an introduction to information graphics and data visualisation

max van kleek
INFO6005 - 12.02.2013
tuesday outline

biological basis of information design
visual dimensions and data dimensions
tasks
deception and bad infographics
friday outline

interacting with visualisations: filtering, searching, selection

multidimensional data

toolkits: a D3 primer
key objectives
what are the goals of visualisation?

how do you choose a visual representation for data?

how do you evaluate a visualisation?

key objectives
aesthetics + engagement – is ‘pretty’ better?

identifying distortion + deception

wielding power tools (excel / matlab / etc ) vs hacking bespoke approaches

minor objectives
recommended texts

**Information Visualization**

Second Edition

Perception for Design

Colin Ware

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**The Visual Display of Quantitative Information**

Edward R. Tufte
biological basis of information design
Typical computer architecture

CPU → GPU → framebuffer(s) → display
framebuffer(s)

display

eye / iris / fovea

parietal lobe + frontal cortex

occipital lobe

spatial orientation
focus of attention
eye control, perceptual fusion

visual cortex (pattern detection)

retina (sensing)
serial / deliberative processing  
“attention-focused”

highly parallel 
visual processing routines  
optimised for purpose

parietal lobe + frontal cortex

spatial orientation  
focus of attention  
eye control,  
perceptual fusion

access to  
long term memory

Tuesday, 12 February 13
Frontal lobe
- Planning
- Thinking
- Deliberation
- Action

Parietal lobe
- Spatial reasoning
- Perceptual fusion

V1
- Occipital lobe

Dorsal stream
- "Where/How" pathways

V2

V3

V4

V5

Ventrical stream
- "What" pathway

Language
- Semiotics

Tuesday, 12 February 13
John Snow, 1854
London Cholera Outbreak


Tuesday, 12 February 13
There was one significant anomaly - none of the monks in the adjacent monastery contracted cholera. Investigation showed that this was not an anomaly, but further evidence, for they drank only beer, which they brewed themselves.

| Sepal length | Sepal width | Petal length | Petal width | Species   | Sepal length | Sepal width | Petal length | Petal width | Species   | Sepal length | Sepal width | Petal length | Petal width | Species   |
|-------------|-------------|--------------|-------------|-----------|-------------|-------------|--------------|-------------|-----------|-------------|-------------|--------------|-------------|-----------|-----------|
| 5.1         | 3.5         | 1.4          | 0.2         | *I. setosa* | 5.4         | 3.4         | 1.5          | 0.4         | *I. setosa* | 5.4         | 3.4         | 1.5          | 0.4         | *I. setosa* |
| 4.9         | 3           | 1.4          | 0.2         | *I. setosa* | 5.2         | 4.1         | 1.5          | 0.1         | *I. setosa* | 5.2         | 4.1         | 1.5          | 0.1         | *I. setosa* |
| 4.7         | 3.2         | 1.3          | 0.2         | *I. setosa* | 4.9         | 4.2         | 1.4          | 0.2         | *I. setosa* | 4.9         | 4.2         | 1.4          | 0.2         | *I. setosa* |
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| 4.3         | 3           | 1.1          | 0.1         | *I. setosa* | 5.1         | 3.8         | 1.9          | 0.4         | *I. setosa* | 5.1         | 3.8         | 1.9          | 0.4         | *I. setosa* |
| 5.8         | 4           | 1.2          | 0.2         | *I. setosa* | 4.8         | 3           | 1.4          | 0.3         | *I. setosa* | 4.8         | 3           | 1.4          | 0.3         | *I. setosa* |
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| 5.1         | 3.8         | 1.5          | 0.3         | *I. setosa* | 7           | 3.2         | 4.7          | 1.4         | *I. versicolor* | 7           | 3.2         | 4.7          | 1.4         | *I. versicolor* |
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| 8.5         | 3.4         | 1.9          | 0.2         | *I. setosa* | 5.7         | 2.8         | 4.5          | 1.3         | *I. versicolor* | 5.7         | 2.8         | 4.5          | 1.3         | *I. versicolor* |
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Species: *I. setosa*, *I. versicolor*
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Edgar Anderson’s Iris data set
parallel coordinates
so how do we come up with these visual representations and which do we choose for a dataset?
Visual and Data Dimensions
so you have a dataset...

