



Information Visualization

Paolo Buono – Information Visualization – 23 marzo 2012, 27 aprile 2012



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Definition

Visualization is:

- Use of
- computer-supported
- interactive
- visual representation of data
- to amplify cognition

Shneiderman, 2004

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Definition

Information visualization is:

- Use of
- computer-supported
- interactive
- visual representation of **abstract** data
- to amplify cognition

Shneiderman, 2004

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Information Visualization

- Use of computer-supported interactive visual representation of abstract data to amplify cognition
- Compact graphical presentation
 - manipulating large numbers of items
 - possibly extracted from far large datasets
- Enables users to make discoveries, decisions, or explanations
- About patterns, groups of items, individual items

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Tufte about graphical excellence

- Excellence consists of complex ideas communicated with clarity, precision, efficiency. Graphical display should:
 - Show the data
 - Induce the viewer to think about the substance rather than about methodology, graphic design, the technology of graphic production, ...
 - Avoid distorting what the data have to say
 - Present many numbers in a small space
 - Make large data sets coherent
 - Encourage the eye to compare different pieces of data
 - Reveal the data at several levels of detail
 - Serve a reasonably clear purpose: description, exploration, tabulation, decoration
 - Be closely integrated with the statistical and verbal descriptions of a data set

*E. R. Tufte, *The Visual Display of Quantitative Information*. Graphics Press, Cheshire, Connecticut, 1983*

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More definitions

- “a process of transforming data and information that are not inherently spatial into a visual form, allowing the user to observe and understand the information...”
Gershon & Eick, 1995
- “the communication of abstract data through the use of interactive visual interfaces”
Keim et al., 2006
- “a process of forming a mental model of data, thereby gaining insight into and understanding of that data”
Spence, 2007
- “produces (interactive) visual representations of abstract data to reinforce human cognition; thus enabling the viewer to gain knowledge about the internal structure of the data and causal relationships in it”
InfoVis Wiki (<http://www.infovis-wiki.net>)

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What is Information Visualization

- Visualization is more than method of computing. It is a process of transforming information into a visual form enabling the user to observe the information
- We need to take into account human perceptual and cognitive capabilities, human variations, and task characteristics
- Visualization is more than pretty pictures. Successful visualizations can reduce the time it takes to get information, make sense out of it, and enhance creative thinking
- Information is usually non-spatial data or abstract
- Finding a good spatial representation of the information at hand is one of the most difficult tasks

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Information Visualization vs Scientific Visualization

- Scientific visualization is: “The graphical representation of complex physical phenomena in order to assist scientific investigation and to make inferences that aren't apparent in numerical form. Typical examples include processing of satellite photographs and 3D representations of molecules and fluids to examine their dynamics”
Usability first, 2003
- Scientific Visualization (SV) is focused on visually representing physical objects and phenomena
- Information Visualization (IV) focuses on more abstract data
- IV tackles applications that deal with data (e.g., Web site accesses) which are outside the scope of SV

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Visualization in everyday life

- Table in a newspaper
- Train/subway map with arrival/departure times
- Map of a region
- Weather chart
- Stock market graph
- Your product vs leading brand comparison plot
- 3D reconstruction of a body part generated from a CT scan
- Instruction manual
- Highway signs

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Domains

- Finance
- Engineering
- Medicine
- Physics
- Statistics
- Data analysis
- Simulation
- Marketing / advertisement
- ...

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Importance of Visualization

- Billions of potential users
- Huge amounts of existing information
 - Information overload
 - Difficult to make sense
- New visual computing, display technologies, and visualization methods make it possible to represent information effectively

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Importance of good Visualization

Same data

Different scale

(a) Equally (uniformly) large scale in both x and y
(b) Large scale in y
(c) Large scale in y
(d) Scale determined by range of x- and y-values.

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Visualization choice influence (important) decisions

Table

	Conventional treatment	Investigational treatment
Total no	30	35
% Fail	33	11
Good prognosis	30	35
Poor prognosis	20	25
Total	50	60
	38	12

Pie chart

(Negatively framed tables displayed failure rates in red. Positively framed tables displayed response rates in green)

Continue or abort the trial?

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Bar graph

Icon

(Negatively framed tables displayed failure rates in red. Positively framed tables displayed response rates in green)

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Peltier's alternative proposal

Success Rate

Investigational Treatment
Conventional Treatment

Success Rate

Poor Prognosis
Good Prognosis

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Jamie's alternative proposal

Conventional vs Investigational Treatment

Conventional Good Prognosis
Conventional Poor Prognosis
Investigational Good Prognosis
Investigational Poor Prognosis

Response Fail

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<http://eagereyes.org/blog/2011/visualization-choice-influences-decisions>

Early Visualizations

One of the Lascaux cave paintings on the northern slopes of the French Pyrenees on the banks of the Vézère river

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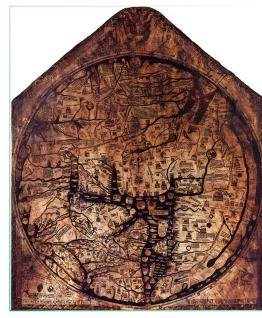
Early Visualizations



One of the 12 pages of the Peutinger Map set, showing the roads of the Roman Empire

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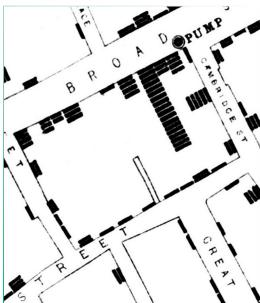
Early Visualizations



- The famous Hereford map, the largest surviving map of the Middle Ages (1280s)

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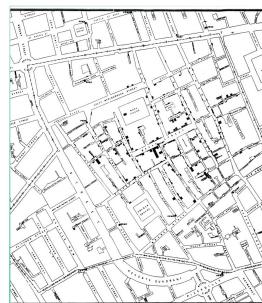
Early Visualizations



- A section of John Snow's map of the deaths from cholera in London in 1854
- Each bar within the houses represents one deceased individual

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Early Visualizations

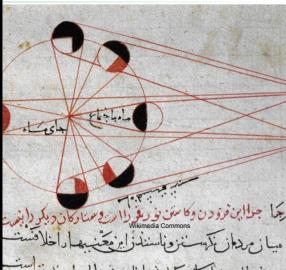


- Overview map of the deaths from Cholera in London in 1854
- Note the concentration around the Broad Street Water Pump
- Note as well the outliers

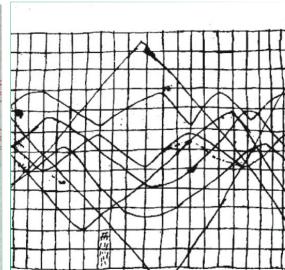
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Early Visualizations (Biruni circa 1030)

Shows planetary motion

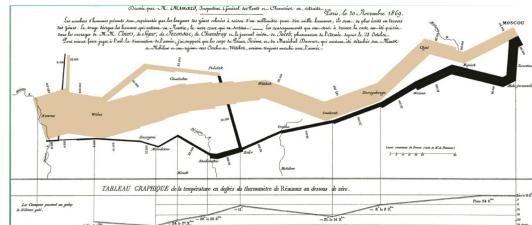


Phases of the moon in orbit



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Early Visualizations: Minard's map



Width: size of the army at that location
Color: direction of movement
Temperature: along the retreat at the bottom

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Early Visualizations

William Playfair

National debt over time

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Early Visualizations

A Specimen of a Chart of Biography

Joseph Priestley: the longevity of famous people (1765)

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Early Visualizations

- Florence Nightingale's coxcomb chart showing monthly deaths from battle and other causes
- Blue: deaths from disease
- Red: deaths from wounds
- Black: all other deaths

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Early Visualizations

Leonardo Da Vinci's study of the motion of the human arm (1510)

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Visualization Today

Bari underground map

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Visualization Today

The google.com map directions from 198 Riverside St., Lowell, MA (UMass Lowell, North Campus) to 883 Broadway St., Lowell, MA (UMass Lowell, South Campus) Google.com maps provide graphical cues drawn on top of road maps to indicate driving directions from point A to point B

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Visualization Today

Dow Jones Industrial Average (DJIA) from 1900 to 2000. The Dow Jones Industrial Average is a U.S. stock index based on the weighted average of the stock prices of 30 large and actively traded U.S. companies. The divisor changes over time as stock splits, so as not to alter that average in those cases.

