Exercise: Two numbers

9 and 26

• How can you visually represent these two numbers?
  – Solo: quickly sketch 3 ideas
  – Pair: compare with your neighbor
    • Q: how many matched?
  – Together: sketch 2 more different ones

• Keep pix for Foundations 2
  • (snap a picture so each of you has it)

• Many possibilities!
  https://visual.ly/blog/45-ways-to-communicate-two-quantities/
Marks and Channels
Visual encoding

• how to systematically analyze idiom structure?

• marks & channels
  – marks: represent items or links
  – channels: change appearance of marks based on attributes
Marks for items

• basic geometric elements

Points

Lines

Areas

0D

1D

2D

• 3D mark: volume, rarely used
Marks for links

➡️ Containment

➡️ Connection
Containment can be nested

[Untangling Euler Diagrams, Riche and Dwyer, 2010]
Channels

• control appearance of marks
  – proportional to or based on attributes

• many names
  – visual channels
  – visual variables
  – retinal channels
  – visual dimensions
  – ...

- Position
  - Horizontal
  - Vertical
  - Both

- Color

- Shape

- Tilt

- Size
  - Length
  - Area
  - Volume
Visual encoding

- analyze idiom structure
  - as combination of marks and channels

1: vertical position
   mark: line

2: vertical position
   horizontal position
   mark: point

3: vertical position
   horizontal position
   color hue
   mark: point

4: vertical position
   horizontal position
   color hue
   size (area)
   mark: point
Redundant encoding

• multiple channels
  – sends stronger message
  – but uses up channels

Length, Position, and Value
What is wrong with this picture?

- should use channel proportional to data!

https://twitter.com/ChaseThomason/status/1118478036507164672?s=19
When to use which channel?

**expressiveness**

match channel type to data type

**effectiveness**

some channels are better than others
Channels

Position on common scale
Position on unaligned scale
Length (1D size)
Tilt/angle
Area (2D size)
Depth (3D position)
Color luminance
Color saturation
Curvature
Volume (3D size)
Spatial region
Color hue
Motion
Shape

Channels: Expressiveness Types And Effectiveness Ranks
Channels: Matching Types

**Magnitude Channels: Ordered Attributes**
- Position on common scale
- Position on unaligned scale
- Length (1D size)
- Tilt/angle
- Area (2D size)
- Depth (3D position)
- Color luminance
- Color saturation
- Curvature
- Volume (3D size)

**Identity Channels: Categorical Attributes**
- Spatial region
- Color hue
- Motion
- Shape

- expressiveness principle
  - match channel and data characteristics
  - magnitude for ordered
    - how much? which rank?
  - identity for categorical
    - what?
Channels: Rankings

**Magnitude Channels: Ordered Attributes**
- Position on common scale
- Position on unaligned scale
- Length (1D size)
- Tilt/angle
- Area (2D size)
- Depth (3D position)
- Color luminance
- Color saturation
- Curvature
- Volume (3D size)

**Identity Channels: Categorical Attributes**
- Spatial region
- Color hue
- Motion
- Shape

- **expressiveness principle**
  - match channel and data characteristics
- **effectiveness principle**
  - encode most important attributes with highest ranked channels
• expressiveness principle
  – match channel and data characteristics
• effectiveness principle
  – encode most important attributes with highest ranked channels
  – spatial position ranks high for both
Quiz: Name those channels

• A: Inconvenient Truth

https://www.youtube.com/watch?v=9tkDK2mZlOo
Quiz: Name those channels

• B: Tax Rates

Quiz: Name those channels

• C: Alpen Forest Fires

Burned area in hectares on the southern side of the Alps

Source: Swissfire forest fire database

Quiz: Name those channels

• D: More Alpen Forest Fires

Monthly distribution of forest fires in the Alpine regions caused by,,

- den Menschen
- Blitzschläge
- unbekannt

Alpensüdseite

andere Alpengebiete

Average numbers in the period 2000-2018
Source: Swissfire forest fire database

Quiz: Name those channels

• E: Netherlands Commuters

Reminder: Marks and channels

• marks
  – basic geometric elements

• channels
  – control appearance of marks

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<th>Lines</th>
<th>Areas</th>
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Quiz: Name that mark

• A: Shooting Media Coverage

https://twitter.com/MonaChalabi/status/1158779046693679106?s=20
Quiz: Name that mark

• B: Sunsqatch

https://flowingdata.com/2017/08/20/sunsquatch-the-only-eclipse-map-you-need/
Quiz: Name that mark