\( \{ x_1, x_2, x_3, x_4, \ldots \} \)

\( x_1 \)
so you have a dataset...

\[ \{x_1, x_2, x_3, x_4, \ldots \} \]

\[ \{1, 200, 5, 6, \ldots \} \]

\[ \{1.0, 2.0, 1.2, 4, \ldots \} \]

\{'a', 'b', '12c', 'd' \ldots\}

\[ \{20\%, 30\%, 1\%, 5\% \ldots\} \]

\{\text{pear, apple, orange, banana, pineapple} \ldots\}

\{f(\text{pear, apple}), g(\text{apple, orange}), q(\text{orange, pineapple}) \ldots\}

\(x_1\)

integral

fixed point

alpha(-numeric)

fractions of a population

categorical

relational
so you have a dataset...

\[
\{x_1, x_2, x_3, x_4, \ldots \} \quad x_1
\]

\[
\{1, 200, 5, 6, \ldots \} \quad \text{integral}
\]

\[
\{1.0, 2.0, 1.2, 4, \ldots \} \quad \text{fixed point}
\]

\[
\{'a', 'b', '12c', 'd', \ldots \} \quad \text{alpha(-numeric)}
\]

\[
\{20\%, 30\%, 1\%, 5\% \ldots \} \quad \text{fractions of a population}
\]

\[
\{\text{pear}, \text{apple}, \text{banana}, \text{pineapple}, \ldots \} \quad \text{categorical}
\]

\[
\{f(\text{pear}, \text{apple}), g(\text{apple}, \text{banana}), q(\text{banana}, \text{pineapple}) \ldots \} \quad \text{relational}
\]

**objective** - help the user to understand: **relationships among the elements of the set**
so you have a dataset...

\[
x = \{ \vec{x}_1, \vec{x}_2, \vec{x}_3, \vec{x}_4, \ldots \}
\]

if these are observations of the (same) of object(s) over time
“time series”

if these are observations of different things at a single point in time
“population”

if these are observations of different things at a different points in time
“observations”
so you have a dataset...

\[ \mathbf{x} = \{ \mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_3, \mathbf{x}_4, \ldots \} \]

\[ \mathbf{x} = \begin{bmatrix} x_1 & x_2 & x_3 \\ y_1 & y_2 & y_3 & \ldots \\ \mathbf{\tau}_1 & \mathbf{\tau}_2 & \mathbf{\tau}_3 \end{bmatrix} \]

it’s probably multivariate

if these are observations of the (same) of object(s) over time “time series”

if these are observations of different things at a single point in time “population”

if these are observations of different things at a different points in time “observations”

**objective** - help the user to understand:

1. elements - specifically relationships among dimensions (through a large number of examples)
2. relationships - among different elements
data dimension types

integral

fixed point

alpha(-numeric)

fractions of a population

categorical

relational

visual dimension type

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### Data Dimension Types

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...
**Data dimension types**

- integral
- fixed point
- alpha(-numeric)
- fractions of a population
- categorical
- relational

**Visual dimension type**

- position
- relative location
- centrality
- shape
- colour
- saturation
- opacity
- size
- width
- height

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data dimension types

integral
fixed point
alpha(-numeric)
fractions of a population
categorical
relational

Visual dimension types

position
shape
colour
size
orientation
stroke

relative location
centrality
saturation
opacity
width
height
colour
pattern, thickness
<table>
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<tr>
<th>Data Dimension Types</th>
<th>Visual Dimension Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integral</td>
<td>Position</td>
</tr>
<tr>
<td>Fixed Point</td>
<td>Relative Location</td>
</tr>
<tr>
<td>Alpha(-numeric)</td>
<td>Centrality</td>
</tr>
<tr>
<td>Fractions of a Population</td>
<td>Shape</td>
</tr>
<tr>
<td>Categorical</td>
<td>Colour</td>
</tr>
<tr>
<td>Relational</td>
<td>Size</td>
</tr>
<tr>
<td>...</td>
<td>Orientation</td>
</tr>
<tr>
<td>...</td>
<td>Stroke</td>
</tr>
<tr>
<td>...</td>
<td>Opacity</td>
</tr>
<tr>
<td>...</td>
<td>Colour, Pattern, Thickness</td>
</tr>
</tbody>
</table>
**data dimension types**

