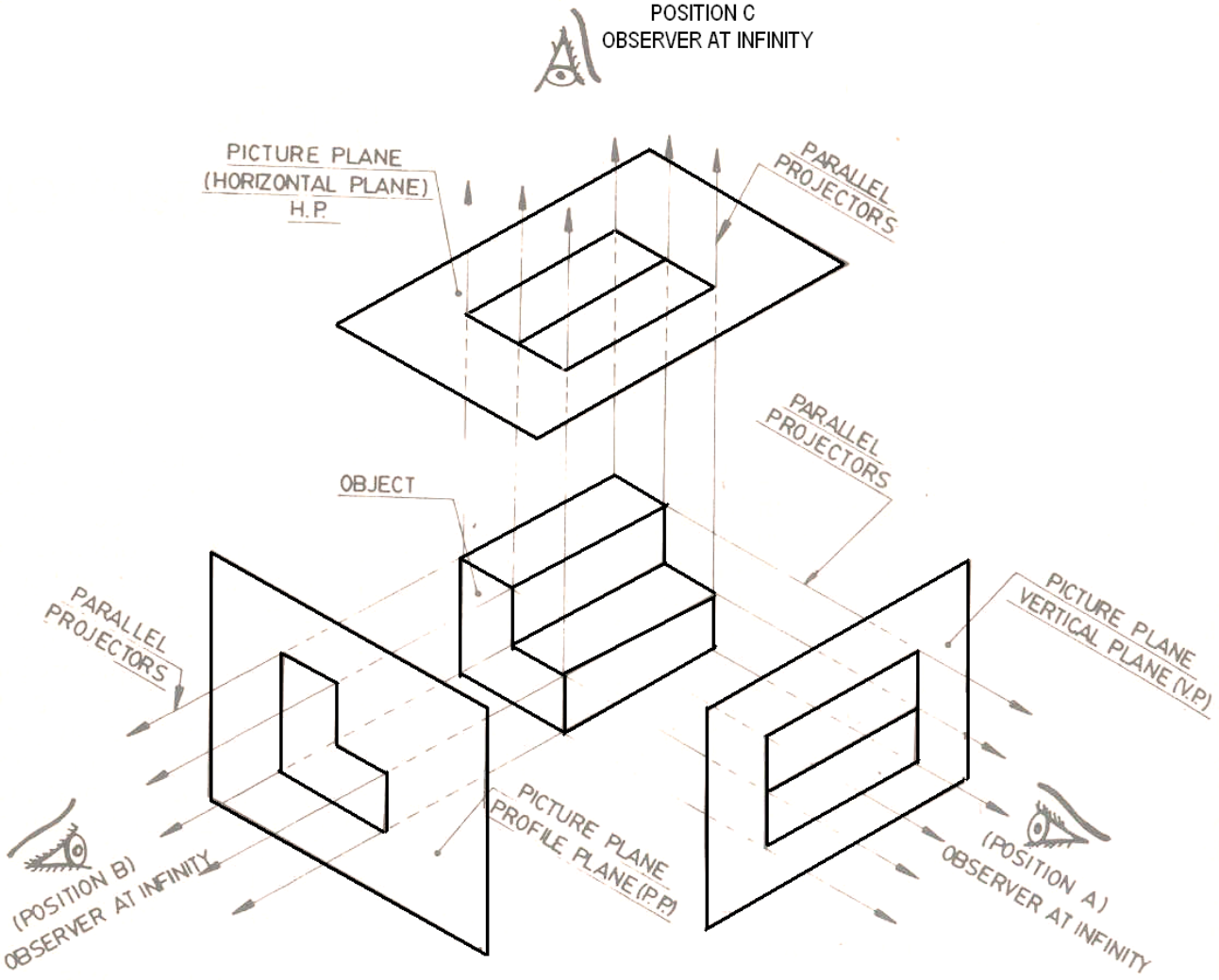
Axis-aligned cut

With cut, the surrounding 3D context is visible.

