Chapter 7

Rules of Thumb

The Big Picture

- **Rules of Thumb: Advice and guidelines**
  - **You can remember each title as a slogan**
  - **An attempt to synthesize the current state of knowledge into a more unified whole**
  - **Come from**
    - **Empirical studies**
    - **Arguments based on the experience**
    - **Arguments proposed previously**
  - **Not a complete list**
    - **Deeply incomplete**
    - **Ongoing research**
    - **Many open questions**

8 Rules of Thumb

- No unjustified 3D
- No unjustified 2D
- Eyes beat memory
- Resolution over immersion
- Overview first, zoom and filter, detail on demand
- Responsiveness is required
- Get it right in black and white
- Function first form next

No unjustified 3D

- **Most people have the intuition that three dimensions must better than two dimensions**
  - **But there are many difficulties in visually encoding information with third spatial dimension**
  - **3D vis is easy to justify when the task involves shape understanding of inherently 3D structures**
    - **For spatial data**
  - **In all other contexts, the use of 3D needs to be carefully justified**
    - **In most cases, instead of 3D of spatial position, 2D of spatial position is a better choice**

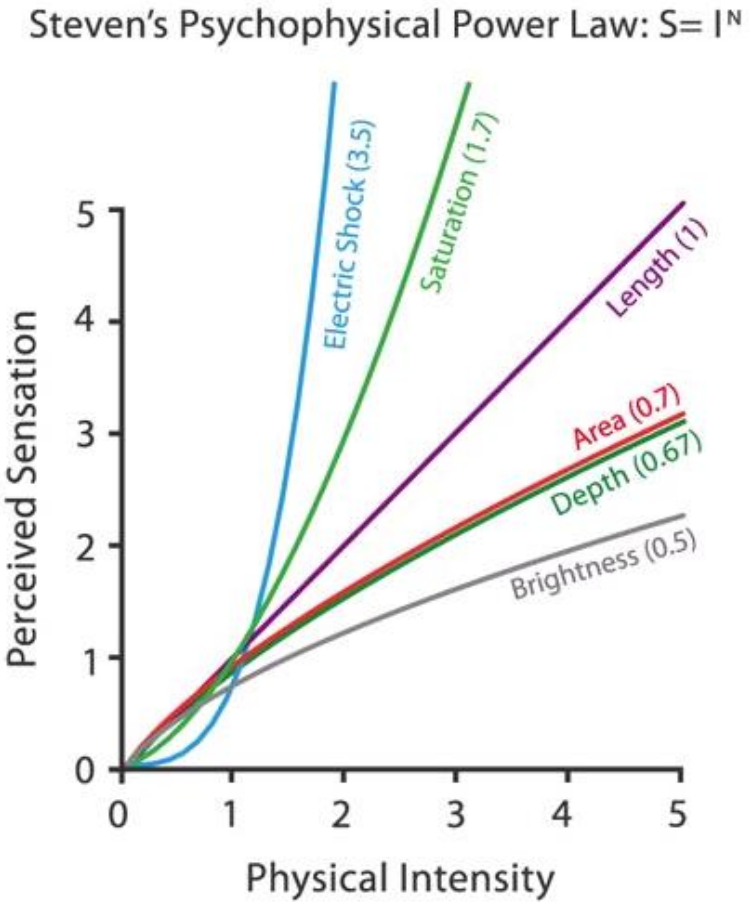
No unjustified 3D

- The cues that convey depth information
  - Occlusion
  - Perspective distortion
  - Shadows and lighting
  - Familiar size
- Topics
  - The power of the plane
  - The disparity of depth
  - Occlusion hides information
  - Perspective distortion dangers
  - Titled text isn't legible

