Visualization for Data Science
Discourse with Data III
Interaction

Adminstrivia

Lecture Flow

- Technical: We've spent roughly half of the class time on tooling, this will shift. There will be some tutorials, but we expect most of your programming learning to come outside of class.
- Theory: We will start spending more time on the WHY of info. Viz so expect to sometimes being required to have assigned readings before class.

Lab this week

- Drop in office hours, TAs will be in the room to support your learning. You are not REQUIRED to attend. I strongly suggest you use this time to work with your groups on PD2.

Final Exam is set by the University

- December 10th at 3:30pm in CBTF for most students
- CFA

  For those who typically write with CBTF, you have received a Ed Chat message from me. Please respond.

Project Updates

PM2 due October 31st at 6pm. Now moved to **November 7th at 6pm.**

- EDA analysis
  - One for each member of the team. Jupyter Notebook
  - In your report state what each person EDA covers, this falls under general

Team Member	Numerical Attributes	Temporal Attributes	Ordinal Attributes	Nominal	Type of Analysis
Frodo Baggins	(2) Cost, Emotion,	Age of Middle Earth	Feet size		Univariate on all mentioned. Bivariate on (feet size and cost)
Gandalf	(1) Length of beard,	Age of Universe		(2) Color of beard, Weapons	

  - Then for each person in your report you should include summaries of what you learned from your EDA. Feel free to include figures from your jupyter notebook. Note that we don't expect code in your report.
- INQUIRY FCOUS
  - Theme, questions, and analytic tasks – SEE UPDATED MILESTONE 2

Tooling/Technical:

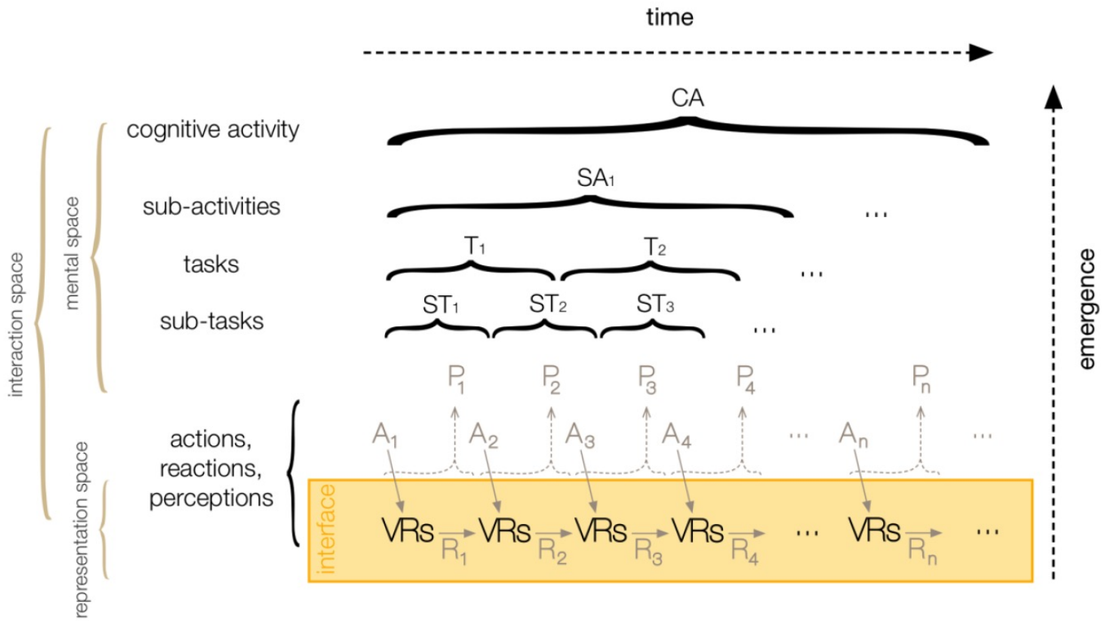
Tutorial 9 is you on your own ooooo

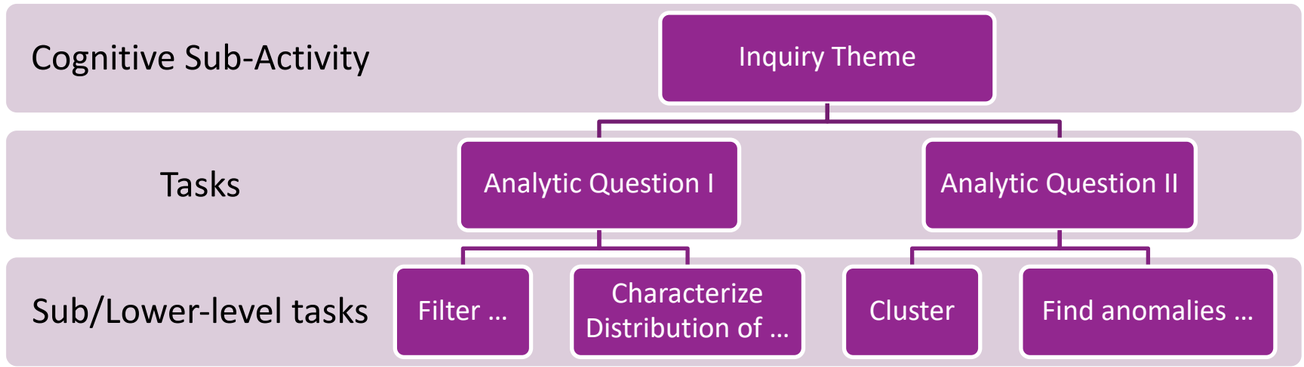
- Read through https://altair-viz.github.io/user_guide/interactions/index.html and it's subpages
  - Parameters, (this was the focus of Lecture 9B)
  - Conditions & Filters
  - Bindings & Widgets
  - Expressions
- Take 3 Altair intearctive vizzes and re-implement the interaction using your own data. Here are some suggestions.