- C: UFC fights

Marks: Constrained vs encodable

• math view: geometric primitives have dimensions
  ➔ Points
  ➔ Lines
  ➔ Areas

• constraint view: mark type constrains what else can be encoded
  – points: 0 constraints on size, can encode more attributes w/ size & shape
  – lines: 1 constraint on size (length), can still size code other way (width)
  – areas: 2 constraints on size (length/width), cannot size code or shape code

• quick check: can you size-code another attribute, or is size/shape in use?
Analyzing marks

• what type of mark?
  – line?
    • no, not length coded
  – point mark with rectangular shape?
    • yes!
  – area?
    • no, area/shape does not convey meaning

Quiz: Name that mark

• D: Yet More Alpen Forest Fires

Most forest fires in Switzerland occur on the southern side of the Alps.

Annual number of forest fires between 1860 and 2014

- < 1 Waldbrand
- 1-2
- 2-3
- 3-5
- 5-15
- > 15

Source: Climate Change Forest: Pyramid et al., 2019

Quiz: Name that mark

• E: Tax Rates

Quiz: Name that mark

- F: Alpen Forest Fires

Burned area in hectares on the southern side of the Alps

Source: Swissfire forest fire database

G: More Alpen Forest Fires

Monthly distribution of forest fires in the Alpine regions caused by, ,

- den Menschen
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Alpensüdseite  |  andere Alpengebiete

Average numbers in the period 2000-2018
Source: Swissfire forest fire database

Scope of analysis

• simplifying assumptions: one mark per item, single view

• later on
  – multiple views
  – multiple marks in a region (glyph)
  – some items not represented by marks (aggregation and filtering)
Channel effectiveness

• accuracy: how precisely can we tell the difference between encoded items?
• discriminability: how many unique steps can we perceive?
• separability: is our ability to use this channel affected by another one?
• popout: can things jump out using this channel?
Accuracy: Fundamental theory

- length is accurate: linear
- others magnified or compressed
  - exponent characterizes

Steven’s Psychophysical Power Law: $S = I^N$

$S = \text{sensation}$
$I = \text{intensity}$
Accuracy: Vis experiments

Discriminability: How many usable steps?

• must be sufficient for number of attribute levels to show
  – linewidth: few bins but salient
Separability vs. Integrality

Position
+ Hue (Color)

- Fully separable
  - 2 groups each

Size
+ Hue (Color)

- Some interference
  - 2 groups each

Width
+ Height

- Some/significant interference
  - 3 groups total:
    - integral area

Red
+ Green

- Major interference
  - 4 groups total:
    - integral hue
Popout

• find the red dot
  – how long does it take?

• parallel processing on many individual channels
  – speed independent of distractor count
  – speed depends on channel and amount of difference from distractors

• serial search for (almost all) combinations
  – speed depends on number of distractors
• many channels: tilt, size, shape, proximity, shadow direction, ...
• but not all! parallel line pairs do not pop out from tilted pairs
Grouping

• containment
• connection

Marks as Links

- Containment
  ![Containment Diagram]

- Connection
  ![Connection Diagram]

Identity Channels: Categorical Attributes

- Spatial region
  ![Spatial Region]

- Color hue
  ![Color Hue]

- Motion
  ![Motion]

- Shape
  ![Shape]
Relative vs. absolute judgements

- perceptual system mostly operates with relative judgements, not absolute
  - that’s why accuracy increases with common frame/scale and alignment
  - Weber’s Law: ratio of increment to background is constant
    - filled rectangles differ in length by 1:9, difficult judgement
    - white rectangles differ in length by 1:2, easy judgement

length

position along unaligned common scale

position along aligned scale

Factors affecting accuracy

- alignment
- distractors
- distance
- common scale
Relative luminance judgements

- perception of luminance is contextual based on contrast with surroundings

http://persci.mit.edu/gallery/checkershadow
Relative color judgements

- color constancy across broad range of illumination conditions

http://www.purveslab.net/seeforyourself/
Upcoming

• D3 videos to watch, week 3
  – Making a Bar Chart with D3 and SVG [30 min]
• Quiz 2, due by Fri Jan 17, 8am
• labs start this week!
  – Fri 9-10, 11-12, 4-5
  – strongly recommended but optional: we do not track attendance
  – TA office hours for individual consultation and help
    • TAs will typically alternate weeks
  – if you can't register, try attending the one you want
    • seats for registered students first, but may be room

• Foundations Exercise 2 out, due Wed Jan 22
• Programming Exercise 1 out, due Wed Jan 29
Credits

• Visualization Analysis and Design (Ch 5)
• Alex Lex & Miriah Meyer, http://dataviscourse.net/