Perception

Maneesh Agrawala

CS 294-10: Visualization
Spring 2011

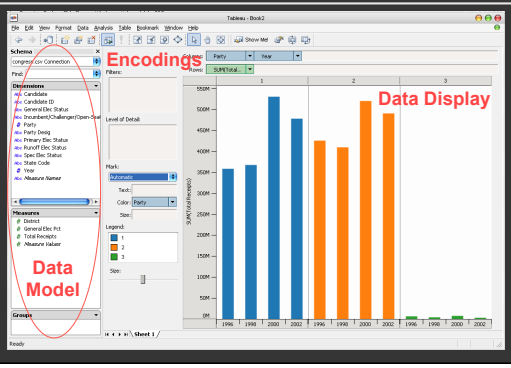
Last Time: Multidimensional Visualization

Visualizing Multiple Dimensions

Strategies
- Avoid "over-encoding"
- Use space and small multiples intelligently
- Reduce the problem space
- Use interaction to generate *relevant* views

There is rarely a single visualization that answers all questions. Instead, the ability to generate appropriate visualizations quickly is key

Tableau



Polaris/Tableau Approach

Insight: simultaneously specify both database queries and visualization

Choose data, then visualization, not vice versa

Use smart defaults for visual encodings

Recently: automate visualization design (ShowMe – Like APT)

Parallel Coordinates

Parallel Coordinates [Inselberg]

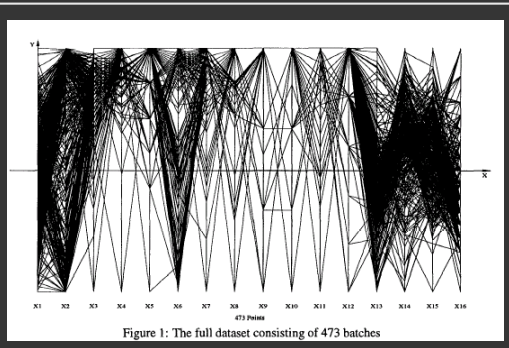


Figure 1: The full dataset consisting of 473 batches

The Multidimensional Detective

The Dataset:
Production data for 473 batches of a VLSI chip
16 process parameters:

X1:	The yield: % of produced chips that are useful
X2:	The quality of the produced chips (speed)
X3 … X12:	10 types of defects (zero defects shown at top)
X13 … X16:	4 physical parameters

The Objective:
Raise the yield (X1) and maintain high quality (X2)

A. Inselberg, Multidimensional Detective, Proceedings of IEEE Symposium on Information Visualization (InfoVis '97), 1997

Parallel Coordinates

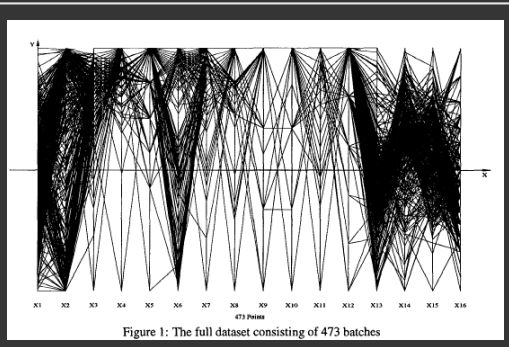


Figure 1: The full dataset consisting of 473 batches

Inselberg's Principles

1. Do not let the picture scare you
2. Understand your objectives
   - Use them to obtain visual cues
3. Carefully scrutinize the picture
4. Test your assumptions, especially the "I am really sure of's"
5. You can't be unlucky all the time!

Each line represents a tuple (e.g., VLSI batch)
Filtered below for high values of **X1** and **X2**

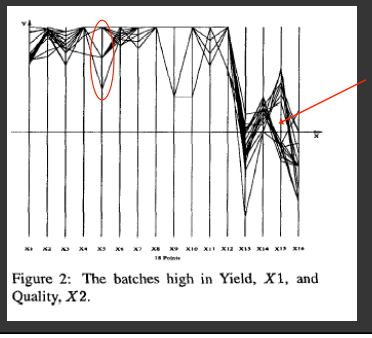
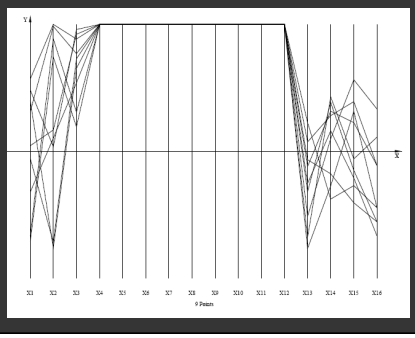


Figure 2: The batches high in Yield, $X1$, and Quality, $X2$.

