Upcoming

- Foundations 3: out Thu Jan 30, due Wed Feb 5 6pm
- Programming 2: out Thu Jan 30, due Wed Feb 12 6pm
- D3 videos/readings week 4
  - The General Update Pattern of D3.js [60 min]
  - Interaction with Unidirectional Data Flow [16 min]
  - Read: Reusable D3 Components
- Quiz 4, due by Fri Jan 31, 8am
Interactive Views
How to handle complexity: 1 previous strategy + 3 more

- Derive

- Derive new data to show within view
- Change view over time
- Facet across multiple views
- Reduce items/attributes within single view

Manipulate

- Change
  - Adapt to
  - Adjust

- Select
  - Choose
  - Sort

- Navigate
  - Move
  - Transition

Facet

- Juxtapose
  - Side-by-side
  - Overlaid

- Partition
  - Divide
  - Segment

- Superimpose
  - Integrate
  - Overlay

Reduce

- Filter
  - Narrow
  - Exclude

- Aggregate
  - Summarize
  - Group

- Embed
  - Integrate
  - Overlay
Manipulate

- Change over Time
- Navigate
- Select

- Item Reduction
  - Zoom
    - Geometric or Semantic
  - Pan/Translate
  - Constrained
Change over time

• change any of the other choices
  – encoding itself
  – parameters
  – arrange: rearrange, reorder
  – aggregation level, what is filtered...

  – interaction entails change
Idiom: **Re-encode**

System: **Tableau**

made using Tableau, [http://tableausoftware.com](http://tableausoftware.com)
Idiom: **Change parameters**

- widgets and controls
  - sliders, buttons, radio buttons, checkboxes, dropdowns/comboboxes

- pros
  - clear affordances, self-documenting (with labels)

- cons
  - uses screen space

- design choices
  - separated vs interleaved
    - controls & canvas

*slide inspired by: Alexander Lex, Utah*
Idiom: **Change order/arrangement**

- **what:** simple table
- **how:** data-driven reordering
- **why:** find extreme values, trends

[Sortable Bar Chart](https://bl.ocks.org/mbostock/3885705)
Idiom: **Reorder**

- **what**: table with many attributes
- **how**: data-driven reordering by selecting column
- **why**: find correlations between attributes

System: **DataStripes**

[http://carlmanaster.github.io/datastripes/]
Idiom: **Change alignment**

- stacked bars
  - easy to compare
    - first segment
    - total bar
- align to different segment
  - supports flexible comparison

**System: LineUp**

Shiny example

- APGI genome browser
  - tooling: R/Shiny
  - interactivity
    - tooltip detail on demand on hover
    - expand/contract chromosomes
    - expand/contract control panes

https://gallery.shinyapps.io/genome_browser/
Idiom: **Animated transitions**

- smooth interpolation from one state to another
  - alternative to jump cuts, supports item tracking
  - best case for animation
  - staging to reduce cognitive load
- example: animated transitions in statistical data graphics

[vimeo.com/19278444](vimeo.com/19278444)

Idiom: **Animated transitions - visual encoding change**

- smooth transition from one state to another
  - alternative to jump cuts, supports item tracking
  - best case for animation
  - staging to reduce cognitive load

[Stacked to Grouped Bars](http://bl.ocks.org/mbostock/3943967)
Idiom: **Animated transition - tree detail**

- animated transition
  - network drilldown/rollup

[Collapsible Tree](https://bl.ocks.org/mbostock/4339083)
Idiom: **Animated transition - bar detail**

- example: hierarchical bar chart
  - add detail during transition to new level of detail

[Hierarchical Bar Chart](https://bl.ocks.org/mbostock/1283663)
Interactive transitions quiz: 4 Ways Budget

• what changed?

Interaction technology

• what do you design for?
  – mouse & keyboard on desktop?
    • large screens, hover, multiple clicks
  – touch interaction on mobile?
    • small screens, no hover, just tap
  – gestures from video / sensors?
    • ergonomic reality vs movie bombast
  – eye tracking?

slide inspired by: Alexander Lex, Utah

Data visualization and the news - Gregor Aisch (37 min)
vimeo.com/182590214

I Hate Tom Cruise - Alex Kauffmann (5 min)
www.youtube.com/watch?v=QXLfT9sFcbc
Selection