No unjustified 3D
The power of the plane

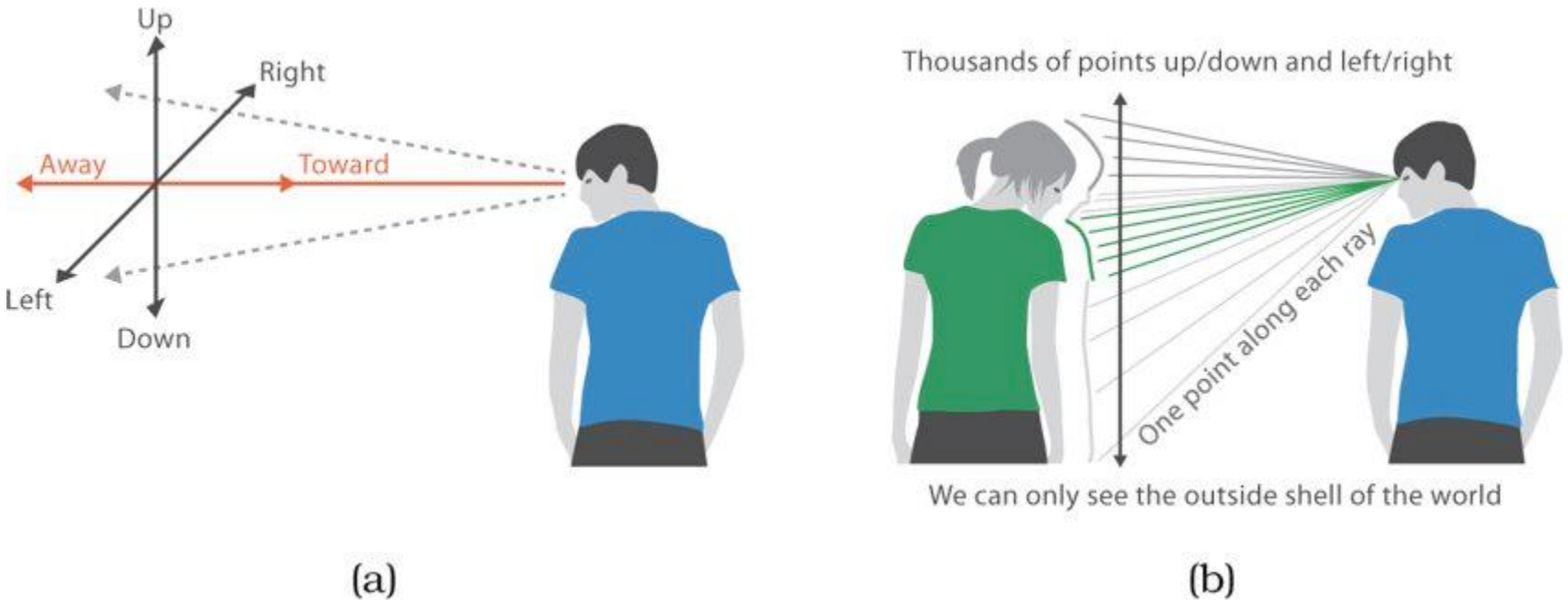
- In channel ranking, spatial position channels apply to planar spatial position, not 3D position
- Vertical & horizontal position are combined into the shared category of planar
  - People perceive height differences more important than horizontal differences
    - Due to effects of gravity in real life
  - While the vertical spatial channel has a slight priority over the horizontal one, standard display gives more horizontal pixels than vertical ones
    - Due to information density consideration

No unjustified 3D
The disparity of depth



- **The power law exponents for accuracy**
  - **Length in 2D: 1.0**
    - **Scale linearly**
  - **Depth in 3D: n=0.67**
    - **Scale nonlinearly**
    - **Distances and angles are distorted**
    - **Even worse than area (0.7)**

No unjustified 3D
The disparity of depth



(a) The sideways and up–down axes are fundamentally different from the toward–away depth axis.

(b) Along the depth axis we can see only one point for each ray, as opposed to millions of rays for the other two axes.

line-of-sight ambiguity: in order to get more information hidden, we need to change the viewpoint