Look for batches with *nearly* zero defects (9/10)
Most of these have low yields → defects OK.



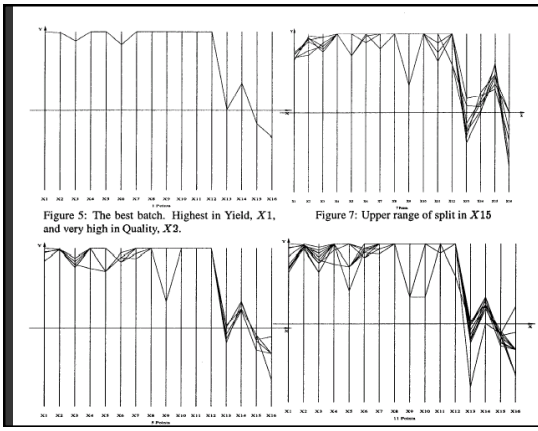


Figure 5: The best batch. Highest in Yield, $X1$, and very high in Quality, $X2$.

Figure 7: Upper range of split in $X15$

Notice that X6 behaves differently.
Allow 2 defects, including X6 → best batches

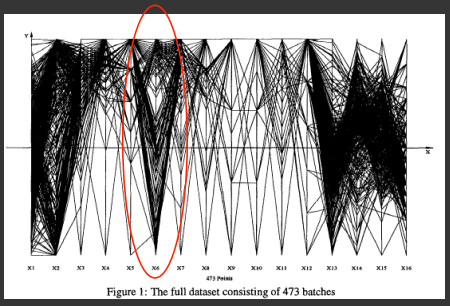


Figure 1: The full dataset consisting of 473 batches

Radar Plot / Star Graph

"Parallel" dimensions in polar coordinate space

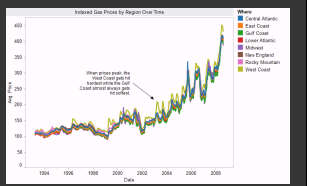
Best if same units apply to each axis

Announcements

Assignment 2: Exploratory Data Analysis

Use existing software to formulate & answer questions

First steps
- Step 1: Pick a domain
- Step 2: Pose questions
- Step 3: Profile data
- Iterate



Create visualizations
- Interact with data
- Refine your questions
- Tableau

Make wiki notebook
- Keep record of all steps you took to answer the questions

Due before class on Feb 14, 2011

Perception

Mackinlay's ranking of encodings

QUANTITATIVE	ORDINAL	NOMINAL
Position	Position	Position
Length	Density (Val)	Color Hue
Angle	Color Sat	Texture
Slope	Color Hue	Connection
Area (Size)	Texture	Containment
Volume	Connection	Density (Val)
Density (Val)	Containment	Color Sat
Color Sat	Length	Shape
Color Hue	Angle	Length
Texture	Slope	Angle
Connection	Area (Size)	Slope
Containment	Volume	Area
Shape	Shape	Volume

Topics

- Signal Detection
- Magnitude Estimation
- Pre-Attentive Visual Processing
- Using Multiple Visual Encodings
- Gestalt Grouping
- Change Blindness

Detection

Detecting brightness

Which is brighter?

Detecting brightness

(128, 128, 128) (133, 133, 133)

Which is brighter?

Just noticeable difference

JND (Weber's Law)

$$\Delta S = k\frac{\Delta I}{I}$$

- Ratios more important than magnitude
- Most continuous variations in stimuli are perceived in discrete steps

Information in color and value

Value is perceived as ordered

∴ Encode ordinal variables (O)

∴ Encode continuous variables (Q) [not as well]

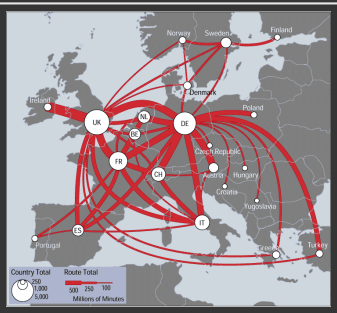
Hue is normally perceived as unordered

∴ Encode nominal variables (N) using color

Steps in font size

Sizes standardized in 16th century

Steps in line width



http://mappa.mundi.net/maps/maps_014/telegeography.html

[based on slide from Munzner]