Reducing Attributes: Project 1/5

- With the **project** design choice, all items are shown, but without the information for specific dimensions chosen to exclude.
- There are three commonly used projections: **orthographic projection**, **perspective projection**, and **map projection**.
- **Orthographic projection**: for each item the values for excluded dimensions are dropped.

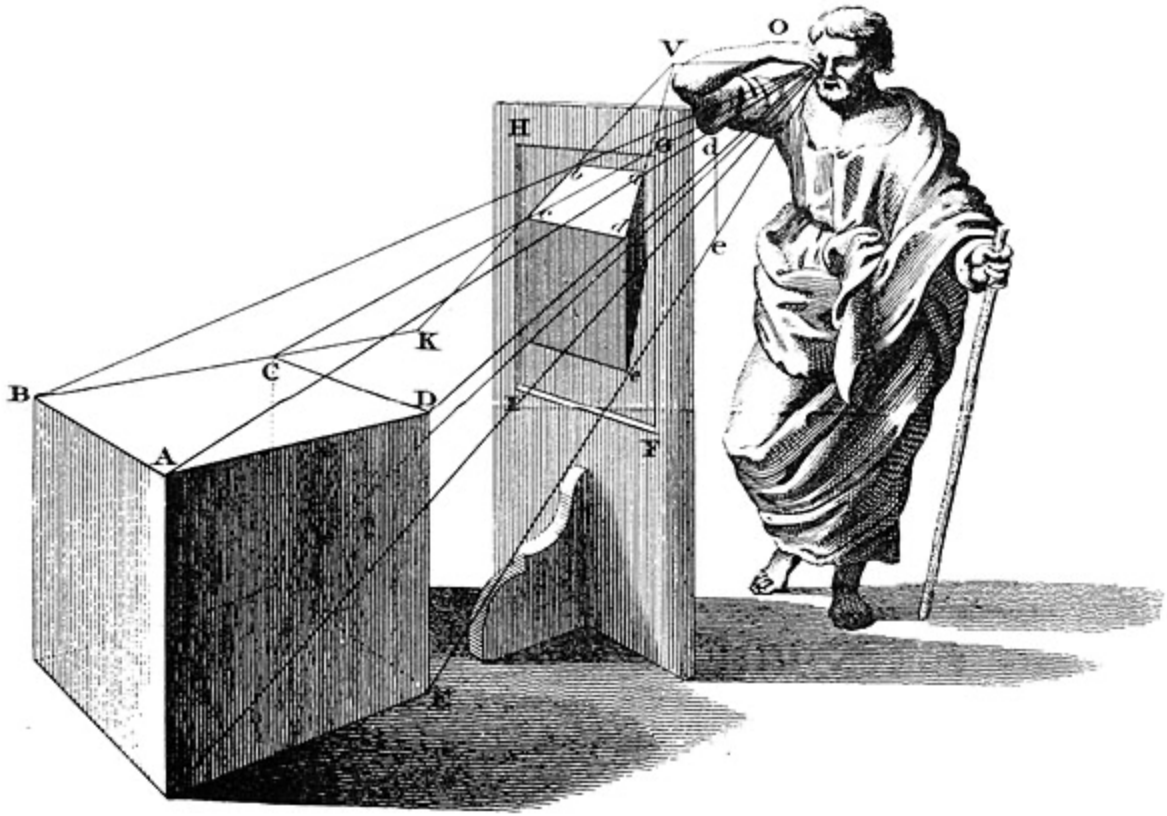
Reducing Attributes: Project 2/5



Taken from the Internet

Reducing Attributes: Project 3/5

- **Perspective projection** also projects from 3D to 2D, with the camera position at a finite point.