• selection: basic operation for most interaction

• design choices

  – how many selection types?
    • interaction modalities
      • click/tap (heavyweight) vs hover (lightweight but not available on most touchscreens)
      • multiple click types (shift-click, option-click, …)
      • proximity beyond click/hover (touching vs nearby vs distant)
    • application semantics
      – adding to selection set vs replacing selection
      – can selection be null?
        – ex: toggle so nothing selected if click on background
      – primary vs secondary (ex: source/target nodes in network)
      – group membership (add/delete items, name group, …)
Highlighting

• highlight: change visual encoding for selection targets
  – visual feedback closely tied to but separable from selection (interaction)

• design choices: typical visual channels
  – change item color
    • but hides existing color coding
  – add outline mark
  – change size (ex: increase outline mark linewidth)
  – change shape (ex: from solid to dashed line for link mark)

• unusual channels: motion
  – motion: usually avoid for single view
    • with multiple views, could justify to draw attention to other views
Tooltips

- popup information for selection
  - hover or click
  - can provide useful additional detail on demand
  - beware: does not support overview!
    - always consider if there’s a way to visually encode directly to provide overview
    - “If you make a rollover or tooltip, assume nobody will see it. If it’s important, make it explicit.”
      - Gregor Aisch, NYTimes
Rule of thumb: **Responsiveness is required**

- **visual feedback: three rough categories**
  - **0.1 seconds: perceptual processing**
    - subsecond response for mouseover highlighting - ballistic motion
  - **1 second: immediate response**
    - fast response after mouseclick, button press - Fitts’ Law limits on motor control
  - **10 seconds: brief tasks**
    - bounded response after dialog box - mental model of heavyweight operation (file load)
- **scalability considerations**
  - highlight selection without complete redraw of view (graphics frontbuffer)
  - show hourglass for multi-second operations (check for cancel/undo)
  - show progress bar for long operations (process in background thread)
  - rendering speed when item count is large (guaranteed frame rate)
Manipulate

- Change over Time
- Navigate
- Select

- Item Reduction
  - Zoom
    - Geometric or Semantic
  - Pan/Translate
  - Constrained
Navigate: Changing viewpoint/visibility

• change viewpoint
  – changes which items are visible within view

• camera metaphor
  – pan/translate/scroll
    • move up/down/sideways
Idiom: **Scrolllytelling**

- **how:** navigate page by scrolling (panning down)
- **pros:**
  - familiar & intuitive, from standard web browsing
  - linear (only up & down) vs possible overload of click-based interface choices
- **cons:**
  - full-screen mode may lack affordances
  - scrolljacking, no direct access
  - unexpected behaviour
  - continuous control for discrete steps

https://eagereyes.org/blog/2016/the-scrolllytelling-scourge

[How to Scroll, Bostock](https://bost.ocks.org/mike/scroll/)

*slide inspired by: Alexander Lex, Utah*
Scrollytelling examples


*slide inspired by: Alexander Lex, Utah*
Navigate: Changing viewpoint/visibility

• change viewpoint
  – changes which items are visible within view

• camera metaphor
  – pan/translate/scroll
    • move up/down/sideways
  – rotate/spin
    • typically in 3D
  – zoom in/out
    • enlarge/shrink world == move camera closer/further
    • geometric zoom: standard, like moving physical object
Navigate: Unconstrained vs constrained

• unconstrained navigation
  – easy to implement for designer
  – hard to control for user
    • easy to overshoot/undershoot
• constrained navigation
  – typically uses animated transitions
  – trajectory automatically computed based on selection
    • just click; selection ends up framed nicely in final viewport
Idiom: Animated transition + constrained navigation

• example: geographic map
  – simple zoom, only viewport changes, shapes preserved

[Zoom to Bounding Box](https://bl.ocks.org/mbostock/4699541)
Idiom: **Animated transition + constrained navigation**

- example: icicle plot
  - transition into containing mark causes aspect ratio (shape) change

[Zoomable Icicle](https://bl.ocks.org/mbostock/1005873)
Interaction benefits

• interaction pros
  – major advantage of computer-based vs paper-based visualization
  – flexible, powerful, intuitive
    • exploratory data analysis: change as you go during analysis process
    • fluid task switching: different visual encodings support different tasks
  – animated transitions provide excellent support
    • empirical evidence that animated transitions help people stay oriented
Interaction limitations

• interaction has a time cost
  – sometimes minor, sometimes significant
  – degenerates to human-powered search in worst case
• remembering previous state imposes cognitive load
• controls may take screen real estate
  – or invisible functionality may be difficult to discover (lack of affordances)
• users may not interact as planned by designer
  – NYTimes logs show ~90% don’t interact beyond scrollytelling - Aisch, 2016
Facet