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Visualization Today

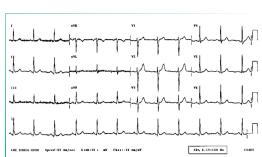
\$11,956,584,748,608.58

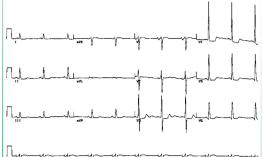
The outstanding United States public debt as of January 22, 2006

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Visualization Today

Two examples of 12-lead ECGs:

A normal adult: 

An 83-year-old adult with heart problems: 

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Visualization Today

Yeast mechanism of action data with regression line

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Visualization Today

A pathway represented by a network with nodes representing genes and color the level of expression

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Visualization vs Computer Graphics

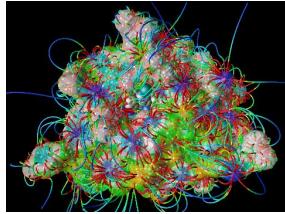
- Originally considered a subfield of CG
- Visualization are always connected to data, do not emphasize visual realism
- CG focuses on graphical objects and organization of graphical primitives. A secondary application of CG is in art and entertainment

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Scientific Data Visualization vs Information Visualization

Still in early 2000 SciVis and InfoVis were differentiated

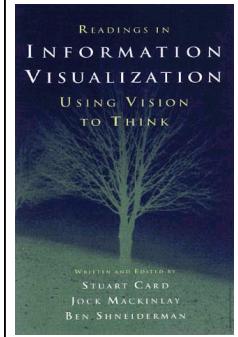
- Both provide representations of data
- Dataset are often different



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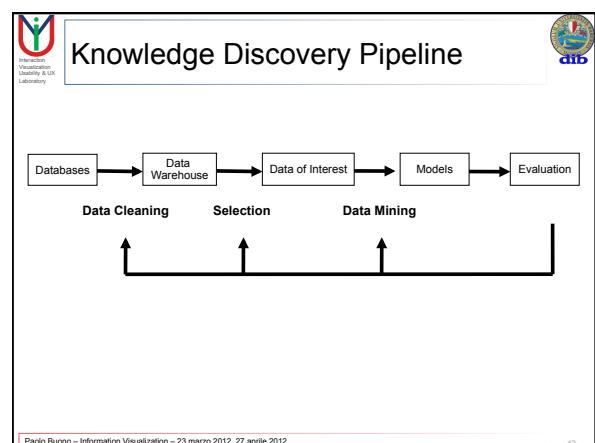
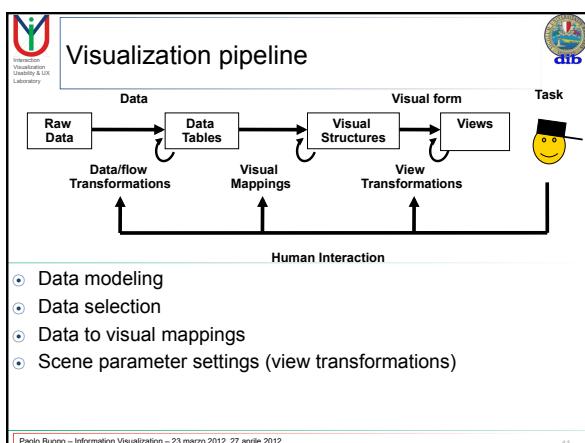
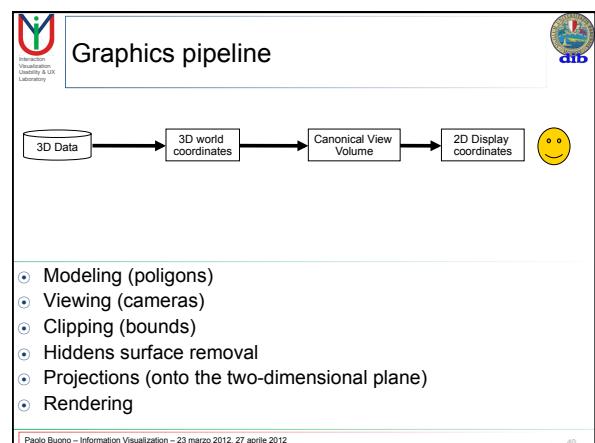
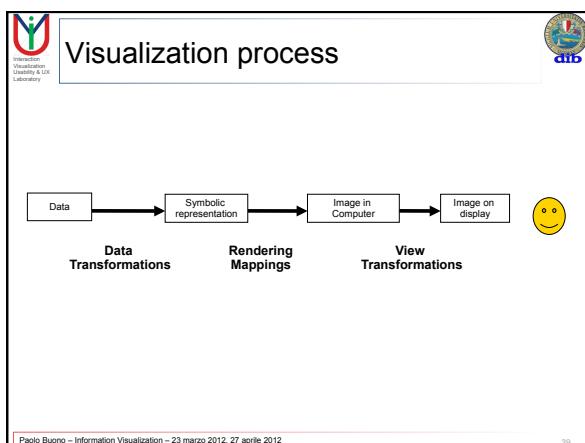
Information Visualization: Using Vision to Think

READINGS IN INFORMATION VISUALIZATION
USING VISION TO THINK





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The role of the User

Interaction Visualization Usability + UX Laboratory

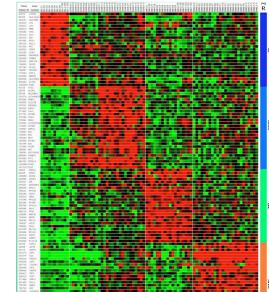
Can be involved in most stages of visualization pipeline

- Exploration
- Confirmation
- Presentation (primary)

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Exploratory visualization

Interaction Visualization Usability + UX Laboratory



J. Zhou, G. Grinstein, and K. Marrs. "A New Gene Selection Method for Visual Analysis." Scientific Report No. 015, University of Massachusetts Lowell, 2007.

- microarray gene expression experiment analysis

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Interaction Visualization Usability + UX Laboratory

Find what you need
Understand what you Find

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Simple visualization: Scatterplot