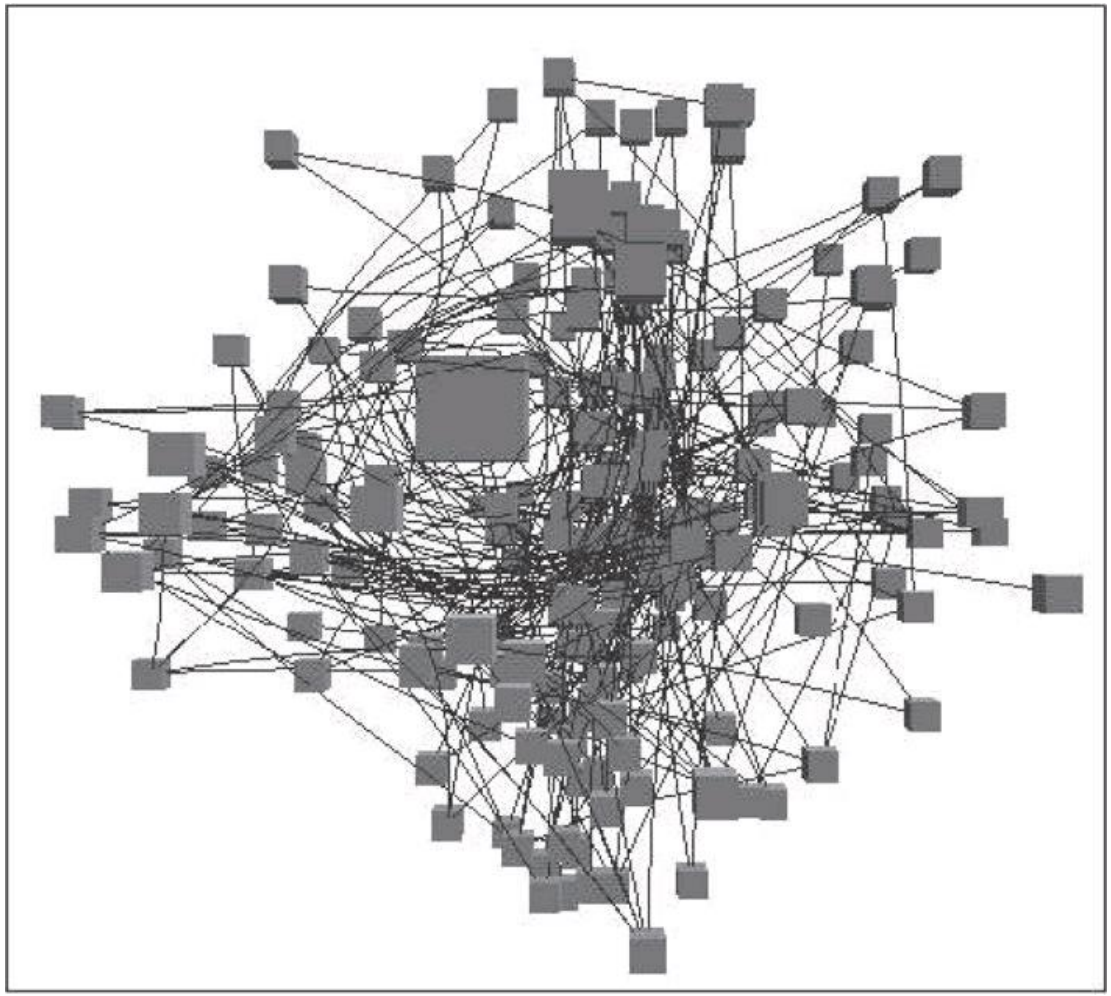
No unjustified 3D
Occlusion hides information

- Occlusion: the most powerful depth cue
- Motion parallax
  - Occlusion relationships between objects change as we move around
    - Allow us to understand the relative distance between objects
  - For realistic scenes with familiar objects
    - Motion parallax does not impose cognitive load
  - For synthetic scenes
    - Interactive navigation takes longer than inspecting a single image

No unjustified 3D
Occlusion hides information

- **Occlusion in visual encoding**
  - **Presumably important information is hidden and discovering it via navigation has a time cost**
    - **Occluded detail might be critical**
    - **Especially important when using spatial position as a visual channel for abstract, non-spatial data**
  - **If the objects have unpredictable and unfamiliar shape**
    - **Understanding such scenes can be appreciable cognitive load**
      - **People must use the internal memory to remember what have seen, and internally synthesize an understanding of the structure**
      - **Common when using the spatial position channel for visual encoding**