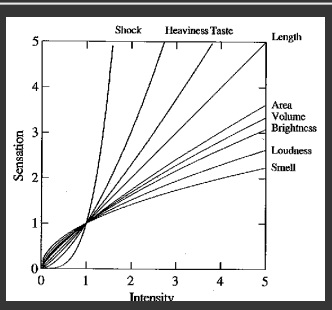
Estimating Magnitude

Compare area of circles

Steven's power law

$$S = I^p$$

p < 1 : underestimate
p > 1 : overestimate



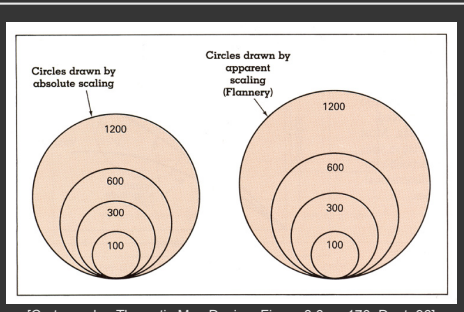
[graph from Wilkinson 99, based on Stevens 61]

Exponents of power law

Sensation	Exponent
Loudness	0.6
Brightness	0.33
Smell	0.55 (Coffee) - 0.6 (Heptane)
Taste	0.6 (Saccharine) -1.3 (Salt)
Temperature	1.0 (Cold) – 1.6 (Warm)
Vibration	0.6 (250 Hz) – 0.95 (60 Hz)
Duration	1.1
Pressure	1.1
Heaviness	1.45
Electic Shock	3.5

[Psychophysics of Sensory Function, Stevens 61]

Apparent magnitude scaling

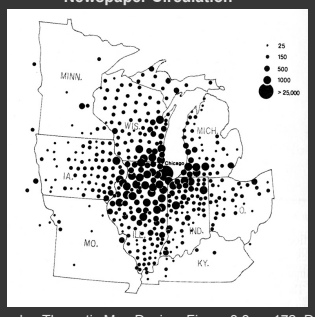


[Cartography: Thematic Map Design, Figure 8.6, p. 170, Dent, 96]

$S = 0.98A^{0.87}$ [from Flannery 71]

Proportional symbol map

Newspaper Circulation



[Cartography: Thematic Map Design, Figure 8.8, p. 172, Dent, 96]

Graduated sphere map

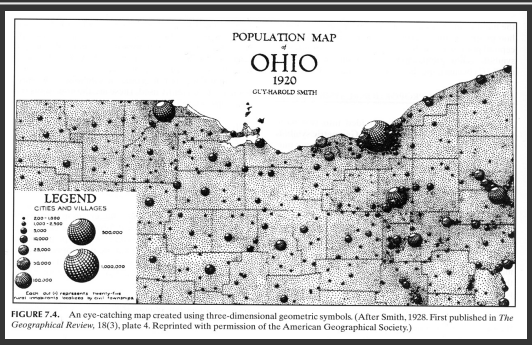


FIGURE 7.4. An eye-catching map created using three-dimensional geometric symbols. (After Smith, 1928. First published in *The Geographical Review*, 18(3), plate 4. Reprinted with permission of the American Geographical Society.)

Cleveland and McGill

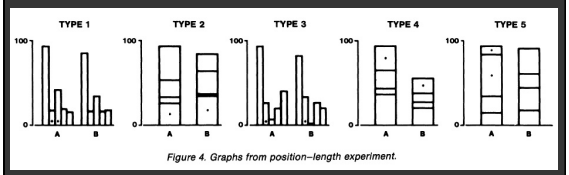


Figure 4. Graphs from position–length experiment.

[Cleveland and McGill 84]

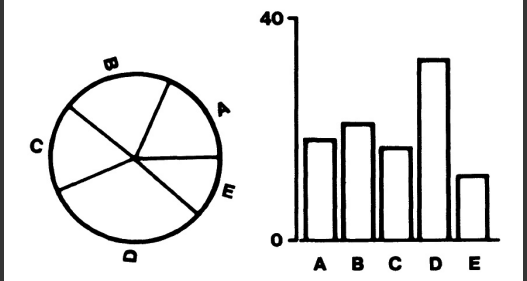


Figure 3. Graphs from position–angle experiment.

[Cleveland and McGill 84]

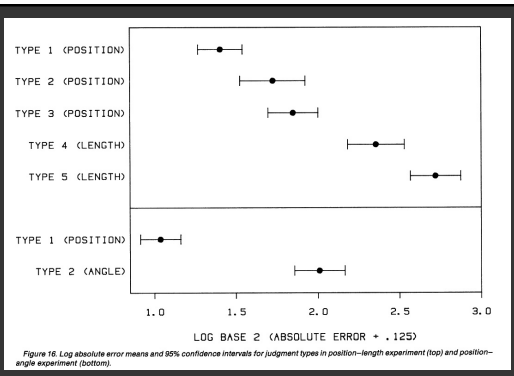


Figure 16. Log absolute error means and 95% confidence intervals for judgment types in position–length experiment (top) and position–angle experiment (bottom).