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The scatterplot

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```
Scatterplot(xDim,yDim,cDim,rDim,rMin,rMax)
for each record i 'for each record
  do x <- Normalize(i,xDim) 'derive location
  y <- Normalize(i,yDim)
  r <- Normalize(i,rDim,rMin,rMax) 'radius
  MapColor(i,cDim) 'and color then
  Circle(x,y,r) 'draw the record as circle
```

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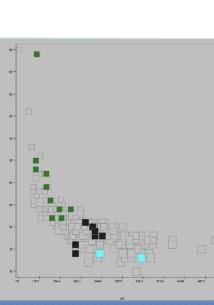
The Scatterplot

Interaction Visualization Usability + UX Laboratory

Vehicle Name	Sedan	Sports	SUV	Wagon	Minivan	Pickup	AWD	RWD	Price
Acura 3.5 RL 4dr	1	0	0	0	0	0	0	0	43755
Acura MDX	0	0	1	0	0	0	1	0	36945
Suzuki XL-7 EX	0	0	1	0	0	0	0	0	23699

A simple partial table of the car and truck data. Note that you can think of this as a row-based table (cars and trucks) or a column-based table (car attributes)

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The figure is a scatterplot titled "The Scatterplot". The x-axis is labeled "Horsepower" and ranges from 50 to 300. The y-axis is labeled "MPG" (Miles per Gallon) and ranges from 10 to 40. The plot shows data points for Toyota vehicles, with a clear negative correlation between horsepower and MPG. The data points are colored according to their vehicle class, with a legend on the right side of the slide showing categories like Sedan, Hatchback, SUV, etc., each represented by a different color.

- A scatterplot of horsepower versus city MPG for Toyota vehicles
- The vehicle class is mapped to color

The Scatterplot

Vehicle	Weight	Displacement
LS460	4.6	4.6
LS460L	4.6	4.6
LS600h	4.6	4.6
LS600hL	4.6	4.6
GS300	3.0	3.0
GS350	3.5	3.5
GS430	4.3	4.3
GS450h	4.5	4.5
GS460	4.6	4.6
GS460h	4.6	4.6
GS500	5.0	5.0
GS500F	5.0	5.0
GS550	5.5	5.5
GS550F	5.5	5.5
GS600	6.0	6.0
GS600F	6.0	6.0
IS250	2.5	2.5
IS300	3.0	3.0
IS350	3.5	3.5
IS450	4.5	4.5
IS500	5.0	5.0
IS600	6.0	6.0
IS600F	6.0	6.0
IS-F	4.5	4.5
ES300	3.0	3.0
ES330	3.3	3.3
ES350	3.5	3.5
ES350F	3.5	3.5
ES430	4.3	4.3
ES450	4.5	4.5
ES500	5.0	5.0
ES600	6.0	6.0
ES600F	6.0	6.0
SC430	4.3	4.3
SC450	4.5	4.5
SC500	5.0	5.0
SC500F	5.0	5.0
UX300	3.0	3.0
UX350	3.5	3.5
UX450h	4.5	4.5
UX500h	5.0	5.0
UX500hF	5.0	5.0
UX550h	5.5	5.5
UX550hF	5.5	5.5
UX600h	6.0	6.0
UX600hF	6.0	6.0
UX650h	6.5	6.5
UX650hF	6.5	6.5
UX700h	7.0	7.0
UX700hF	7.0	7.0
UX750h	7.5	7.5
UX750hF	7.5	7.5
UX800h	8.0	8.0
UX800hF	8.0	8.0
UX850h	8.5	8.5
UX850hF	8.5	8.5
UX900h	9.0	9.0
UX900hF	9.0	9.0
UX950h	9.5	9.5
UX950hF	9.5	9.5
UX1000h	10.0	10.0
UX1000hF	10.0	10.0
UX1050h	10.5	10.5
UX1050hF	10.5	10.5
UX1100h	11.0	11.0
UX1100hF	11.0	11.0
UX1150h	11.5	11.5
UX1150hF	11.5	11.5
UX1200h	12.0	12.0
UX1200hF	12.0	12.0
UX1250h	12.5	12.5
UX1250hF	12.5	12.5
UX1300h	13.0	13.0
UX1300hF	13.0	13.0
UX1350h	13.5	13.5
UX1350hF	13.5	13.5
UX1400h	14.0	14.0
UX1400hF	14.0	14.0
UX1450h	14.5	14.5
UX1450hF	14.5	14.5
UX1500h	15.0	15.0
UX1500hF	15.0	15.0
UX1550h	15.5	15.5
UX1550hF	15.5	15.5
UX1600h	16.0	16.0
UX1600hF	16.0	16.0
UX1650h	16.5	16.5
UX1650hF	16.5	16.5
UX1700h	17.0	17.0
UX1700hF	17.0	17.0
UX1750h	17.5	17.5
UX1750hF	17.5	17.5
UX1800h	18.0	18.0
UX1800hF	18.0	18.0
UX1850h	18.5	18.5
UX1850hF	18.5	18.5
UX1900h	19.0	19.0
UX1900hF	19.0	19.0
UX1950h	19.5	19.5
UX1950hF	19.5	19.5
UX2000h	20.0	20.0
UX2000hF	20.0	20.0
UX2050h	20.5	20.5
UX2050hF	20.5	20.5
UX2100h	21.0	21.0
UX2100hF	21.0	21.0
UX2150h	21.5	21.5
UX2150hF	21.5	21.5
UX2200h	22.0	22.0
UX2200hF	22.0	22.0
UX2250h	22.5	22.5
UX2250hF	22.5	22.5
UX2300h	23.0	23.0
UX2300hF	23.0	23.0
UX2350h	23.5	23.5
UX2350hF	23.5	23.5
UX2400h	24.0	24.0
UX2400hF	24.0	24.0
UX2450h	24.5	24.5
UX2450hF	24.5	24.5
UX2500h	25.0	25.0
UX2500hF	25.0	25.0
UX2550h	25.5	25.5
UX2550hF	25.5	25.5
UX2600h	26.0	26.0
UX2600hF	26.0	26.0
UX2650h	26.5	26.5
UX2650hF	26.5	26.5
UX2700h	27.0	27.0
UX2700hF	27.0	27.0
UX2750h	27.5	27.5
UX2750hF	27.5	27.5
UX2800h	28.0	28.0
UX2800hF	28.0	28.0
UX2850h	28.5	28.5
UX2850hF	28.5	28.5
UX2900h	29.0	29.0
UX2900hF	29.0	29.0
UX2950h	29.5	29.5
UX2950hF	29.5	29.5
UX3000h	30.0	30.0
UX3000hF	30.0	30.0
UX3050h	30.5	30.5
UX3050hF	30.5	30.5
UX3100h	31.0	31.0
UX3100hF	31.0	31.0
UX3150h	31.5	31.5
UX3150hF	31.5	31.5
UX3200h	32.0	32.0
UX3200hF	32.0	32.0
UX3250h	32.5	32.5
UX3250hF	32.5	32.5
UX3300h	33.0	33.0
UX3300hF	33.0	33.0
UX3350h	33.5	33.5
UX3350hF	33.5	33.5
UX3400h	34.0	34.0
UX3400hF	34.0	34.0
UX3450h	34.5	34.5
UX3450hF	34.5	34.5
UX3500h	35.0	35.0
UX3500hF	35.0	35.0
UX3550h	35.5	35.5
UX3550hF	35.5	35.5
UX3600h	36.0	36.0
UX3600hF	36.0	36.0
UX3650h	36.5	36.5
UX3650hF	36.5	36.5
UX3700h	37.0	37.0
UX3700hF	37.0	37.0
UX3750h	37.5	37.5
UX3750hF	37.5	37.5
UX3800h	38.0	38.0
UX3800hF	38.0	38.0
UX3850h	38.5	38.5
UX3850hF	38.5	38.5
UX3900h	39.0	39.0
UX3900hF	39.0	39.0
UX3950h	39.5	39.5
UX3950hF	39.5	39.5
UX4000h	40.0	40.0
UX4000hF	40.0	40.0
UX4050h	40.5	40.5
UX4050hF	40.5	40.5
UX4100h	41.0	41.0
UX4100hF	41.0	41.0
UX4150h	41.5	41.5
UX4150hF	41.5	41.5
UX4200h	42.0	42.0
UX4200hF	42.0	42.0
UX4250h	42.5	42.5
UX4250hF	42.5	42.5
UX4300h	43.0	43.0
UX4300hF	43.0	43.0
UX4350h	43.5	43.5
UX4350hF	43.5	43.5
UX4400h	44.0	44.0
UX4400hF	44.0	44.0
UX4450h	44.5	44.5
UX4450hF	44.5	44.5
UX4500h	45.0	45.0
UX4500hF	45.0	45.0
UX4550h	45.5	45.5
UX4550hF	45.5	45.5
UX4600h	46.0	46.0
UX4600hF	46.0	46.0
UX4650h	46.5	46.5
UX4650hF	46.5	46.5
UX4700h	47.0	47.0
UX4700hF	47.0	47.0
UX4750h	47.5	47.5
UX4750hF	47.5	47.5
UX4800h	48.0	48.0
UX4800hF	48.0	48.0
UX4850h	48.5	48.5
UX4850hF	48.5	48.5
UX4900h	49.0	49.0
UX4900hF	49.0	49.0
UX4950h	49.5	49.5
UX4950hF	49.5	49.5
UX5000h	50.0	50.0
UX5000hF	50.0	50.0
UX5050h	50.5	50.5
UX5050hF	50.5	50.5
UX5100h	51.0	51.0
UX5100hF	51.0	51.0
UX5150h	51.5	51.5
UX5150hF	51.5	51.5
UX5200h	52.0	52.0
UX5200hF	52.0	52.0
UX5250h	52.5	52.5
UX5250hF	52.5	52.5
UX5300h	53.0	53.0
UX5300hF	53.0	53.0
UX5350h	53.5	53.5
UX5350hF	53.5	53.5
UX5400h	54.0	54.0
UX5400hF	54.0	54.0
UX5450h	54.5	54.5
UX5450hF	54.5	54.5
UX5500h	55.0	55.0
UX5500hF	55.0	55.0
UX5550h	55.5	55.5
UX5550hF	55.5	55.5
UX5600h	56.0	56.0
UX5600hF	56.0	56.0
UX5650h	56.5	56.5
UX5650hF	56.5	56.5
UX5700h	57.0	57.0
UX5700hF	57.0	57.0
UX5750h	57.5	57.5
UX5750hF	57.5	57.5
UX5800h	58.0	58.0
UX5800hF	58.0	58.0
UX5850h	58.5	58.5
UX5850hF	58.5	58.5