No unjustified 3D
Occlusion hides information

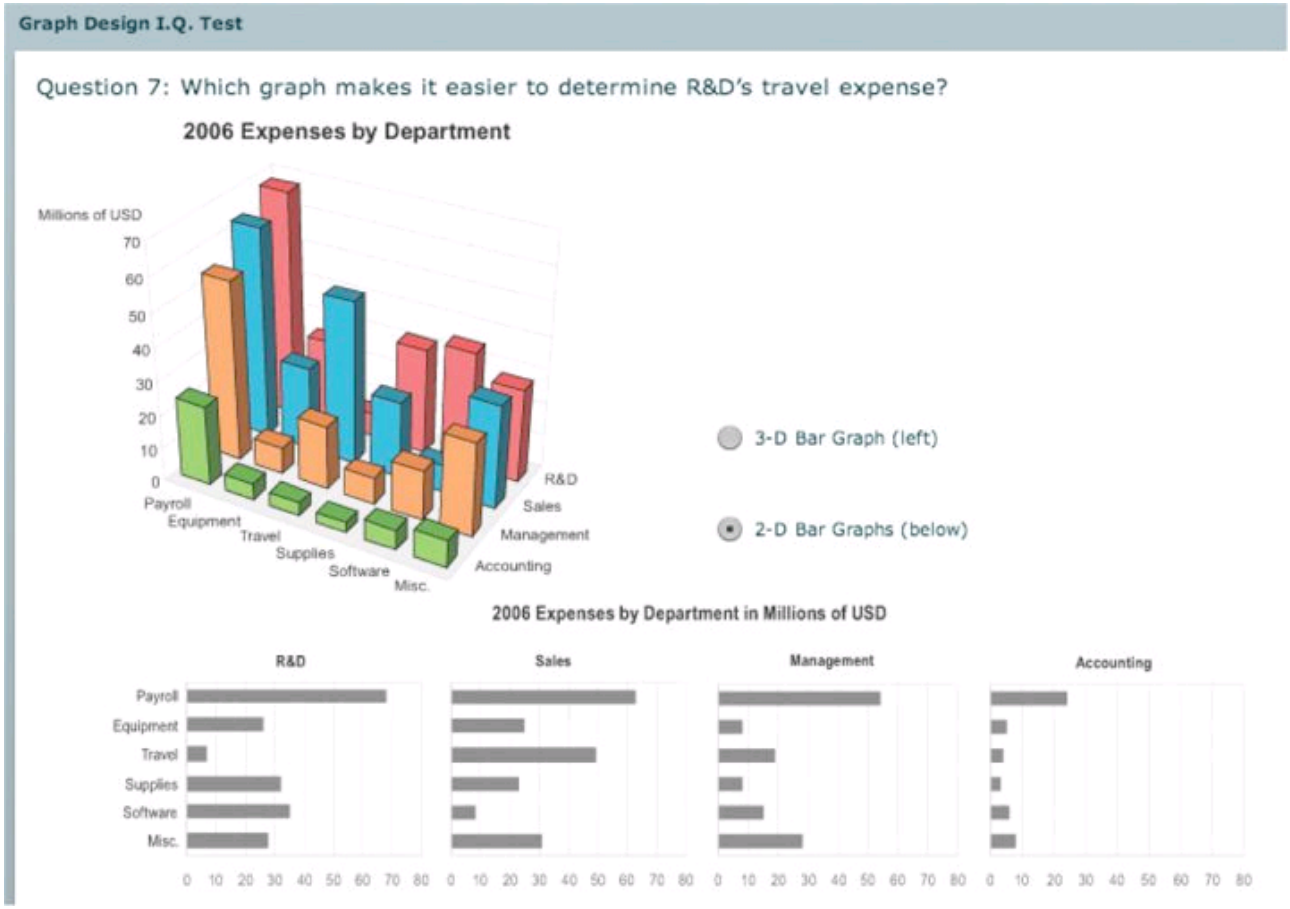


A node-link graph laid out in 3D

No unjustified 3D
Perspective distortion dangers

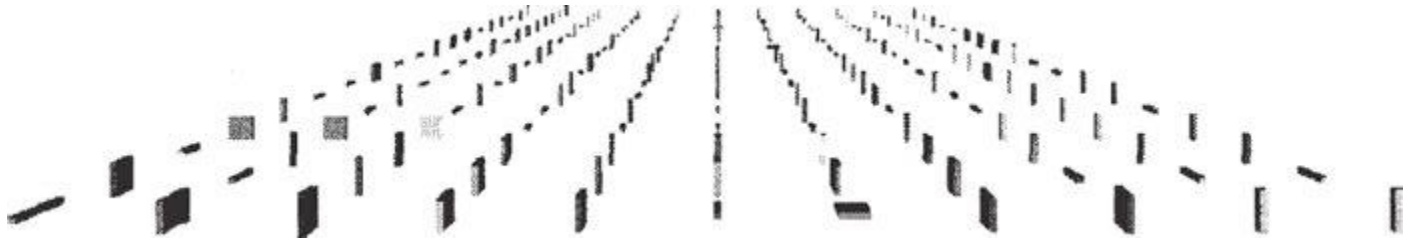
- **Perspective**
  - **Painting based on perspective can create very realistic images – a good thing**
  - **For visual encoding abstract data – very bad**
- **Perspective distortion**
  - **Distant objects appear smaller and change their planar position on the image**
  - **Is one of the main dangers of depth because the power of the plane is lost**
  - **It interferes with visual encodings that use the planar spatial position channels and size channel**

No unjustified 3D
Perspective distortion dangers



3D bar charts are more difficult than 2D bar charts because of both perspective distortion and occlusion

No unjustified 3D
Perspective distortion dangers



With perspective distortion, the power of the planar spatial position channel is lost, as is the size channel.
The bar size cannot be directly compared as a simple perceptual Operation.