[Cleveland and McGill 84]

Relative magnitude estimation

Most accurate

Position (common) scale
Position (non-aligned) scale

Length

Slope

Angle

Area

Volume

Least accurate

Color hue-saturation-density

Mackinlay's ranking of encodings

QUANTITATIVE	ORDINAL	NOMINAL
Position	Position	Position
Length	Density (Val)	Color Hue
Angle	Color Sat	Texture
Slope	Color Hue	Connection
Area (Size)	Texture	Containment
Volume	Connection	Density (Val)
Density (Val)	Containment	Color Sat
Color Sat	Length	Shape
Color Hue	Angle	Length
Texture	Slope	Angle
Connection	Area (Size)	Slope
Containment	Volume	Area
Shape	Shape	Volume

Conjectured *effectiveness* of visual encodings

Preattentive vs. Attentive

How many 3's

12817687561389765469845069856049828267629809858458224509856458945098450980943585909103020990595959577256467505067890456788457898098216776548763649085609129496868

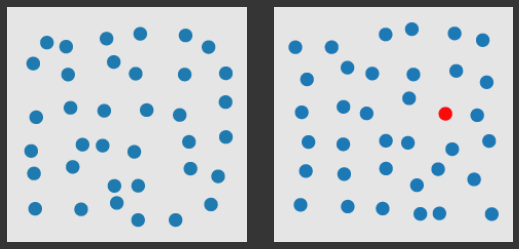
[based on slide from Stasko]

How many 3's

12817687561389765469845069856049828267629809858458224509856458945098450980943585909103020990595959577256467505067890456788457898098216776548763649085609129496863

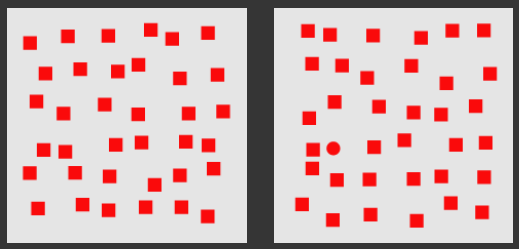
[based on slide from Stasko]

Visual pop-out: Color



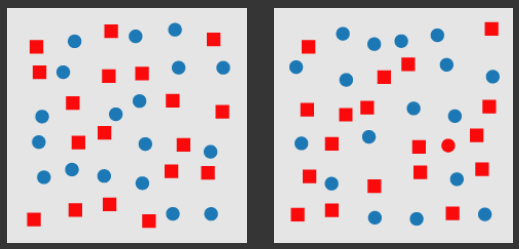
http://www.csc.ncsu.edu/faculty/healey/PP/index.html

Visual pop-out: Shape



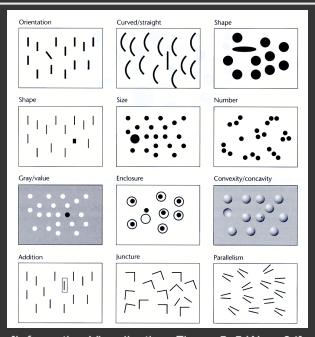
http://www.csc.ncsu.edu/faculty/healey/PP/index.html

Feature conjunctions



http://www.csc.ncsu.edu/faculty/healey/PP/index.html

Preattentive features



[Information Visualization. Figure 5. 5 Ware 04]

More preattentive features

Line (blob) orientation	Julesz & Bergen [1983]; Wolfe et al. [1992]
Length	Triesman & Gormican [1988]
Width	Julesz [1985]
Size	Triesman & Gelade [1980]
Curvature	Triesman & Gormican [1988]
Number	Julesz [1985]; Trick & Pylyshyn [1994]
Terminators	Julesz & Bergen [1983]
Intersection	Julesz & Bergen [1983]
Closure	Enns [1986]; Triesman & Souther [1985]
Colour (hue)	Nagy & Sanchez [1990, 1992]; D'Zmura [1991]; Kawai et al. [1995]; Bauer et al. [1996]
Intensity	Beck et al. [1983]; Triesman & Gormican [1988]
Flicker	Julesz [1971]
Direction of motion	Nakayama & Silverman [1986]; Driver & McLeod [1992]
Binocular lustre	Wolfe & Franzel [1988]
Stereoscopic depth	Nakayama & Silverman [1986]
3-D depth cues	Enns [1990]
Lighting direction	Enns [1990]