- **Juxtapose**

- **Partition**

- **Superimpose**
Juxtapose and coordinate views

- Share Encoding: Same/Different
  - Linked Highlighting

- Share Data: All/Subset/None

- Share Navigation
Idiom: Linked highlighting

- see how regions contiguous in one view are distributed within another
  - powerful and pervasive interaction idiom

- encoding: different
  - multiform

- data: all shared

- aka: brushing and linking

Linked views

• unidirectional vs bidirectional linking

http://www.ralphstraumann.ch/projects/swiss-population-cartogram/
http://peterbeshai.com/linked-highlighting-react-d3-reflux/
Linked views: Multidirectional linking

http://buckets.peterbeshai.com/

https://medium.com/@pbesh/linked-highlighting-with-react-d3-js-and-reflux-16e9c0b2210b
Video: Visual Analysis of Historical Hotel Visitation Patterns

https://www.youtube.com/watch?v=Tzsv6wkZoiQ
http://www.cs.ou.edu/~weaver/improvise/examples/hotels/
Complex linked multiform views

System: Pathfinder

https://www.youtube.com/watch?v=aZF7AC8aNXo
**Idiom: Overview-detail views**

- **encoding**: same
- **data**: subset shared
- **navigation**: shared
  - bidirectional linking

- **differences**
  - viewpoint
  - (size)

- **special case**: *birds-eye map*

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**System: Google Maps**

Idiom: **Overview-detail navigation**

- encoding: same
- data: subset shared
- navigation: shared
  - unidirectional linking
  - select in small overview
  - change extent in large detail view

https://www.highcharts.com/demo/dynamic-master-detail

https://bl.ocks.org/mbostock/34f08d5e11952a80609169b7917d4172
Overview-detail

- multiscale: three viewing levels
  - linked views
  - dynamic filtering
  - tooling: processing
    (modern version: p5js.org)

System: MizBee

https://www.youtube.com/watch?v=86p7brwuzu2g
https://www.youtube.com/watch?v=UcKDbGqHsdE
Flows: R/Shiny

https://gallery.shinyapps.io/TSupplyDemand/
Idiom: **Parallel sets**

[Diagram showing parallel sets with categories for survived and perished, sex, age, and class.]
Idiom: Mosaic plots

http://www.theusrus.de/blog/understanding-mosaic-plots/

http://www.theusrus.de/Mondrian/

http://www.theusrus.de/blog/making-movies/
Idiom: **Small multiples**

- **encoding:** same
- **data:** none shared
  - different attributes for node colors
  - (same network layout)
- **navigation:** shared

System: **Cerebral**

### Coordinate views: Design choice interaction

<table>
<thead>
<tr>
<th>Encoding</th>
<th>Data</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>All</td>
<td>Subset</td>
</tr>
<tr>
<td>Same</td>
<td>Redundant</td>
<td><img src="image1.png" alt="Overview/Detail" /></td>
<td><img src="image2.png" alt="Overview/Detail" /></td>
</tr>
<tr>
<td>Different</td>
<td>Multiform</td>
<td><img src="image4.png" alt="Multiform, Overview/Detail" /></td>
<td><img src="image5.png" alt="Multiform, Overview/Detail" /></td>
</tr>
</tbody>
</table>

- **why juxtapose views?**
  - benefits: eyes vs memory
    - lower cognitive load to move eyes between 2 views than remembering previous state with single changing view
  - costs: display area, 2 views side by side each have only half the area of one view
Why not animation?

• disparate frames and regions: comparison difficult
  – vs contiguous frames
  – vs small region
  – vs coherent motion of group

• safe special case
  – animated transitions
System: **Improvise**

- investigate power of multiple views
  - pushing limits on view count, interaction complexity
  - how many is ok?
    - open research question
- reorderable lists
  - easy lookup
  - useful when linked to other encodings

Quiz: Multiple views

• gerrymandering

<table>
<thead>
<tr>
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<th>All</th>
<th>Subset</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same</td>
<td>Redundant</td>
<td>Overview/Detail</td>
<td>Small Multiples</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Different</td>
<td>Multiform</td>
<td>Multiform, Overview/Detail</td>
<td>No Linkage</td>
<td></td>
</tr>
</tbody>
</table>

**Quiz: Multiple views**

- **terrain**

   ![Image of Antarctic Terrain](https://earthobservatory.nasa.gov/images/144367/taking-measure-of-antarctic-terrain)