No unjustified 3D
Other depth cues

- **Size of familiar objects**
  - **A depth cue in real life**
  - **For visually encoded objects in the scene, we do not have access to this depth cue**
- **Shadow and surface shading**
  - **Problems**
    - **Shading**
      - **create visual clutter that distracts the viewer's attention**
      - **Interfere with the color mapping**
    - **Shadow**
      - **could be mistaken by the viewer for true marks that are the substrate for the visual channels showing attribute information**
      - **Occlude true marks**

No unjustified 3D
Other depth cues

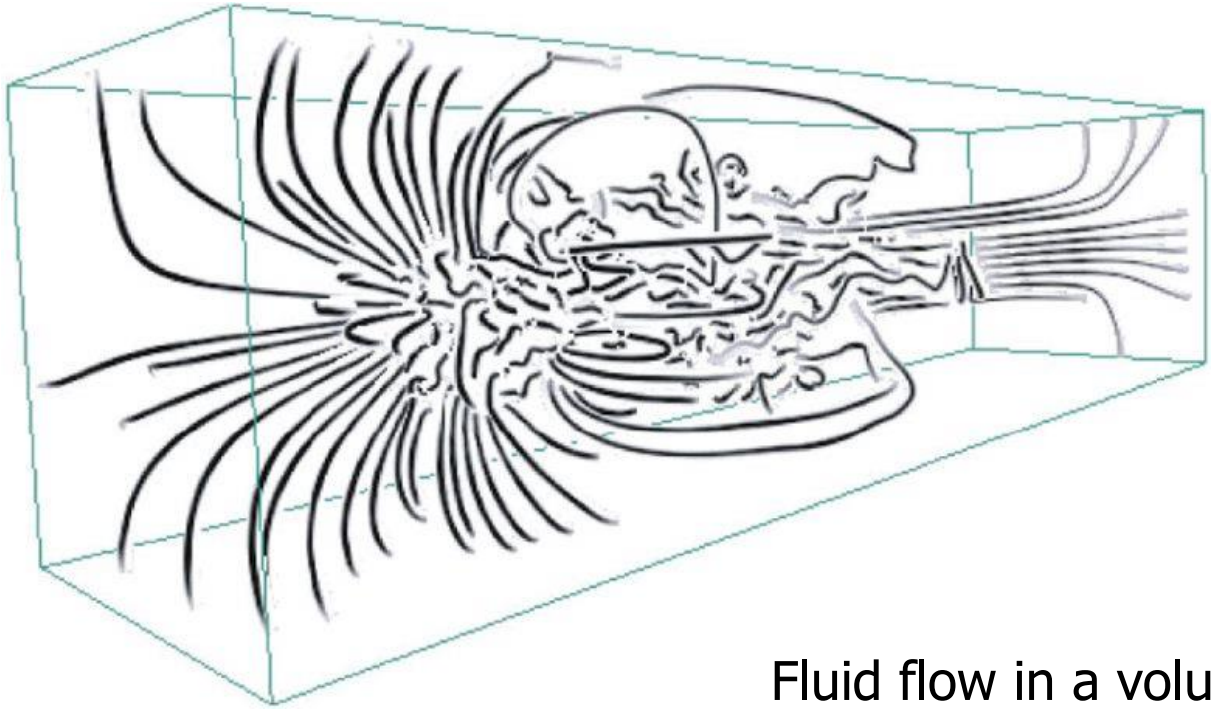
- **Stereo displays**
  - **Pros**
    - **Help user realize the depth information**
    - **Will not interfere to other visual channels**
  - **Cons**
    - **Useful only for the nearby objects at the same depth**
    - **Cannot solve any problem with perspective distortion**

No unjustified 3D Titled text isn't legible

- **The use of 3D dramatically impaired text legibility**
  - **The text positioned at arbitrary orientations in 3D space is usually not rendered well**
    - **Problems**
      - **Blocky (解析度不均勻)**
      - **Jaggy (鋸齒)**
- **The high-resolution displays may solve this problem in the future, but legibility is a major problem**