UX5900h	59.0	59.0
UX5900hF	59.0	59.0
UX5950h	59.5	59.5
UX5950hF	59.5	59.5
UX6000h	60.0	60.0
UX6000hF	60.0	60.0
UX6050h	60.5	60.5
UX6050hF	60.5	60.5
UX6100h	61.0	61.0
UX6100hF	61.0	61.0
UX6150h	61.5	61.5
UX6150hF	61.5	61.5
UX6200h	62.0	62.0
UX6200hF	62.0	62.0
UX6250h	62.5	62.5
UX6250hF	62.5	62.5
UX6300h	63.0	63.0
UX6300hF	63.0	63.0
UX6350h	63.5	63.5
UX6350hF	63.5	63.5
UX6400h	64.0	64.0
UX6400hF	64.0	64.0
UX6450h	64.5	64.5
UX6450hF	64.5	64.5
UX6500h	65.0	65.0
UX6500hF	65.0	65.0
UX6550h	65.5	65.5
UX6550hF	65.5	65.5
UX6600h	66.0	66.0
UX6600hF	66.0	66.0
UX6650h	66.5	66.5
UX6650hF	66.5	66.5
UX6700h	67.0	67.0
UX6700hF	67.0	67.0
UX6750h	67.5	67.5
UX6750hF	67.5	67.5
UX6800h	68.0	68.0
UX6800hF	68.0	68.0
UX6850h	68.5	68.5
UX6850hF	68.5	68.5
UX6900h	69.0	69.0
UX6900hF	69.0	69.0
UX6950h	69.5	69.5
UX6950hF	69.5	69.5
UX7000h	70.0	70.0
UX7000hF	70.0	70.0
UX7050h	70.5	70.5
UX7050hF	70.5	70.5
UX7100h	71.0	71.0
UX7100hF	71.0	71.0
UX7150h	71.5	71.5
UX7150hF	71.5	71.5
UX7200h	72.0	72.0
UX7200hF	72.0	72.0
UX7250h	72.5	72.5
UX7250hF	72.5	72.5
UX7300h	73.0	73.0
UX7300hF	73.0	73.0
UX7350h	73.5	73.5
UX7350hF	73.5	73.5
UX7400h	74.0	74.0
UX7400hF	74.0	74.0
UX7450h	74.5	74.5
UX7450hF	74.5	74.5
UX7500h	75.0	75.0
UX7500hF	75.0	75.0
UX7550h	75.5	75.5
UX7550hF	75.5	75.5
UX7600h	76.0	76.0
UX7600hF	76.0	76.0
UX7650h	76.5	76.5
UX7650hF	76.5	76.5
UX7700h	77.0	77.0
UX7700hF	77.0	77.0
UX7750h	77.5	77.5
UX7750hF	77.5	77.5
UX7800h	78.0	78.0
UX7800hF	78.0	78.0
UX7850h	78.5	78.5
UX7850hF	78.5	78.5
UX7900h	79.0	79.0
UX7900hF	79.0	79.0
UX7950h	79.5	79.5
UX7950hF	79.5	79.5
UX8000h	80.0	80.0
UX8000hF	80.0	80.0
UX8050h	80.5	80.5
UX8050hF	80.5	80.5
UX8100h	81.0	81.0
UX8100hF	81.0	81.0
UX8150h	81.5	81.5
UX8150hF	81.5	81.5
UX8200h	82.0	82.0
UX8200hF	82.0	82.0
UX8250h	82.5	82.5
UX8250hF	82.5	82.5
UX8300h	83.0	83.0
UX8300hF	83.0	83.0
UX8350h	83.5	83.5
UX8350hF	83.5	83.5
UX8400h	84.0	84.0
UX8400hF	84.0	84.0
UX8450h	84.5	84.5
UX8450hF	84.5	84.5
UX8500h	85.0	85.0
UX8500hF	85.0	85.0
UX8550h	85.5	85.5
UX8550hF	85.5	85.5
UX8600h	86.0	86.0
UX8600hF	86.0	86.0
UX8650h	86.5	86.5
UX8650hF	86.5	86.5
UX8700h	87.0	87.0
UX8700hF	87.0	87.0
UX8750h	87.5	87.5
UX8750hF		

The Scatterplot

- Scatterplot of all vehicles
- There is lots to explore here



Information Visualization: Data Types taxonomy (*Shneiderman*)



 Information Visualization:
Tasks taxonomy (*Sneiderman*)

- Overview
- Zoom
- Filter
- Details-on-demand
- Relate
- History
- Extract
- ...?
- Search

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 End of part 1

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 Part 2

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 Information Visualization:
Data Types taxonomy (*Keim*)

- Ordinal
 - Binary
 - Discrete
 - Continuous
- Nominal
 - Categorical
 - Ranked (young, adult, elderly)
 - Arbitrary
- Scale
 - Ordering relation
 - Distance metric
 - Existence of absolute zero (

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 Structures within and between records

- Scalar, vector, tensors
 - Scalar: tensor of rank 0 - vector: tensor of rank 1
- Geometry and grids
 - Especially for 3D objects
 - Coordinates in different systems (cartesian, spherical, hyperbolic, ...)
 - Irregular geometry is common (wind flow simulation)
- Other forms
 - Timestamp (dealing with time, which has one of the widest range of possible value, ranging from picoseconds to millennia, and can also be relative or absolute, uniformly spaced or unevenly spaced)
 - Topology (connection between data), important for resampling and interpolation

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 Examples of various structured data

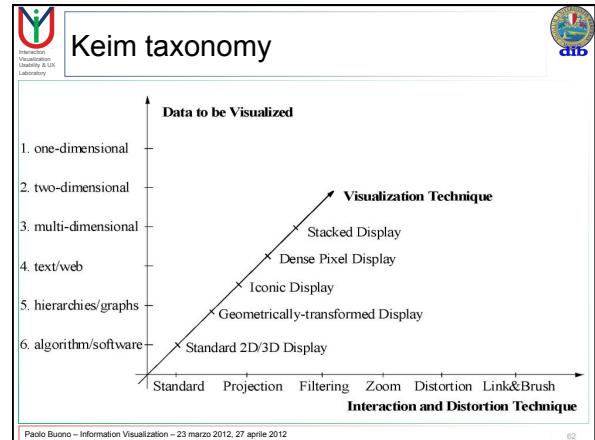
- MRI** (scalar, 3 spatial attribute, 3D connectivity)
- CFD** (3-dim for displacement, one temporal, 3 spatial attributes, 3D connectivity)
- Financial** (non geometric, n possibly independent components, nominal and ordinal, temporal attributes)
- CAD** (3 spatial attributes, edge and polygon connections, surface properties)
- Remote sensing** (multiple channels, 2/3 spatial attributes, 1 temporal attribute, grid connectivity)
- Census** (multiple fields of all types, spatial attributes, temporal attribute, connectivity implied by similarities in fields)
- Social Network** (nodes consisting of multiple fields of all types, various connectivity: spatial, temporal, other)

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Keller & Keller taxonomy
(Peter R. Keller and Mary M. Keller, Visual Cues: Practical Data Visualization, IEEE Computer Society Press, 1994)

• Data types	• Tasks
<ul style="list-style-type: none"> ◦ Scalar ◦ Nominal ◦ Direction ◦ Shape ◦ Position ◦ Spatially extended region / object 	<ul style="list-style-type: none"> ◦ Identify (recognize) ◦ Locate (abs/rel) ◦ Distinguish (#identify) ◦ Categorize ◦ Cluster ◦ Rank ◦ Compare (sims & diffs) ◦ Associate (link) ◦ Correlate (connection)

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Information Visualization: Design Guidelines (Shneiderman)

- Direct manipulation strategies
 - Visual presentation of query components
 - Visual presentation of results
 - Rapid, incremental and reversible actions
 - Selection by pointing (not typing)
 - Immediate and continuous feedback
 - Reduces errors
 - Encourages exploration

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Information Visualization: Mantra

- Overview, zoom & filter, details-on-demand
- ...

Shneiderman

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Strategies for Visual Information Reduction

- Difficulties to represent all information in the limited space of a display, and to navigate within the representation at different levels of detail
- Fish-eye views (Furnas, 1981 & 1986)
 - "... an example of a more basic strategy for the display of large structures. This basic strategy uses a Degree of Interest (DOI) function which assigns to each point in the structure a number telling how interested the user is in seeing that point, given the current task. A display of any desired size, n, can then be made by simply showing the n most interesting points, as indicated by the DOI function."