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Same</td>
<td>All: Redundant</td>
</tr>
<tr>
<td></td>
<td>Subset: Overview/Detail</td>
</tr>
<tr>
<td></td>
<td>None: Small Multiples</td>
</tr>
<tr>
<td>Different</td>
<td>All: Multiform</td>
</tr>
<tr>
<td></td>
<td>Subset: Multiform, Overview/Detail</td>
</tr>
<tr>
<td></td>
<td>None: No Linkage</td>
</tr>
</tbody>
</table>

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Relative Elevation (m)

October 26 - November 23, 2018
Quiz: Multiple views

• where the wild things glow

Facet

- Juxtapose

- Partition

- Superimpose
Partition into views

• how to divide data between views
  – split into regions by attributes
  – encodes association between items using spatial proximity
  – order of splits has major implications for what patterns are visible

Partition into Side-by-Side Views

Superimpose Layers
Juxtapose and Coordinate Multiple Side-by-Side Views
Share Data: All/Subset/None
Sharing: All/Subset
Multiple, Over view/Detail
None
Redundant
No Linkage
Small Multiples
Over view/Detail
Linked Highlighting
Partitioning: List alignment

• single bar chart with grouped bars
  – split by state into regions
    • complex glyph within each region showing all ages
  – compare: easy within state, hard across ages

• small-multiple bar charts
  – split by age into regions
    • one chart per region
  – compare: easy within age, harder across states
Partitioning: Recursive subdivision

- split by neighborhood
- then by type
- then time
  - years as rows
  - months as columns
- color by price
- neighborhood patterns
  - where it’s expensive
  - where you pay much more for detached type

Partitioning: Recursive subdivision

- switch order of splits
  - type then neighborhood

- switch color
  - by price variation

- type patterns
  - within specific type, which neighborhoods inconsistent

Partitioning: Recursive subdivision

- different encoding for second-level regions
  – choropleth maps

System: HIVE

Partitioning: Recursive subdivision

- size regions by sale counts
  - not uniformly
- result: treemap

Superimpose layers

• **layer**: set of objects spread out over region
  – each set is visually distinguishable group
  – extent: whole view

• design choices
  – how many layers, how to distinguish?
    • encode with different, nonoverlapping channels
    • two layers achievable, three with careful design
  – small static set, or dynamic from many possible?
Static visual layering

• foreground layer: roads
  – hue, size distinguishing main from minor
  – high luminance contrast from background
• background layer: regions
  – desaturated colors for water, parks, land areas
• user can selectively focus attention
• “get it right in black and white”
  – check luminance contrast with greyscale view

Superimposing limits

• few layers, but many lines
  – up to a few dozen
  – but not hundreds

• superimpose vs juxtapose: empirical study
  – superimposed for local, multiple for global
  – tasks
    • local: maximum, global: slope, discrimination
  – same screen space for all multiples vs single superimposed

Idiom: **Trellis plots**

- superimpose within same frame
  - color code by year

- partitioning
  - split by site, rows are wheat varieties

- main-effects ordering
  - derive value of median for group, use to order
  - order rows within view by variety median
  - order views themselves by site median
Dynamic visual layering

• interactive based on selection
• one-hop neighbour highlighting demos: click vs hover (lightweight)

Partition into views

- how to divide data between views
  - split into regions by attributes
  - encodes association between items using spatial proximity
  - order of splits has major implications for what patterns are visible

- no strict dividing line
  - **view**: big/detailed
    - contiguous region in which visually encoded data is shown on the display
  - **glyph**: small/iconic
    - object with internal structure that arises from multiple marks
**How?**

**Encode**

- **Arrange**
  - Express
  - Separate
- **Order**
  - Align
- **Use**
  - Map
    - from **categorical** and **ordered** attributes
    - Color
      - Hue
      - Saturation
      - Luminance
    - Size, Angle, Curvature, ...
    - Shape
      - + • □ △
    - Motion
      - Direction, Rate, Frequency, ...

**Manipulate**

- **Change**

**Facet**

- **Juxtapose**

**Reduce**

- **Filter**
- **Aggregate**
- **Embed**
Credits

• Visualization Analysis and Design (Ch 11, 12)
• Alex Lex & Miriah Meyer, http://dataviscourse.net/
• Effectiveness of Animation in Trend Visualization.
  George Robertson, Roland Fernandez, Danyel Fisher, Bongshin Lee, and John Stasko.
  https://www.cc.gatech.edu/~stasko/papers/infovis08-anim.pdf