http://www.csc.ncsu.edu/faculty/healey/PP/index.html

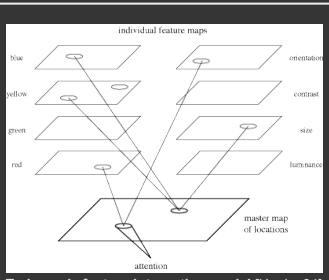
Preattentive conjunctions

Spatial conjunctions are often preattentive

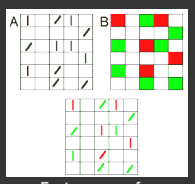
- Motion and 3D disparity
- Motion and color
- Motion and shape
- 3D disparity and color
- 3D disparity and shape

Most conjunctions are not preattentive

Feature-integration theory



Treisman's feature integration model [Healey04]

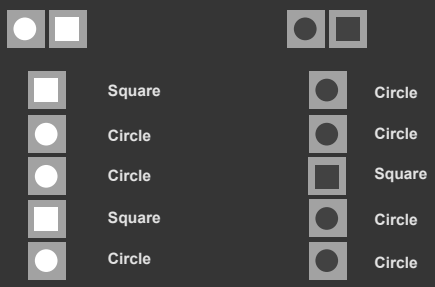


Feature maps for orientation & color [Green]

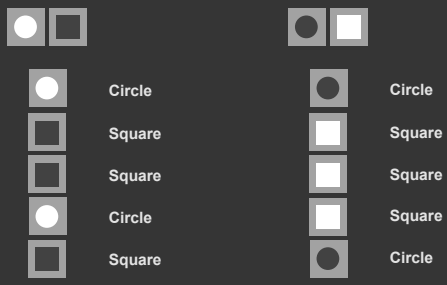
Multiple Attributes

One-dimensional: Lightness

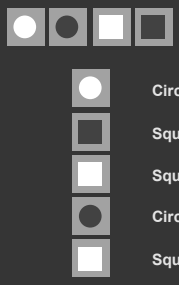
One-dimensional: Shape



Correlated dims: Shape or lightness



Orthogonal dims: Shape & lightness



Speeded classification

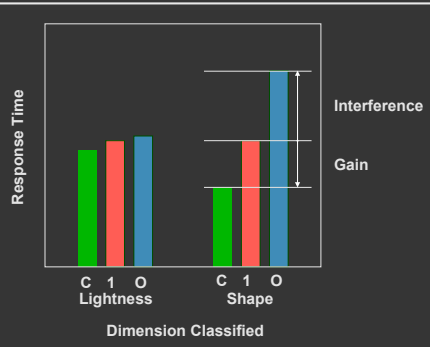
Redundancy gain

Facilitation in reading one dimension when the other provides redundant information

Filtering interference

Difficulty in ignoring one dimension while attending to the other

Speeded classification



Types of dimensions

Integral

Filtering interference and redundancy gain

Separable

No interference or gain

Configural

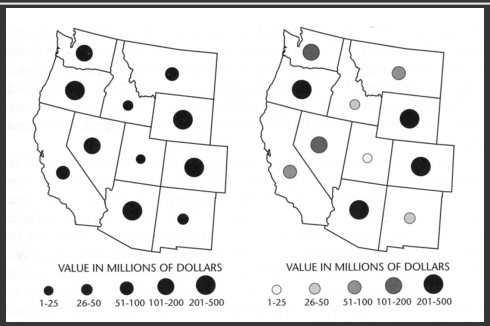
Only interference, but no redundancy gain

Asymmetrical

One dimension separable from other, not vice versa

Stroop effect – Color naming influenced by word identity, but word naming not influenced by color

Correlated dims: Size and value



W. S. Dobson, Visual information processing and cartographic communication: The role of redundant stimulus dimensions, 1983 (reprinted in MacEachren, 1995)

Othogonal dims: Aspect ratio

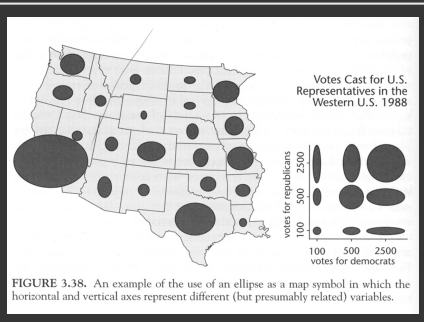


FIGURE 3.38. An example of the use of an ellipse as a map symbol in which the horizontal and vertical axes represent different (but presumably related) variables.

[MacEachren 95]