Visualization

- Presenting information visually to increase understanding

C.J. Minard drew this map in 1869 to show the plight of Napoleon’s army in the Russian campaign of 1812. (Popularized by E Tufte, *The Visual Display of Quantitative Information*)

Plots against time: size of army, 2D location, direction of march, temperature during retreat
Visualization

- C.J. Minard’s map showing plight of Napoleon’s army in Russian campaign of 1812. (Popularized by E Tufte, The Visual Display of Quantitative Information)

Scientific Visualization

- “Visualization is a method of computing. It transforms the symbolic into the geometric, enabling researchers to observe their simulations and computations. Visualization offers a method for seeing the unseen…

Richard Hamming observed many years ago that ‘The purpose of [scientific] computing is insight, not numbers.’ The goal of visualization is to leverage existing scientific methods by providing new scientific insight through visual methods.”
Information Visualization

- S. Card, J. Mackinlay, & G. Robertson, Xerox PARC, early 90s
- Used “3D graphics workstations” to visualize data from fields other than science
  - Exploit human perceptual system
  - Present data that is not inherently spatial
- But, not just visual presentation
  - Audio, haptic, …

Visual Analytics \( \text{http://vis.pnnl.gov} \)

- “Addresses the issues faced by analysts, border personnel, and first responders”
- “Visual analytics is the science of analytical reasoning facilitated by interactive visual interfaces…."

Visual analytics is a multidisciplinary field that includes the following focus areas:
- Analytical reasoning techniques that enable users to obtain deep insights that directly support assessment, planning, and decision making
- Visual representations and interaction techniques that take advantage of the human eye’s broad bandwidth pathway into the mind to allow users to see, explore, and understand large amounts of information at once
- Data representations and transformations that convert all types of conflicting and dynamic data in ways that support visualization and analysis
- Techniques to support production, presentation, and dissemination of the results of an analysis to communicate information in the appropriate context to a variety of audiences.

—J. Thomas and K. Cook (eds.), *Illuminating the Path: The Research and Development Agenda for Visual Analytics*, National Visualization and Analytics Center, 2005
Visual Information-Seeking Mantra

- “Overview first, zoom and filter, then details on demand” — B. Shneiderman

Data Types: 1D Linear

- Text
  - Documents
  - Source code
  - Lists
Techniques: Nonlinear Magnification

- In-place magnification of selected element(s) that preserves global context
  - Non-selected elements are typically minified
  - Level-of-detail is often changed along with size
- Related terms
  - Distortion viewing
  - Bifocal display
  - Fisheye views
  - Focus+context
    - Fisheye and focus+context also refer to techniques that do not magnify, but do change level-of-detail

R. Spence and M.D. Apperley, Bifocal display, 1982
https://www.youtube.com/watch?v=r0N02kXugDP4
Fisheye Views  G. Furnas, CHI 86

- Address limited screen space with level-of-detail analogy to photographic fisheye lens (often without geometric distortion)
- Balance *local detail* with *global context*

G. Furnas, Generalized fisheye views, CHI 86
G. Furnas, A fisheye followup: Further reflections on focus + context, CHI 06
Fisheye Views  G. Furnas, CHI 86

- Compute Degree of Interest (DOI)
  - Assign a value to each element in a structure, indicating its interest to the user, given the current task
- Create display
  - Present top $n$ elements by choosing $n$ with highest DOI
- So, how to define DOI?

Fisheye Views  G. Furnas, CHI 86

- $\text{DOI}_{FE}(x \mid.= y) = \text{API}(x) - D(x,y)$
  - $\text{DOI}_{FE}(x \mid.= y)$ is degree of interest in element $x$, given that the current element of focus is $y$
  - API$(x)$ is global a priori importance of $x$
  - D$(x,y)$ is distance between $x$ and $y$
  - Degree of interest in $x$ increases with a priori importance and decreases with distance to $y$
- Given threshold $k$, display only $x$ where $\text{DOI}_{FE}(x \mid.= y) \geq k$
  - $k$ determines # elements in fisheye view
Fisheye Views  
G. Furnas, CHI 86