- DOI of an object is computed with respect to a particular focus fp
- $DOI(x | fp=y) = API(x) - D(x,y)$
- $API(x)$ is the a priori interest of point x
- $D(x,y)$ is the current distance between x and fp
- Applicazioni: hierarchies, structured text, calendars, ...
- Focus + context (Card et al., CHI '91)
- Information Visualization Seeking Mantra (Shneiderman, 1996)
- [Want to know more? Stasko may help...](#)

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User Interface Design Goals

- Cognitively comprehensible:
Consistent, predictable & controllable
- Affectively acceptable:
Mastery, satisfaction & responsibility
- NOT: Adaptive, autonomous & anthropomorphic

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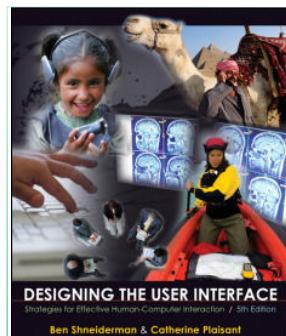
Scientific Approach (beyond user friendly)

- Specify users and tasks
- Predict and measure
 - time to learn
 - speed of performance
 - rate of human errors
 - human retention over time
- Assess subjective satisfaction
(Questionnaire for User Interface Satisfaction)
- Accommodate individual differences
- Consider social, organizational & cultural context

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Design Issues

- Input devices & strategies
 - Keyboards, pointing devices, voice, gestures
 - Direct manipulation
 - Menus, forms, commands
- Output devices & formats
 - Screens, windows, color, sound
 - Text, tables, graphics
 - Instructions, messages, help
- Collaboration & communities
- Manuals, tutorials, training



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Perceptual issues

Human Perception and Information Processing

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Perception?

- The process by which we interpret the world around us, forming a mental representation of the environment
- Non-isomorphic representation since the brain have to overcome inherent ambiguity in all sensory data
- Visual representation can be misinterpreted

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Two seated figures



N. Yoshigahara

Two seated figures, making sense at a higher, more abstract level, but still disturbing
On closer inspection, these seats are not realizable

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Two seated figures



N. Yoshigahara

Two seated figures, making sense at a higher, more abstract level, but still disturbing
On closer inspection, these seats are not realizable

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Two seated figures



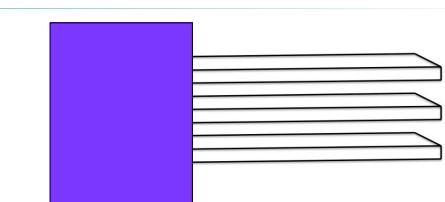
N. Yoshigahara

Two seated figures, making sense at a higher, more abstract level, but still disturbing
On closer inspection, these seats are not realizable

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T3

Four ≠ three

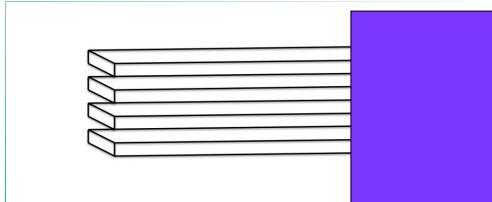


This object would have a problem being built (there are four boards on the left and three on the right)

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T4

Four ≠ three

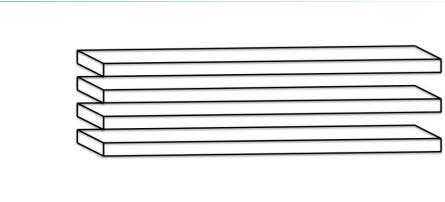


This object would have a problem being built (there are four boards on the left and three on the right)

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T5

Four ≠ three

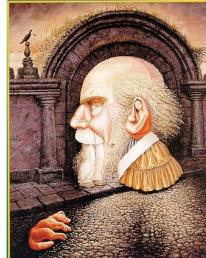


This object would have a problem being built (there are four boards on the left and three on the right)

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T6

Two people making a face



A more complex illusion:
There are two people drawn as part of the face

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T7

Two people making a face



A more complex illusion:
There are two people drawn as part of the face

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T8

Grid illusion

The Hermann grid illusion: (left) illusory black squares appear over the complete image as you gaze at it; (right) similar to (left) but even more dynamic and engaging

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Classic straight lines example

The Hering illusion: red lines are straight

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No trick, lines are straight

The Hering illusion: red lines are straight

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The Kanizsa illusion

A triangle seems to pop out of the image even though no such triangle is drawn

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Preattention

Works

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Preattention

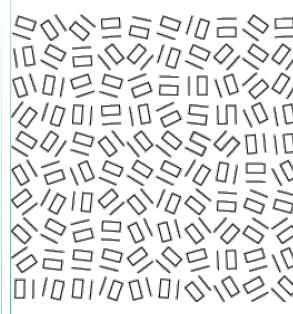
Do not works

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Attention processing

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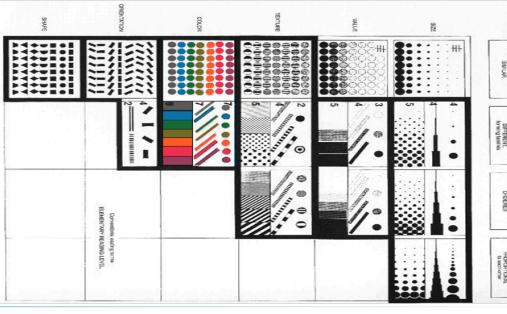
- Preattentive
- Attentive
- Postattentive



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Different encoding and performance

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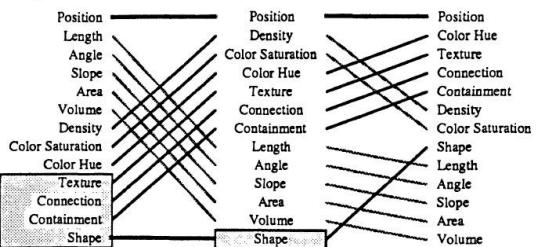


J. Bertin

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Ordering by task

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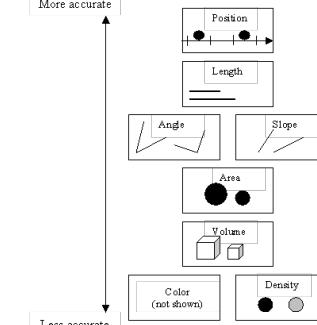


J. Mackinlay

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Accuracy

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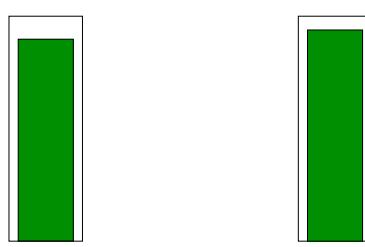


J. Mackinlay

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Relative judgment

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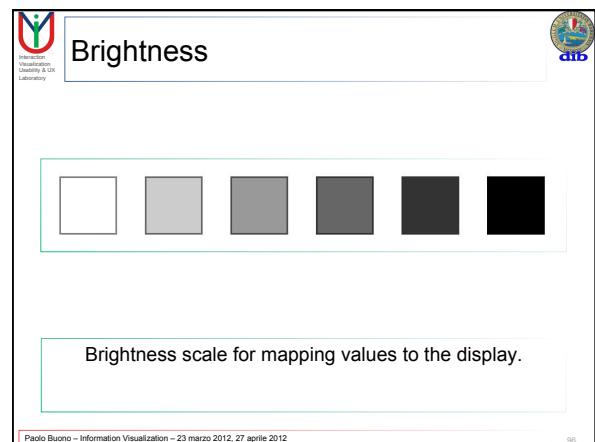
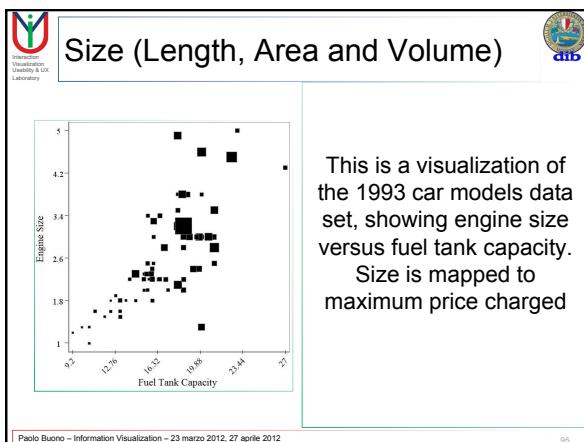
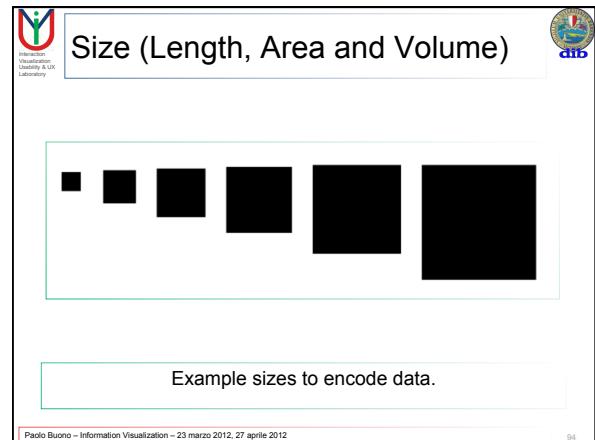
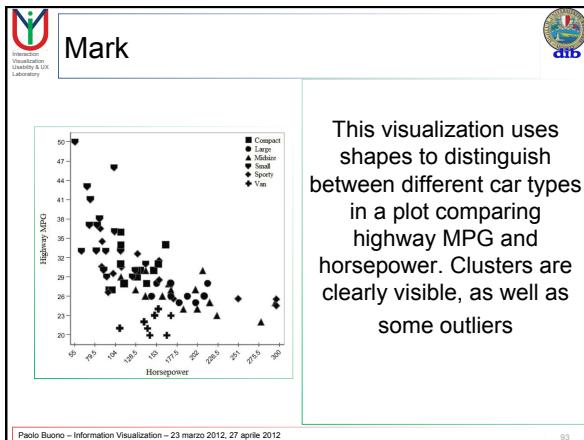
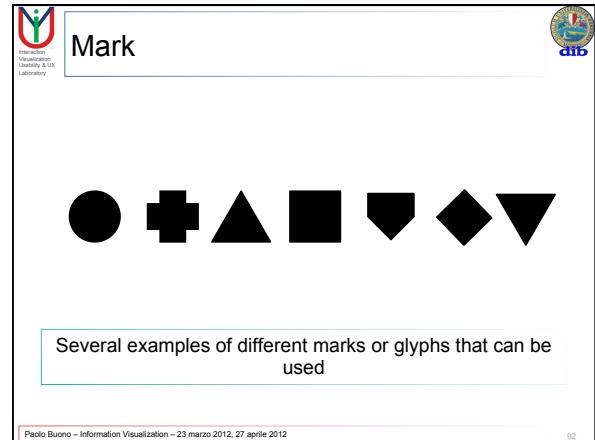
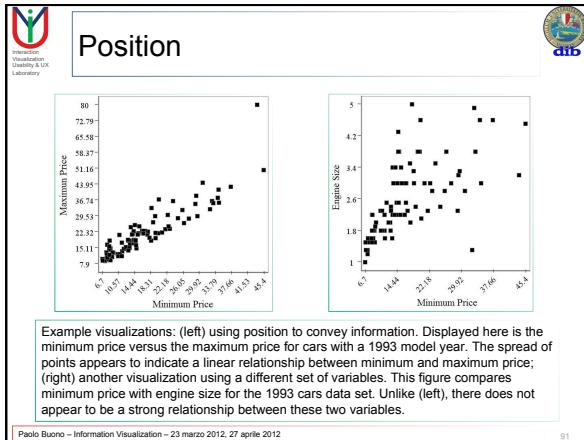
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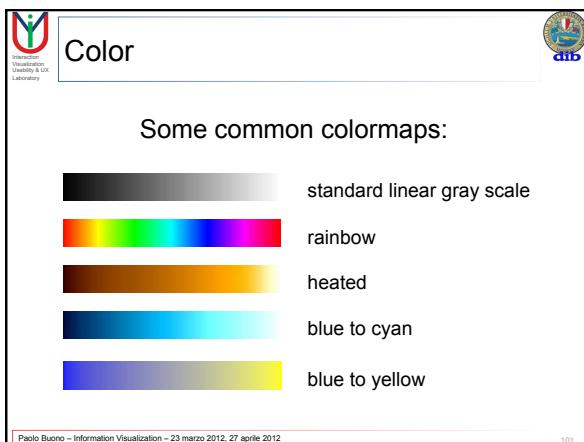
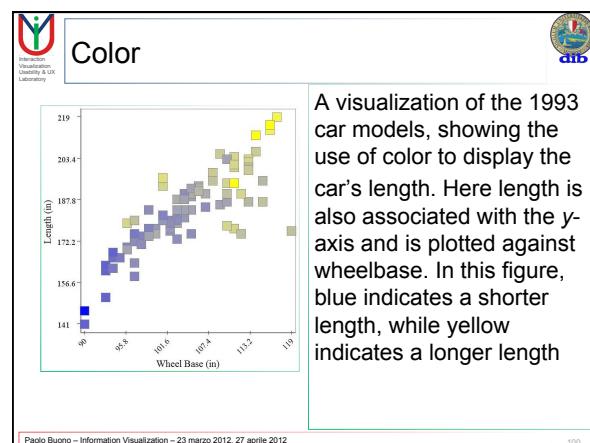
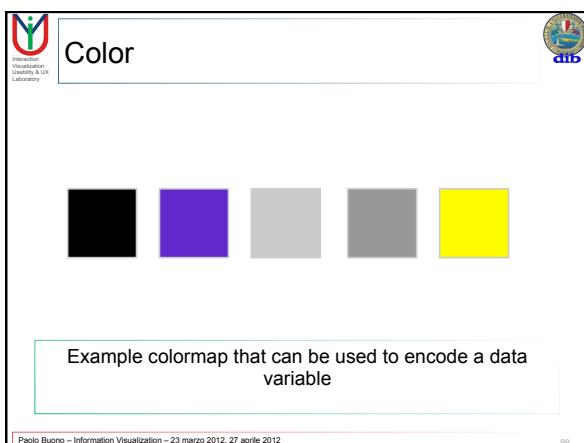
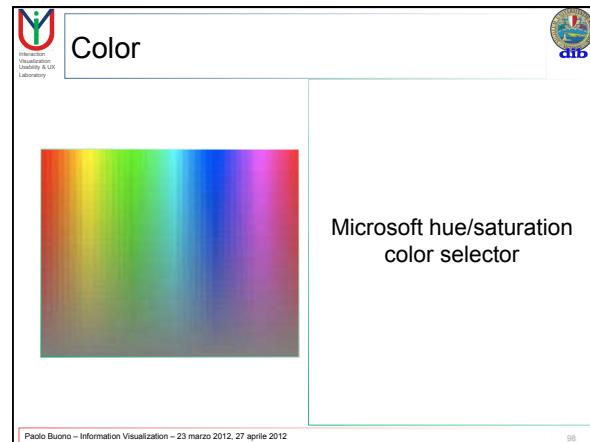
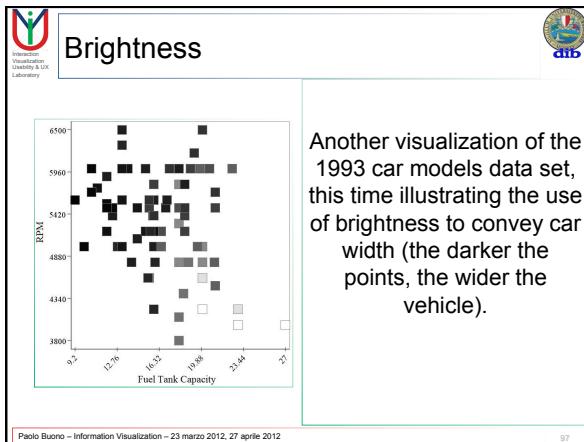
The eight visual variables

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- Position
- Mark
- Size
- Brightness
- Color
- Orientation
- Texture
- Motion