No unjustified 3D
Benefits of 3D: Shape perception

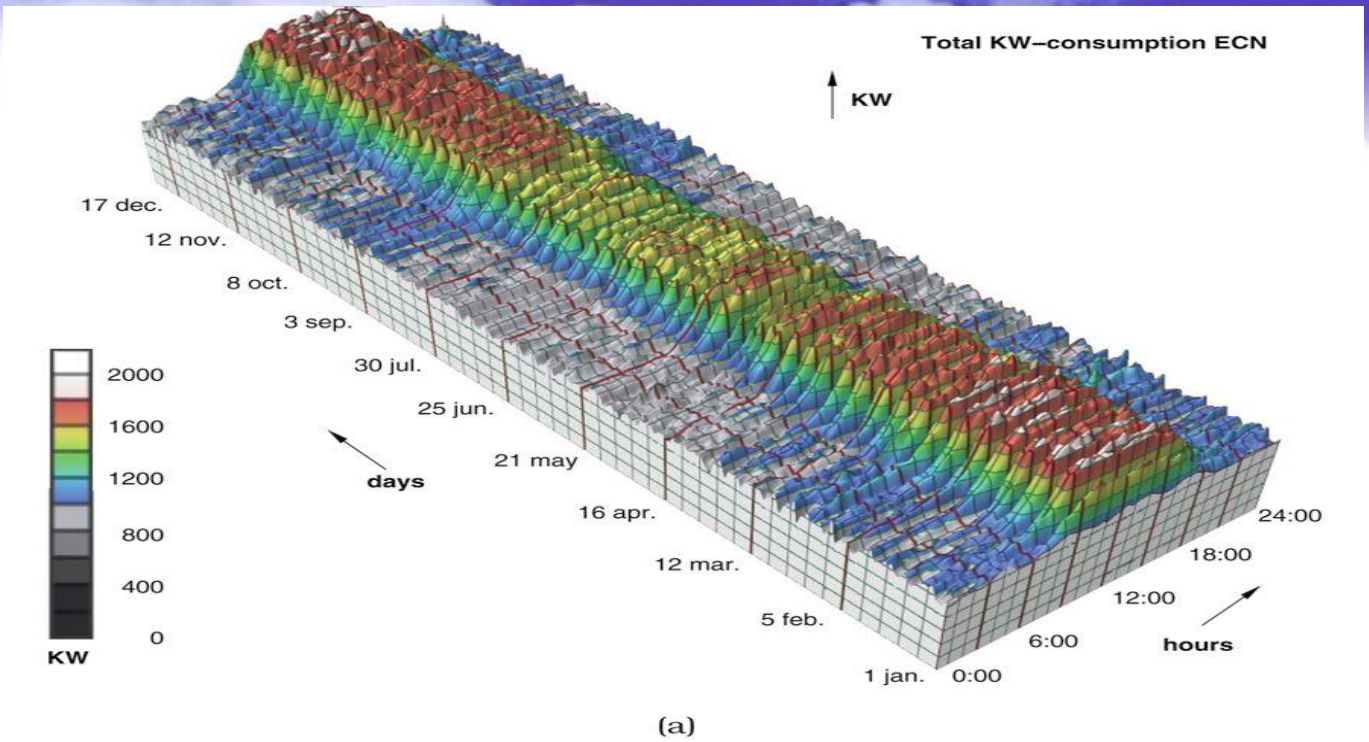
- **3D is good for task that fundamentally requires understanding 3D geometric structure of objects**