- Difference from optical fisheye lens
  - Select (what to show) rather than distort (how to show)
    - Distortion can be used as a companion technique
    - Distortion (scaling larger/smaller) also affects what is shown
      - Scaling smaller decreases legibility
    - Other approaches (sometimes called fisheye, too) emphasize distortion
  - Distance is not necessarily geometric

Fisheye Views  
G. Furnas, CHI 86

- DOI_{FE}(x \mid y) = API(x) - D(x, y)
- Example: For a tree visualization
  - API(x) = -d_{tree}(x, root)
    - Negative of the path length between x and root
      (farther from root → less important)
Fisheye Views G. Furnas, CHI 86

- DOI_{FE}(x |.= y) = API(x) − D(x,y)
- Example: For a tree visualization
  - D(x,y) = d_{tree}(x,y)
    - Path length between x and y (where y is the focus)

- DOI_{FE(tree)}(x |.= y) = −d_{tree}(x,root) − d_{tree}(x,y)
  = −(d_{tree}(x,root)+d_{tree}(x,y))
**Fisheye Views** G. Furnas, CHI 86

- \( \text{DOI}_{FE}(x \mid y) = \text{API}(x) - D(x, y) \)
- Given \( k \), display only \( x \) where \( \text{DOI}_{FE}(x) \geq k \)
  - Creates fisheye views of different sizes
    - Zero-order tree fisheye \( (k = -3) \)

We can also redraw the tree, ignoring original layout.
Fisheye Views  G. Furnas, CHI 86

- $\text{DOI}_{\text{FE}}(x | y) = \text{API}(x) - D(x, y)$
- Given $k$, display only $x$ where $\text{DOI}_{\text{FE}}(x) \geq k$
  - Creates fisheye views of different sizes
    - Zero-order tree fisheye ($k = -3$)

Fisheye Views  G. Furnas, CHI 86

- $\text{DOI}_{\text{FE}}(x | y) = \text{API}(x) - D(x, y)$
- Given $k$, display only $x$ where $\text{DOI}_{\text{FE}}(x) \geq k$
  - Creates fisheye views of different sizes
    - First-order tree fisheye ($k = -5$)
Fisheye Views

- $\text{DOI}_{FE}(x, y) = \text{API}(x) - D(x, y)$
- Given $k$, display only $x$ where $\text{DOI}_{FE}(x) \geq k$
  - Creates fisheye views of different sizes
  - Second-order tree fisheye ($k = -7$)

Generalizing Fisheye Views

- **What to show**
  - $\text{DOI}_{FE}$
- **How to show**
  - E.g., distortion of position and scale
  - *How can also influence what through legibility!*

Feiner, COMS W4170, Fall 2017
Fisheye Views  G. Furnas, CHI 86

Conventional view of C program

```c
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t[0] = (t[0] + 10000)
- x[i];
for(i=1;i<k;i++){
    t[i] = (t[i] + 10000)
    - x[i]
    - (i - t[i-1]/10000);
}

} [k-1] %= 10000;
break;
case 'f';
for(i=0;i<k;i++) t[i] = x[i];
break;
case 'g';
exit(0);
default:
    if(noprime = 1;
    break;
}

if(noprime)
    for(i=k-1;i>0;i--)
        printf("%d", t[i]);
if(i > 0} {
```

First-order fisheye view of C program, where focus is line 39 (same number of lines, redrawn using compaction)
Fisheye Views  G. Furnas, CHI 86

First-order fisheye
(underlined code) vs.
conventional view (boxed
code)

Fisheye Menus

- Apple macOS dock with “Magnification” enabled
  - But, remember Fitts’s Law!
Data Types: 2D Spatial

- Inherently spatial data
  - Maps

- Use of distortion viewing to provide “focus+context”
  - Change scale in focus relative to context

Simple magnification loses context

Robertson and Mackinlay. UIST 93
**Data Types: 2D Spatial**

Inherently spatial data: Distortion viewing applied to a map

- Abstract data
  - Need to select bindings to XY coordinates
  - Can use *semantic zoom*
    - Zooming (magnification/minification) that changes the representation (e.g., shape, format, level of detail) instead of or in addition to geometric scale

Bederson et al., TOCHI 04