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Orientation

Example orientations of a representation graphic, where the lowest value maps to the mark pointing upward and increasing values rotate the mark in a clockwise rotation

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103

Orientation

Sample visualization of the 1993 car models data set depicting using highway milesper-gallon versus fuel tank capacity (position) with the additional data variable, midrange price, used to adjust mark orientation

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104

Texture

Six possible example textures that could be used to identify different data values

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105

Texture

Example visualization using texture to provide additional information about the 1993 car models data set, showing the relationship between wheelbase versus horsepower (position) as related to car types, depicted by different textures

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106

Chart suggestions

Chart Suggestions—A Thought-Starter

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107





Links



- 7 classic Vis Papers:
<http://feliinlovewithdata.com/guides/7-classic-foundational-vis-papers>
- 6 niches visualization blogs:
<http://eagereyes.org/blog/2011/six-niche-visualization-blogs>



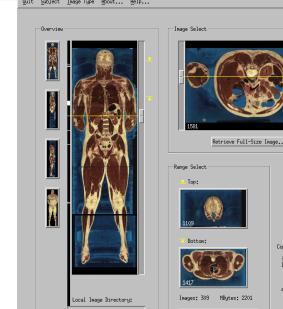
Interaction
Visualization
Usability + UX
laboratory



UNIVERSITÀ
DEGLI STUDI DI BARI
ALDO MORO

 **Visible Human Explorer (NLM)**

Doctors
Surgeons
Researchers
Students



The screenshot shows the main interface of the Visible Human Explorer. At the top, there's a navigation bar with links for 'Build Subject', 'Image Type', 'Search...', and 'Help...'. Below this is a search bar with the placeholder 'Overview'.

The central area displays anatomical images. On the left, there are thumbnail images of the human body from various perspectives. In the center, there's a large image of a human torso with internal organs visible. To the right, there's another image of a human torso, and below it, a small image of a brain.

On the right side of the interface, there are several buttons and labels:

- 'Image Select' button with a 'Retrieves Full-Scale Images...' link.
- 'Range Select' section with 'Tags' and 'Sort by' dropdown menus.
- 'Copyright © 1995' text.
- 'Image Statistics' section showing 'Images: 393' and 'Bytes: 205'.
- 'Retrieves Full-Scale Images...' button.
- A small logo for 'HOMI' at the bottom right.

NASA Environmental Data

Interactive Visualization, University of MD Laboratory

Global Change Master Directory

Query Preview

Area Selection:

Select attributes of interest by clicking on map area

Topic Selection

Topic	Selection
Atmosphere	2153
Biosphere	1083
Chemistry	213
Human Dimensions	395
Hydrology	643
Land Surface	1802
Oceanography	132
Paleontology	113
Radiance Or Imagery	738
Soil Sciences	113
Solid Earth	429
Not Specified	0

Year Selection:

Year	Selection
Prehistoric	0
1900 - 1950	120
1950 - 1970	151
1970 - 1990	71
1990 - 1999	365
2000 - 2009	469
2010 - 2011	413
1940 - 1949	488
1950 - 1959	111
1960 - 1969	978
1970 - 1979	1649
1980 - 1989	3445
1990 - 1999	2391
Not Specified	1644

Attributed

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112

The screenshot shows a map of Boston with numerous house icons scattered across it. A specific area is highlighted by a red dashed rectangle. Two yellow markers, labeled 'A' and 'B', are placed on the map within this rectangle. A cursor is positioned near marker 'B'. To the right of the map is a control panel titled 'Dynamic HomeFinder'.

Dynamic HomeFinder	
Reset	Quit
Save	Print
Dist to A:	
<input type="button" value="30"/>	30
Dist to B:	
<input type="button" value="30"/>	30
Bedrooms:	
<input checked="" type="checkbox"/> 1	?
<input checked="" type="checkbox"/> 2	?
Cost:	
\$50k	-\$500k
Look at:	
House	TH
Land	Cbd
Features:	
Grn	Fpl
Crc	New

Instructions:
 The yellow dots above are homes in the BD area for sale. You may get more information on a home by selecting it. You may drag the 'A' and 'B' distance markers to your office or home to find houses that you live near. Select distances, bedrooms, and cost ranges by dragging the corresponding slider boxes on the right. Select features and amenities services by pressing the labelled buttons on the right.

Starfield display: FilmFinder

Popularity

Y-axis: 2, 3, 4, 5, 6, 7, 8, 9

X-axis: 1960, 1965, 1970, 1975, 1980, 1985, 1990, 1995

Length: 231

Rating: PG-13 [R]

Films Shown: 210

Cinema (C) 1993 HCL

Witches of Eastwick, The

Director: Miller, George Year: 1987

Country: USA Language: English

Actors:

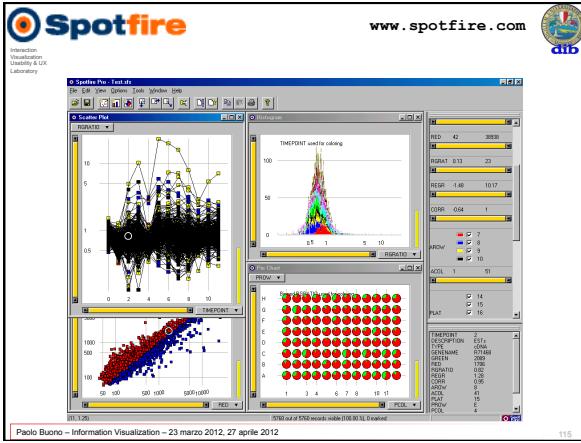
- Nicholson, Jack
- Jenkins, Richard
- Jokum, Keith
- Strucker, Carel
- Cher
- Sarandon, Susan
- Pfeiffer, Michelle
- Carwright, Vera

Length: 231

Rating: PG-13 [R]

Films Shown: 210

Drama Mystery Comedy Music Action War Sci-Fi Western Horror





Fisheye Views & Zooming User Interfaces



- Distortion to magnify areas of interest
User-control, zoom factors of 3-5
- Multi-scale spaces
Zoom in/out & Pan left/right
- Smooth zooming
- Semantic zooming
- Overviews + details-on-demand

Zooming User Interfaces, e.g. DateLens

DateLens

ok

Weekdays
TuWed

ThFr SatSu

27 28 29 30 31 1 2

3 4 5 6 7 8 9

10 11 12 13 14 15 16

17 18 19 20 21 22 23

24 25 26 27 28 29 30

1 2 3 4 5 6 7

8 9 10 11 12 13 14

15 16 17 18 19 20 21

D2 Review Meeting

11:00am D2 mtg
12:00pm Lunch w/ Ben S.
4:00pm ICDL telecon

23 24 25 26 27 28

29 30 31 1 2 3 4

5 6 7 8 9 10 11

12 13 14 15 16 17 18

19 20 21 22 23 24 25

ok

Weekdays
MonTue Wed Thu Fri Sat Sun

3 4 5 6 7 8

9 10 11 12 13 14 15

16 17 18 19 20 21 22

23 24 25 26 27 28 29

30 1 2 3 4 5 6

8 9 10 11 12 13 14

15 16 17 18 19 20 21

22 23 24 25 26 27 28

29 30 31 1 2 3 4

11 12 13 14 15 16 17

18 19 20 21 22 23 24

ok

New View Where Are My...? Find

New View Where Are My...? Find