- integral
- fixed point
- alpha(-numeric)
- fractions of a population
- categorical
- relational

**visual dimension types**

- position
- shape
- colour
- size
- orientation
- stroke
- opacity
- texture

- relative location
- centrality
- saturation
- opacity
- width
- height
- colour pattern, thickness

...
| Data Dimension Types          | Visual Dimension Types          |
|------------------------------|---------------------------------
<p>| integral                     | position                       |
| fixed point                  | relative location              |
| alpha(-numeric)              | centrality                     |
| fractions of a population    | shape                          |
| categorical                  | colour                         |
|                              | saturation                     |
|                              | opacity                        |
|                              | width                          |
|                              | height                         |
|                              | orientation                    |
|                              | stroke                         |
|                              | colour pattern, thickness      |
|                              | opacity                        |
|                              | texture                        |
|                              | movement                       |
| ...                          | ...                             |</p>
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<td>position relative location centrality</td>
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<tr>
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<td>shape saturation opacity</td>
</tr>
<tr>
<td>alpha(-numeric)</td>
<td>colour width height</td>
</tr>
<tr>
<td>fractions of a population</td>
<td>size orientation colour pattern, thickness</td>
</tr>
<tr>
<td>categorical</td>
<td>stroke opacity</td>
</tr>
<tr>
<td>relational</td>
<td>opacity texture movement</td>
</tr>
<tr>
<td></td>
<td>juxtaposition</td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
</tbody>
</table>
data dimension types

- integral
- fixed point
- alpha(-numeric)
- fractions of a population
- categorical
- relational
- ...
position
position

linear mapping of values
logarithmic..
bin and count..
only have up to 3 spatial dimensions to work with
only have up to 3 spatial dimensions to work with
orientation
orientation

range-limited
orientation

range-limited
orientation

range-limited

symmetry properties of the geometry
range-limited

symmetry properties of the geometry
orientation

range-limited symmetry properties of the geometry

pop-out
orientation
popouts using multiple dimensions
orientation

popouts using multiple dimensions

1D colour
orientation

diagram using multiple dimensions

1D colour 1D orientation
orientation

popouts using multiple dimensions

1D colour

1D orientation

2D color/orientation
Using colour for continuous values
Using colour for continuous values
Using colour for continuous values
Using colour for continuous values

problem 1: No natural ordering
Using colour for continuous values

problem 1: No natural ordering
Using colour for continuous values

problem 1: No natural ordering
Using colour for continuous values

problem 1: No natural ordering
Using colour for continuous values

Drag and drop the colors in each row to arrange them by hue order.
The first and last color chips are fixed. Click on "Score Test" when done.

http://www.colormunki.com/game/huetest_kiosk

problem 1: No natural ordering
Using colour for continuous values

http://www.colormunki.com/game/huetest_kiosk

problem 1: No natural ordering
Using colour for continuous values

Protanopia affects 8% of males, 0.5% females of Northern European ancestry

problem 2: colour sensitivity
Using colour for continuous values

problem 3: yellow is special
Using colour for continuous values

problem 3: yellow is special
Using colour for continuous values

problem 4: Details: overemphasised or obscured

hue ‘borders’ overemphasise small changes, hue ‘middles’ blend potentially important details
Using colour for continuous values

problem 4: Details: overemphasised or obscured

hue ‘borders’ overemphasise small changes, hue ‘middles’ blend potentially important details
Using colour for continuous values

problem 4: Details: overemphasised or obscured

hue ‘borders’ overemphasise small changes, hue ‘middles’ blend potentially important details
Using colour for continuous values

Problem 5: pop out can drown out
juxtaposition: small multiples
The 892 unique ways to partition a $3 \times 4$ grid
The 892 unique ways to partition a 3×4 grid

703 × Black
Asymmetric
Changed by horizontal reflection, vertical reflection, and 180° rotation.

61 × Blue
Top-bottom symmetry
Changed by horizontal reflection and 180° rotation.

26 × Green
Rotational symmetry
Changed by horizontal and vertical reflection.

76 × Orange
Left-right symmetry
Changed by vertical reflection and 180° rotation.