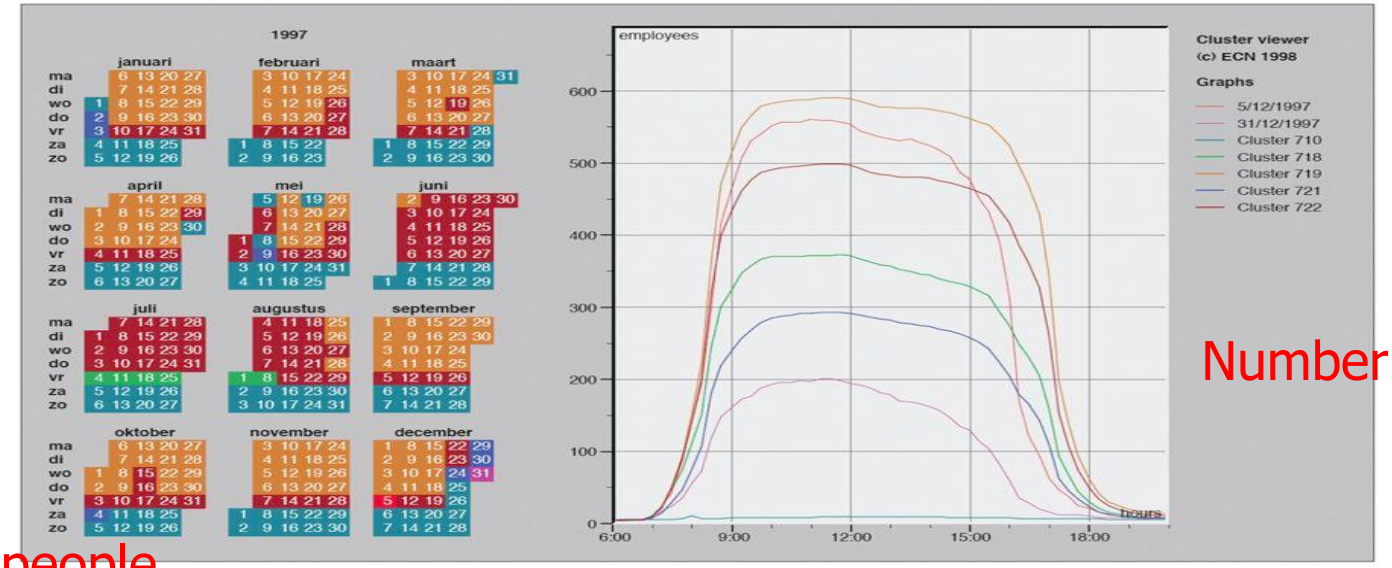
Fluid flow in a volume

No unjustified 3D Justification and alternatives

- The use of 3D for abstract data requires careful justification
- Example
  - Cluster-calendar time-series vis
    - Two sets of measurements for a year
      - Number of people inside a building
      - Amount of power consumed
  - 3D display
    - Problems of occlusion and perspective distortion
  - Multiple linked 2D views
    - Derived data
      - a hierarchical clustering of the time series curves where the most similar curves are merged and represented by the average curve.



(a)



(b)

Number of people

Number of people

No unjustified 2D

- **Laying out data in 2D space should be explicitly justified, compared with the alternative of simply showing the data with 1D list**
  - **Lists can show the maximal amount of information density, such as text labels, in minimal**
    - **Compared with 2D graph – requires more space**
  - **Lists are excellent for lookup tasks when they are ordered appropriately**
    - **Compared with 2D graph – finding a specific label might require hunting around the graph**

No unjustified 2D

- When the task truly requires understanding the topological structure of the network
  - The benefits of showing those relationships in 2D outweigh the space cost required
- Some tasks are handled well by linear lists even if the original data has network structure

Eyes beat memory

- **Using eyes to switch between different views that are visible simultaneously has much lower cognitive load than consulting our memory to compare a current view with what was seen before**
- **Many interactions idioms implicitly rely on memory**
- **During navigation, maintaining a sense of orientation implicitly relies on memory**

Eyes beat memory
Memory and attention

- **Human memory**
  - **Long-term memory**
    - **Can last a lifetime**
    - **Doesn't have a strict upper limit**
  - **Short-term memory (working memory)**
    - **Lasts several seconds**
    - **Very limited space**
- **Cognitive load**
  - **When the space limits are reached, people fail to absorb all of the information that is presented**

Eyes beat memory
Memory and attention

- **Human attention also have severe limits**
  - **Conscious search for items**
    - **Becomes more difficult with the number of items to be checked**
  - **Vigilance (警覺)**
    - **Ability to perform visual search degrades quickly with time**

Eyes beat memory
Animation vs. side-by-side views

- **Some animation idioms impose significant cognitive load due to implicit memory demand**
- **Three definitions of animation**
  - **Narrative storytelling, as in movies**
    - **In Vis, might have simultaneous changes in many parts of the view**
  - **Transition from just one state to another**
    - **Extremely powerful because it helps the user maintain context**
    - **Are most useful when only a few things change**
  - **Video-style playback of a multi-frame sequence**
    - **Play, pause, stop, rewind, forward/back**

Eyes beat memory
Animation vs. side-by-side views

- For tasks requiring detailed comparison across many frame
  - Seeing all frames at once side by side can be more effective
    - The number of frames must be small

Eyes beat memory
Change blindness

- **Change blindness**
  - **Human do not have detailed internal memory of the visual field that surrounds us**
  - **We fail to notice even quite drastic changes if our attention is directed elsewhere**
- **Implications**
  - **It is difficult to track complex and widespread changes across multi-frame animation**