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A screenshot of the PhotoMesa software interface. The window title is "PhotoMesa". The main area displays a grid of thumbnail images representing various photo albums. Some visible album names include "Bike New York", "Camping ju", "Chris Emma Wedding", "Dana and Momoko", "Dana birthday party feb-2002", "Daria Dressup", "Daria Ri", "Daria's Clubhouse ju", "France Jan-2002", "Marilyn opening", "Mother - Peasover ap 13x (High)", "Snow", "Stacy Jim Wedding Ju", "Theragomin", "Windfall aug-2002", "Windfall dec-2002", and "Windsor june-2002". On the left side, there is a sidebar titled "My Computer" which lists various drives and folders. At the bottom left, there is a copyright notice: "© 2002 PhotoMesa Software Inc. All rights reserved. PhotoMesa is a registered trademark of PhotoMesa Software Inc." A watermark "PhotoMesa" is also present at the bottom right.



Feature Detection in High-Dimensional Spaces



- Correlations - Trends - Patterns
- Clusters
- Outliers
- Gaps
- Multiple View Coordination
- Rank-by-Feature
- Knowledge Integration

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Spectrum of 3-D Visualizations

- Immersive Virtual Environment
 - with head-mounted stereo display and head tracking
- Desktop 3-D for 3-D worlds
 - medical, architectural, scientific visualizations
- Desktop 3-D for artificial worlds
 - Bookhouse, file-cabinets, shopping malls
- Desktop 3-D for information visualization
 - cone/cam trees, perspective wall, web-book
 - SGI directories, Visible Decisions, Media Lab landscapes
 - XGobi scatterplots, Themescape, Visage
- Chartjunk 3-D: barcharts, piecharts, histograms

Microsoft: Task Gallery

research.microsoft.com/ui/TaskGallery/

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Clockwise3d

www.clockwise3d.co

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Challenges

- Dealing with large volume of data
 - Also problem of missing data, uncertainty, data provenance
- Combining visual with textual representations
- Collaborative exploration
 - Environments for publishing results, sharing knowledge
 - Large shared displays
- Integrating with data mining
- Specialized toolkits and development tools
- Addressing Universal Usability
- Evaluation

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Large volume of data e.g. Million-Item Treemap

See www.cs.umd.edu/hcil/millionvis

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Showing uncertainty. Examples from MacEachren et al., Environment & Planning A, 1998

Cause 16 - Age-adjusted Death Rates, 1980-1992

Sample Test Maps:

- cause: 16
- scale: quarter
- color scheme: purple-green
- reliability scheme: white
- color change texture overlay

Bivariate color scheme

Double hatch unreliable

Cause 16 - Age-adjusted Death Rates, 1980-1992

Cause 16 - Age-adjusted Death Rates, 1980-1992

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Combining visual and textual information

Clusters hard to name

caida

Excentric Labeling

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<http://citydashboard.org>

The dashboard displays the following data:

- WEATHER (CASA)**: Wind Speed: 6.0 mph, Wind Gusts: 8 mph, Direction: SW, Temperature: 11.1 °C, Humidity: 66%, Rain Today: 0.0 mm, Pressure: 1001.0 mbars, Forecast: Clear Night.
- WEATHER (METAR)**: London City Airport, Mostly clear, 88°F at 12 mph, 10°C.
- Forecaster (Goodis)**: 7-day forecast from Thu to Sun: 15°C, 16°C, 11°C, 12°C.
- Tube Line Status (TfL)**: Shows service status for Bakerloo, Central, Circle, District, H & C, Jubilee, Metropolitan, Northern, Piccadilly, Victoria, and Overground lines.
- Bike Sharing (TfL)**: 6.2% bike share, 20.1% bike share, 6364 available bikes, 788 bike or dock faults.
- Air Quality (casa)**: Bloombury, Marylebone Rd, N Kensington, 1- Low, 2- Moderate, 3- High, 4- Very High. NO₂, SO₂, PM₁₀, PM_{2.5}.
- GENDER COUNTER (CASA)**: CASA Office, 7 counts per minute.
- River Levels (PLA)**: Data unavailable.
- TWITTER TRENDS FOR LONDON**: #bbcqt, Andrew Roberts, Nigel Farage, Diane Abbott, Simon Hughes, Kensington and Chelsea, Chris Grayling, Polly Toynbee.
- ABOUT**: Includes links to UCL, NeiSS, JISC, and a Twitter link.

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[Many eyes: http://www-958.ibm.com](http://www-958.ibm.com)

The platform features:

- Explore**: Visualizations, Data sets, Collections, Topic centers.
- Participate**: Create your own visualization, Upload a data set, Register a topic center.
- Learn more**: Quick start, Visualization types, About Many Eyes, Press, Blog.
- Try our featured visualizations**: Look - Character Connections, Recommended Daily Caloric Intake, U.S. Testing and Driving Data.
- Income and Living Conditions in poverty**: Survey on Income and Living Conditions in poverty.
- NFL Average Player Salary vs Number of Wins**: Restoring between average player salary and number of wins serving by WORKERS!
- Food Group Consumption**: By state.

An experiment brought to you by IBM Research and the IBM Cognos software group

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Collaboration - Wall-Size Displays

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Toolkits – d3.js

The toolkit includes:

- d3.js**: A small, free JavaScript library for manipulating documents based on data.
- Data-Driven Documents**: Examples of data-driven documents.
- Selections**: D3's core interface.
- Enter and Exit**: Transitions, not Representation transitions.
- Transformations**: Subsections.
- Data-join**: Modules.

D3 allows you to bind arbitrary data to a Document Object Model (DOM), and then query dom-objects you've bound to the data. For example, you can use D3 to generate a simple HTML table from an array of numbers. Or, use the same data to create an interactive SVG bar chart with smooth transitions and mouse events.

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Toolkits – gRaphaël

gRaphaël—JavaScript Library

gRaphaël's goal is to help you create stunning charts on your website. It is based on [Raphael graphics library](#). Check out the demos to see static and interactive charts in action.

gRaphaël currently supports Firefox 3.0+, Safari 3.0+, Opera 9.5+ and Internet Explorer 6.0+.

How to use it?

