Marks + Channels

Visualization
Torsten Möller
Overview

• Marks + channels

• Channel effectiveness
  – Accuracy
  – Discriminability
  – Separability
  – Popout

• Channel characteristics
  – Spatial position
  – Colour
  – Size
  – Tilt (angle)
  – Shape (glyph)
  – Stipple (texture)
  – Curvature
  – Motion
Readings

• Munzner, “Visualization Analysis and Design”:
  – Chapter 5 (Marks and Channels)

• Colin Ware:
  – Chapter 4 (Color)
  – Chapter 5 (Visual Attention and Information that Pops Out)

• The Visualization Handbook:
  – Chapter 1 (Overview of Visualization)

• Additional (background) reading
Marks + Channels

• Mark: basic graphical element / geometric primitive:
  – point (0D)
  – line (1D)
  – area (2D)
  – volume (3D)

• Channel: control appearance (of a mark)
  – position
  – size
  – shape
  – orientation
  – hue, saturation, lightness
  – etc.
According to Bertin ...

Position
Size
(Grey)Value
Texture
Color
Orientation
Shape

Marks
- Points
- Lines
- Areas

Semiology of Graphics [J. Bertin, 67]

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<table>
<thead>
<tr>
<th>property</th>
<th>marks</th>
<th>ordinal/nominal mapping</th>
<th>quantitative mapping</th>
</tr>
</thead>
<tbody>
<tr>
<td>shape</td>
<td>glyph</td>
<td>§ □ ◆ △ S U</td>
<td></td>
</tr>
<tr>
<td>size</td>
<td>rectangle, circle, glyph, text</td>
<td></td>
<td>□ □ □ □ □ □ □ □ □ □ □</td>
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<tr>
<td>orientation</td>
<td>rectangle, line, text</td>
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<td>▼ ▼ ▼ ▼ ▼ ▼ ▼ ▼ ▼ ▼ ▼ ▼</td>
</tr>
<tr>
<td>color</td>
<td>rectangle, circle, line, glyph, y-bar, x-bar, text, gantt bar</td>
<td></td>
<td>min max</td>
</tr>
</tbody>
</table>

“Polaris: A System for Query, Analysis and Visualization of Multi-dimensional Relational Databases”, Chris Stolte and Pat Hanrahan
Progression

a) b) c) d)
Channel types: Where / What

Based on slide from Mazur
What vs. How Much channels

• What: **categorical**
  – shape
  – spatial region
  – colour (hue)

• How Much: **ordered** (ordinal, quantitative)
  – length (1D)
  – area (2D)
  – volume (3D)
  – tilt
  – position
  – colour (lightness)
Mark types

- tables: item = point
- network: node+link
- link types:
  - connection: relationship btw. two nodes
  - containment: hierarchy
Expressiveness + Effectiveness

• expressiveness principle:
  – visual encoding should express all of, and only, the information in the dataset attributes
  – lie factor

• effectiveness principle:
  – importance of the attribute should match the salience of the channel
  – data-ink ratio
Effectiveness of Mappings

- Effectiveness according to neurophysiology
- Cells in Visual Areas 1 and 2 differentially tuned to each of the following properties:
  - Orientation and size (with luminance)
  - Color (two types of signal)
  - Stereoscopic depth
  - Motion
Channels and Marks: Types and Ranks

**Ordered:** Ordinal/Quantitative
- How much
  - position on common scale
  - position on unaligned scale
  - length (1D size)
  - tilt/angle
  - area (2D size)
  - curvature
  - volume (3D size)
  - lightness black/white
  - color saturation
  - stipple density

**Categorical**
- What
  - region
  - color hue
  - shape
  - stipple pattern

**Marks as Items/Nodes**
- points
- lines
- areas

**Marks as Links**
- containment (area)
- connection (line)
Mackinlay’s Retinal Variables

[Quantitative]
- Position
- Length
- Angle
- Slope
- Area
- Volume
- Density
- Saturation
- Hue
- Texture
- Connection
- Containment
- Shape

[Ordinal]
- Position
- Density
- Saturation
- Hue
- Texture
- Connection
- Containment
- Shape

[Nominal]
- Position
- Hue
- Texture
- Connection
- Containment
- Density
- Saturation
- Shape

[Mackinlay, Automating the Design of Graphical Presentations of Relational Information, ACM TOG 5:2, 1986]
Effectiveness -- Accuracy

- perceptual judgement vs. stimulus
- Weber’s law: $S = I^n$
Effectiveness -- Discriminability

- how many colours can I tell apart?
- how many levels of grey etc.
- Ex: line width
Effectiveness -- Separability

- separable vs. integral channels
According to Ware ...  