26 × Magenta
All three symmetries combined
Unchanged by horizontal reflection, vertical reflection, or 180° rotation.
multidimensional data

Chernoff Faces
multidimensional data

via The Guardian

distorted to make area proportional to votes

Obama–Romney 2012 victories by state

Romney: 235 EV
Obama: 303 EV
270 EV are required to win.
(via http://zompist.wordpress.com/J)
multidimensional data

napoleon’s march to moscow
charles joseph minard
multidimensional data

How many dimensions can you find?

Napoleon’s march to Moscow

Charles Joseph Minard

Tuesday, 12 February 13
multidimensional data

how many dimensions can you find?

ans: 1) size of the army 2-3) path (lat/lng) taken on a map 4) direction army was traveling 5) temperature 6) dates army reached particular locations

napoleon’s march to moscow

charles joseph minard

Tuesday, 12 February 13
multidimensional data

E.J. Marey
La méthode graphique
(1885)
multidimensional data

E.J. Marey
La méthode graphique
(1885)
multidimensional data

TGV
Paris-Lyon

E.J. Marey
La méthode graphique
(1885)
200 years that changed the world

with Hans Rosling
Standard Visualisation Techniques
ordering significant

order insignificant
ordering significant

order insignificant
ordering significant

sorted histogram

median (middle)

Quartiles

box & whisker

extrema (whiskers)

order insignificant

Tuesday, 12 February 13
(an aside: bad stacked areas and “streamgraphs“)
(an aside: bad stacked areas and “streamgraphs”)
(an aside: bad stacked areas and "streamgraphs")
(an aside: bad stacked areas and “streamgraphs”)
TechCrunch Top 8 Name References (May 2006 - May 2008)

"abandon all hope ye who vieweth"
“abandon all hope ye who vieweth”
multivariate relational data: hierarchical
multivariate relational data: hierarchical

tree
multivariate relational data: hierarchical

tree

hyperbolic tree
multivariate relational data: hierarchical

treemap
multivariate relational data: hierarchical
multivariate relational data: hierarchical
multivariate relational data: non-hierarchical

venn diagram
multivariate relational data: non-hierarchical

venn diagram

lattice
multivariate relational data: non-hierarchical

Venn diagram

Parallel sets

Titanic Survivors

Survived

Perished

Sex

Male

Female

Age

Adult

Child

Class

First Class

Second Class

Third Class

Crew

Data: Robert J. MacG. Dawson
multivariate relational data: non-hierarchical

Plenty of other interesting visualisations....

Some favourites I didn’t mention?

send them to: max@hip.cat

and I’ll compile a list for the class

venn diagram

parallel sets
infographic fails: visual + statistical sleight of hand to mislead the audience
IF BUSH TAX CUTS EXPIRE

TOP TAX RATE

NOW 35%

JAN. 1, 2013 39.6%
1. Barchart baseline fail

IF BUSH TAX CUTS EXPIRE

TOP TAX RATE

NOW 35%

JAN. 1, 2013 39.6%
Soaring gas prices

The price of a gallon of regular gas has risen 38 cents in South Florida in the past month. The national average rose 32 cents.

<table>
<thead>
<tr>
<th></th>
<th>Miami</th>
<th>Ft. Lauderdale</th>
<th>Florida</th>
<th>U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$4.0</td>
<td>$3.941</td>
<td>$3.918</td>
<td>$3.789</td>
<td>$3.826</td>
</tr>
<tr>
<td>$3.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$3.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$3.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$3.6</td>
<td>$3.565</td>
<td>$3.529</td>
<td>$3.432</td>
<td>$3.50</td>
</tr>
<tr>
<td>$3.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$3.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$3.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$3.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$3.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$3.0</td>
<td></td>
<td></td>
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</table>

Source: AAA Fuel Gauge Report

THE MIAMI HERALD
Soaring gas prices

The price of a gallon of regular gas has risen 38 cents in South Florida in the past month. The national average rose 32 cents.