```
// Create canvas 500 x 400 at 30px, 50
var r = Raphael('div', 50, 400, 400);
// Create site chart at center at 320, 200,
// radius 100 and data: [55, 28, 13, 32, 5, 1, 2];
r.g.piechart(320, 200, 100, [55, 28, 13, 32, 5, 1, 2]);
```

Demos

Source & Bugs

Download v. 0.5.0

- g.raphael.js (10 Ks)
- g.ps.js (4 Ks)
- g.br.js (8 Ks)
- g.line.js (4 Ks)
- g.pie.js (9 Ks)

Our recommendation is to GZIP it. It will help to reduce file size.

Discussion Group

Twitter

Donate

MIT License

Part of Sencha Labs

Source & Bugs

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Toolkits – OpenLayers

OpenLayers

OpenLayers: Free Maps for the Web

Get OpenLayers Now!

- 2.11 (Stable): [tar.gz](#) | [zip](#)
- 2.12 (Beta): [tar.gz](#) | [zip](#)
- API Documentation, User documentation
- See examples of OpenLayers Usage - Release Examples (2.11), Development Examples
- Fork us on GitHub

About

OpenLayers makes it easy to put a dynamic map in any web page. It can display map tiles and markers loaded from any source. OpenLayers has been developed to further the use of geographic information systems (GIS) in the web browser. OpenLayers is Free Software, released under the 2-clause BSD License (also known as the FreeBSD).

Supporting OpenLayers

OpenLayers is supported by a number of organizations around the world. We are also looking for sponsors to help support the community if you are in a position where you want to support the development of OpenLayers, but do not have development resources to share, you may be interested in supporting through our sponsorship program.

For Developers

OpenLayers is a pure JavaScript library for displaying map data in most modern web browsers, with no server-side dependencies. OpenLayers implements a JavaScript API for building rich web-based geographic applications, similar to the Google Maps and MSN Virtual Earth APIs, with one important difference - OpenLayers is Free Software, developed and released by Open-Source software formats from Packt Publishing.

Books about OpenLayers

OpenLayers 2.10 Beginner's Guide
Eric Coates
[Buy it now](#)

OpenLayers 2.10 Beginner's Guide
Eric Coates
[Buy it now](#)

OpenLayers in German
Til Adams & Marc Janzen
[Buy it now](#)

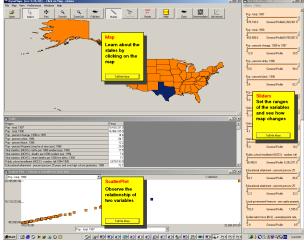
OpenLayers: A Practical Guide to Open-Source Web Mapping
Eric Coates
[Buy it now](#)

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Addressing Universal Usability

▪ **Section 508 / users with disabilities**

▪ **Helping new users get started**



▪ **Dealing with variety of devices and network speed**

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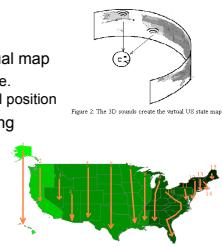
AudioMap: Sonification

Motivation: improve vision-impaired users' access to geo-referenced statistical data

Approach: interactive sonification

- Tie spatial sound to areas to create a virtual map
- Data-to-sound mapping: Piano pitch → value.
Can be followed by short string pitch → vertical position
- Interactions for auditory information seeking
 - Gist (overview): spatial sweepin
 - Navigation: state-by-state exploration
 - Details-on-demand: name & value spoken on request
- Pilot user study (9 sighted subjects)
 - Users can recognize some geographical patterns
 - Users preferred spatial audio map over table

Figure 2: The 3D visualise create the virtual US state map



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Opportunities

- Improve traditional user testing
 - More complex tasks
 - Benchmark datasets AND tasks
 - Longitudinal studies
- Case studies and records of success stories
 - Looking at data from different perspectives, over a long time
 - Answering questions you didn't know you had
 - Discovery and the benefits of awareness

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