- **Integral** display dimensions  
  - Two or more attributes perceived holistically  

- **Separable** dimensions  
  - Separate judgments about each graphical dimension  

- Simplistic classification, with a large number of exceptions and asymmetries  

![Diagram showing integral and separable dimension pairs]
Popout - Preattentive processing

- parallel (visual processing)
Overview

• Marks + channels
• Channel effectiveness
• Channel characteristics
  – Spatial position
  – Color
    • visual system
    • color models
    • color deficiency
  – Size
  – Tilt (angle)
  – Shape (glyph)
  – Stipple (texture)
  – Curvature
  – Motion
Channels

• Spatial position: most effective for all data types (remember the power of the plane)
• Size: ‘how much’, interacts with others
• Shape/Glyph: ‘what channel’
• Stipple/texture: less popular today
• Curvature
• Motion: large popout effect
Spatial position

2.05D

We only see the outside shell of the world.

One point along each ray.
Colour
Visual System
The eye and the retina
Retina detectors

• 1 type of monochrome sensor (rods)
  – Important at low light
• Next level: lots of specialized cells
  – Detect edges, corners, etc.
• Sensitive to contrast
  – Weber’s law: DL ~ L
Retina detectors

- 3 types of color sensors - S, M, L (cones)
  - Works for bright light
  - Peak sensitivities located at approx. 430nm, 560nm, and 610nm for "average" observer.
  - Roughly equivalent to blue, green, and red sensors
Color Opponency

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Color Models
RGB Color Space

- Additive system
- Colors that can be represented by computer monitors
- Not perceptually uniform
HSL Color Space

- Hue - what people think of color
- Saturation - purity, distance from grey
- Lightness - from dark to light
- Not perceptually uniform
Lab Color Space

- Perceptually uniform
- \( L \) approximates human perception of lightness
- \( a, b \) approximate R/G and Y/B channels
- \( a, b \) called chroma
Luminance, Saturation, Hue

• Luminance
  – *How-much* channel
  – discriminability: ~2-4 bins
  – contrast important

• Saturation
  – *How-much* channel
  – discriminability: ~3 bins

• Hue
  – *What* channel
  – discriminability: ~6-12
Ordered Data

- Luminance
- Saturation
- Brightness
- Rainbow is a learned order!
Thanks to Moritz Wustinger
Thanks to Moritz Wustinger
Smiley based on http://upload.wikimedia.org/wikipedia/commons/b/bd/A_Smiley.jpg
Thanks to Moritz Wustinger
Color deficiency
Model “Color blindness”

- Flaw in opponent processing
  - Red-green common (deuteranope, protanope)
  - Blue-yellow possible (tritanope -- most common)
  - Luminance channel almost “normal”
- 8% of all men, 0.5% of all women
- Effect is 2D color vision model
  - Flatten color space
  - Can be simulated (Brettel et. al.)
  - http://colorfilter.wickline.org
Color Blindness

Protanope
No L cones
Red / green deficiencies

Deuteranope
No M cones

Tritanope
No S cones
Blue / Yellow deficiency

Source: M. Stone
Color-Blindness

Normal    Protanope    Deuteranope    Lightness

Source: M. Stone
Overview

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• Channel characteristics
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• Other channels:
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  – Shape (glyph)
  – Stipple (texture)
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Channels and Marks: Types and Ranks

**Ordered: Ordinal/Quantitative**

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  - volume (3D size)
  - lightness (black/white)
  - color saturation
  - stipple density

**Categorical**

- What
  - region
  - color hue
  - shape (circle, square, triangle, etc.)
  - stipple pattern

**Marks as Items/Nodes**

- Points
- Lines
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**Marks as Links**

- Containment (area)
- Connection (line)
Relativ vs. absolute judgement

• Weber’s law says that everything is relative, i.e. the “intensity” depends on the background signal
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