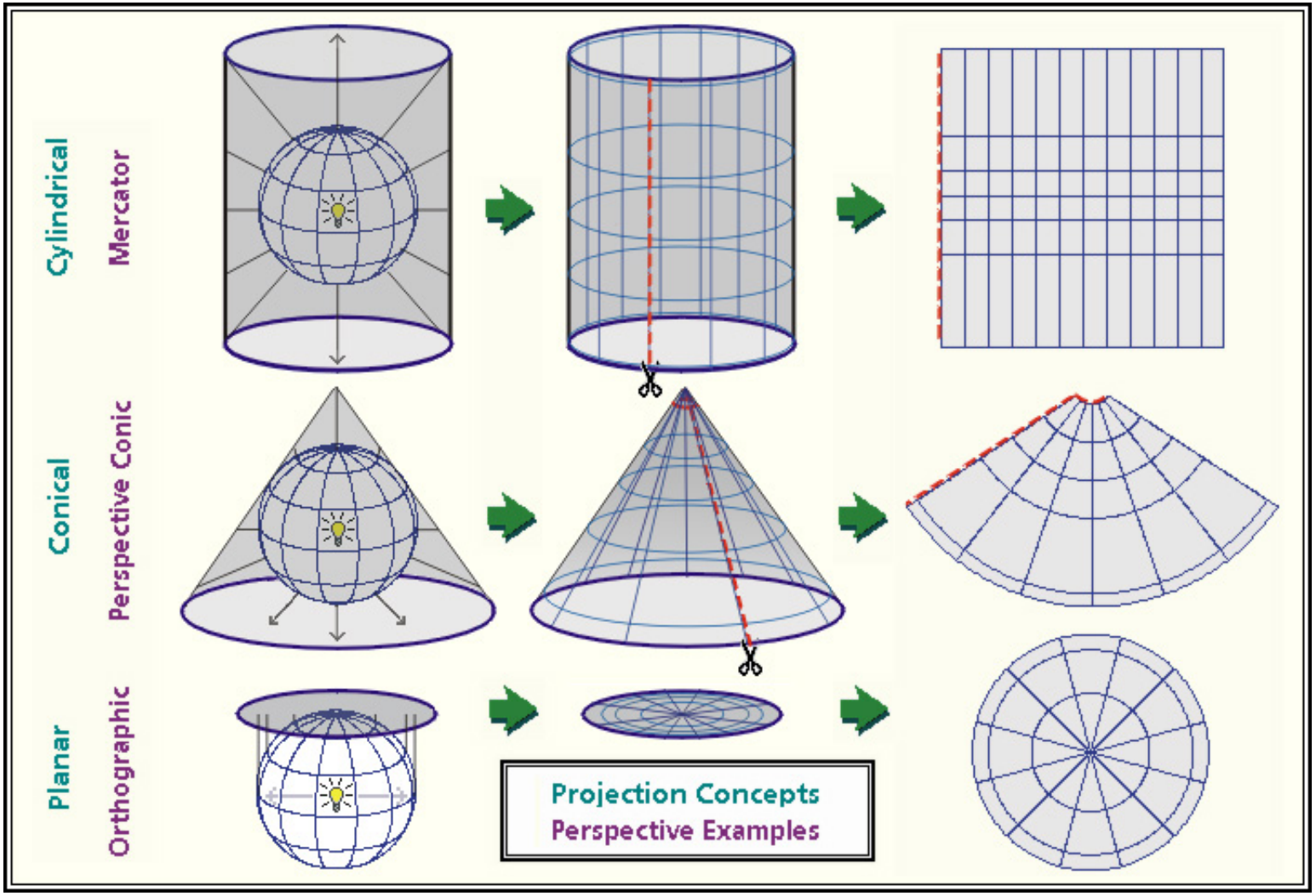


Brook Taylor *New Principles of Linear Perspective*, 4th edition, J. Taylor, London, England

Reducing Attributes: Project 4/5

- **Map projections** project from the surface to a plane, and have been proposed by cartographers, including the well-known Mercator projection.
- These projections transform from a curved to a flat space, and most of the design choices when creating them concern whether distorting angles or areas is less problematic for the intended abstract task.

Reducing Attributes: Project 5/5



The End