Resolution over immersion

- **Immersion**
  - **The feeling of presence in virtual world**
- **Trade-off between resolution and immersion**
  - **Resolution is far more important than immersion**
- **Immersion would be helpful when the chosen abstraction includes 3D spatial data**
  - **Designer should consider whether a sense of presence is worth the penalties of lower resolution and no workflow integration**
  - **Require even more careful justification!**

Overview first, zoom and filter, detail on demand

- **Emphasizes the interplay between**
  - **the need for overview**
  - **The need to see details**
  - **The role of data reduction in general**
  - **Navigation in supporting both**
- **Overview**
  - **Give the user a broad awareness of the entire information space**
  - **An idiom with goal of summarize**
  - **Common goals**
    - **Show all items simultaneously, w/o navigation**
    - **Help users find regions where detailed is needed**

Overview first, zoom and filter, detail on demand

- **Overview creation can be understood in terms of both filtering and aggregation**
  - **Zoom out geometrically so that entire dataset is visible within the frame**
    - **Created by removing all filtering**
      - **Created by changing from a zoomed-in view where some items are filtered out, to a zoomed-out view where all items are shown**
    - **When number of items is large**
      - **One mark per item is impossible**
      - **The number of marks to show must be reduced with aggregation**
  - **Sophisticated overview**
    - **Dynamic aggregation implicitly driven by navigation**

Overview first, zoom and filter, detail on demand

- **Overview vs. detail view**
  - **Detail view pops out in response to a selection action by the user**
  - **Use a single view that dynamically changes over time by providing support for reduce actions such as zooming and filtering**
    - **That single sometimes act as an overview and sometimes as a detail view**
  - **Embed both detailed focus and overview context within a single view**
    - **Focus+context**

Overview first, zoom and filter, detail on demand

- This mantra is most helpful when dealing with dataset of moderate size
- If the size of dataset is too large, an alternative approach is "Search, Show context, Expand on demand"
  - Search results provide the starting point for browsing of local neighborhoods

Responsiveness is required

- **Latency of interaction**
  - **How much time it takes for the system to respond to the user action**
  - **Three categories**
    - **Perceptual processing**
      - **Relevant for operations such as screen updates**
      - **0.1 second**
    - **Immediate response**
      - **Relevant for operations such as visual feedback showing what items selected with a mouse click**
      - **1 second**
    - **Brief tasks**
      - **Relevant for breaking down complex tasks into simpler pieces**
      - **10 seconds**

Time Constant	Value (in seconds)
perceptual processing	0.1
immediate response	1
brief tasks	10

Responsiveness is required Visual feedback

- **Principles**
  - **The user should have some sort of confirmation that the action has completed**
    - **Highlight a selected item**
  - **If an action could take significantly longer than a user would naturally expect, show the progress indicator**

Responsiveness is required Latency and interaction design

- **Successful interaction design depends on having a good match between**
  - **The latencies of the low-level interaction mechanism**
    - **Clicking on the item: move, stop, click**
  - **The visual feedback mechanism**
    - **Show information at the side of screen**
      - **Eyes need to move; see a lot of details**
    - **A popup window at the current cursor location**
      - **No need to move eyes; might occlude other objects, require visual encoding cost**
    - **A visual highlight change directly in the view**

Responsiveness is required Latency and interaction design

- The system update time
  - Redraw the view
    - Guaranteed frame rate rendering
    - Scalable rendering framework
- Cognitive load of operation itself

- When all latencies are well matched
  - The user interacts fluidly and can stay focused on the high-level goals such as building an internal mental model of the dataset

Responsiveness is required interactivity costs

- **Interactivity has both power and cost**
  - **Can explore a larger information space**
  - **Cost: it requires human time and attention**
  - **Automatically detecting features of interest to explicitly bring to the user's attention via the visual encoding is a useful goal**
  - **Trade-off between finding automatable aspects and relying on the human in the loop**

Get it right in black and white

- **We need to make sure the most crucial aspects of vis rep are legible even if the image is transformed from full color to black and white**
  - **Suggest encoding the most important attribute with the luminance channel**

Function first form next

- **The best vis design should shine in both form and function**
  - **Should be both beautiful and effective**
- **It is more important to give an effective design than a beautiful design**
- **Given an effective but ugly design**
  - **It is possible to refine the form to make it more beautiful while maintaining the base of effectiveness**
- **Given a beautiful and ineffective design**
  - **Can do nothing**