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<thead>
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<th>Location</th>
<th>Now</th>
<th>Month Ago</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miami</td>
<td>$3.941</td>
<td>$3.565</td>
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Source: AAA Fuel Gauge Report

THE MIAMI HERALD
New York State
Total Budget Expenditures and Aid to Localities  In billions of dollars
Fiscal 1966-1976

Total Budget
$4.0
$4.6
$5.5
$6.2
$6.7
$7.4
$7.8
$8.5
$9.7
$10.7
$10.8

Total Aid to Localities*
*Varying from a low of 56.7 percent of the total in 1970-71 to a high of 60.7 percent in 1972-73

1966-'67  '67-'68  '68-'69  '69-'70  '70-'71  '71-'72  '72-'73  '73-'74  '74-'75  '75-'76  '76-'77

↑ Estimated  ↑ Recommended
New York State
Total Budget Expenditures and
Aid to Localities  In billions of dollars
Fiscal 1966-1976

Total Budget

Total Aid to Localities*

*Varying from a low of 56.7 percent of the total in 1970-71 to a high of 60.7 percent in 1972-73

1966-67

1967-68

1968-69

1969-70

1970-71

1971-72

1972-73

1973-74

1974-75

1975-76

1976-77

$4.0

$4.6

$5.5

$6.2

$6.7

$7.4

$7.8

$8.5

$9.7

$10.7

$10.8

Estimated

Recommended

Tuesday, 12 February 13
Per capita budget expenditures, in constant dollars

$400
$380
$360
$340
$320
$300


5%
2. “Huge differences” fail

**THE SHRINKING FAMILY DOCTOR**

In California

Percentage of Doctors Devoted Solely to Family Practice

<table>
<thead>
<tr>
<th>Year</th>
<th>1964</th>
<th>1975</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>27%</td>
<td>16.0%</td>
<td>12.0%</td>
</tr>
</tbody>
</table>

1: 2,247 ratio to population

8,023 Doctors

1: 3,167

6,694

1: 4,232

6,212

using area (2 dimensions) to represent one dimension
2. “Huge differences” fail

**THE SHRINKING FAMILY DOCTOR**
In California
Percentage of Doctors Devoted Solely to Family Practice

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**Ratio to Population**

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8,023 Doctors

using area to represent one dimension
2. “Huge differences” fail

ENGAGING WITH CONTACT CENTERS

Call centers are a multi-functional operation. The reason why consumers engage in contact centers may affect the experience they have with them.

- 50%
- 45%
- 40%
- 35%
- 30%
- 25%
- 20%
- 15%
- 10%
- 5%
- 24%
- 32%
- 35%

TO RECEIVE PRODUCT OR SERVICE
BILLING INQUIRY
OBTAIN OTHER INFORMATION
CHECK STATUS OF ORDER
FILE COMPLAINT
OTHER

CONSUMERS ASKED TO "SELECT ALL THAT APPLY"

using area to represent one dimension
2. “Huge differences” fail

Using area to represent one dimension.
Quiz: How does this fail?

**THE ISSUE OF TRUST**

**ACCENTS AND DISTRUST**

Another reason why accents affect customer service is the question of credibility. If I can not understand you, then I can not trust you.

An experiment conducted by the University of Chicago demonstrated this aspect. The question posed, do trivia statements sound less true when spoken by a non-native speaker? Furthermore, listeners were told in advance that all of the trivia questions were provided by the experimenter. This way, even listeners who were knowingly prejudice against non-native accents should not have been affected.

The results showed that the heavier the accent the less trustworthy the person became.

- **NATIVE ACCENT**
- **MILD ACCENT**
- **HEAVY ACCENT**

---

Tuesday, 12 February 13
Distortion factor: 2.5

True data

Distortion factor: 5.0

True data
SUBSIDIZE THIS

THE PRICE THAT YOU PAY FOR ENERGY—WHETHER ELECTRICITY AT YOUR HOUSE OR GAS AT THE PUMP—ISN’T ACTUALLY THE PRICE THAT THE MARKET WOULD SET FOR THAT ENERGY.

The government spends billions of dollars to support the energy industry, which allows it to make energy cheaper than it should cost on the open market. These subsidies—either in the form of tax breaks or direct funding—favor some types of energy over others, giving our country a skewed sense of what each gallon of gas or wind-powered electron costs. This is a look at where the government directed its subsidy dollars from 2002 to 2008.

A collaboration between GOOD and Deeplocal
In conclusion

Designing effective infographics is about effectively conveying or facilitating an understanding of relationships in data offloading “heavy lifting” to our trained neural circuitry.

While still an art, many design principles grounded in usability can provide guidance: natural mappings, simplicity, & avoiding distortion.