Tutorial 10 (Maps) and Tutorial 11 (Color) have been posted

- Work through them and complete the associated exercises.

The Hierarchical Structure of a Complex Cognitive Activity





Sedig & Parsons

How to handle complexity

→ *Derive*

- derive new data to show within view
- change view over time
- facet across multiple views
- reduce items/attributes within single view

Manipulate

Change

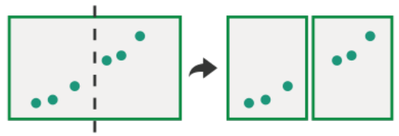
Select

Navigate

Facet

Juxtapose

Partition

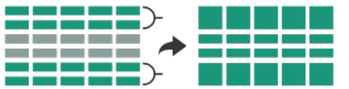


Superimpose

Reduce

Filter

Aggregate



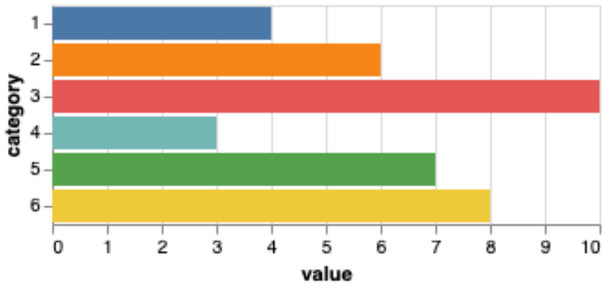
Embed

Learning Outcomes

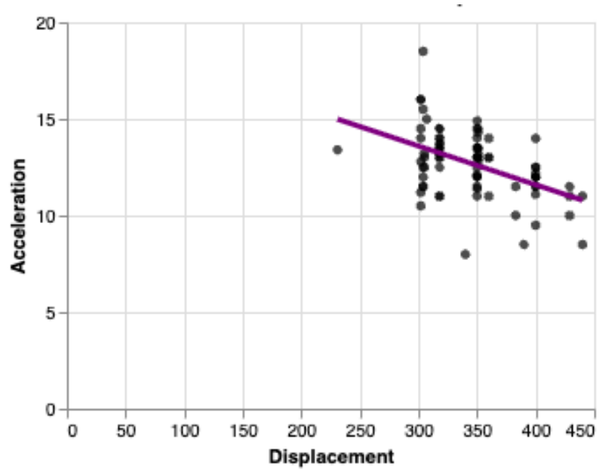
- Describe how interaction can be used for changing data representation, transformation, and communication.
- Describe various interaction techniques and select the technique most appropriate for a given problem.
- Discuss the role of interaction in visualizations and its strength and limitations in data science
- Evaluate the effectiveness of an interaction technique based on the human-computer interaction (HCI) principle of affordances.
- Identify situations where coordinated views would be effective.
- Critique existing visualizations and suggest improvements and refinements.

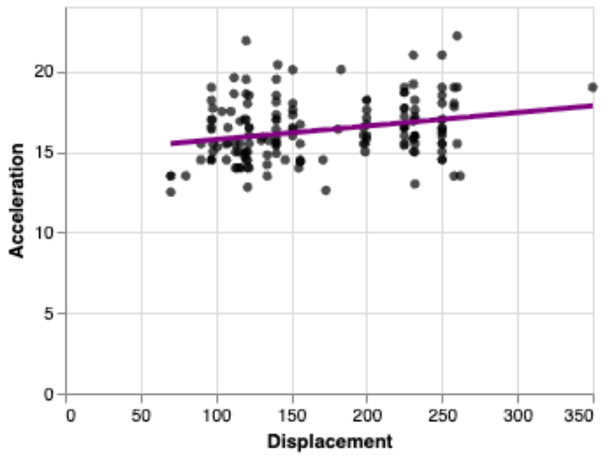
Manipulate by changing

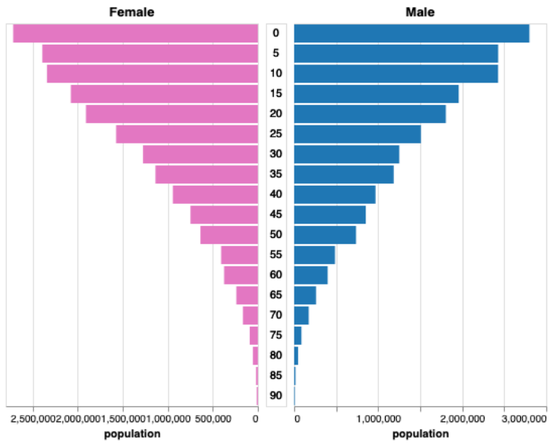
The visual encoding

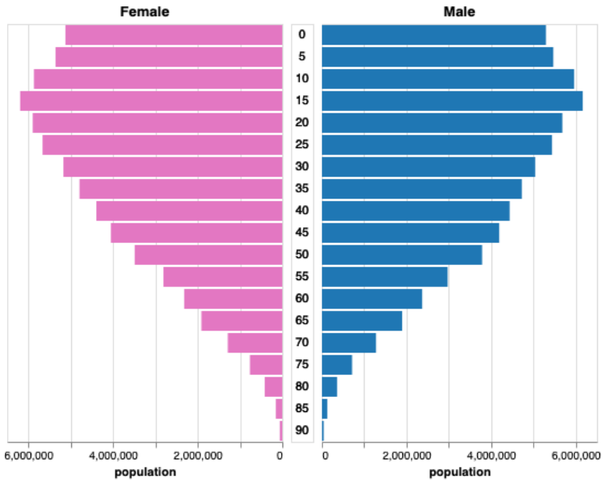


The data



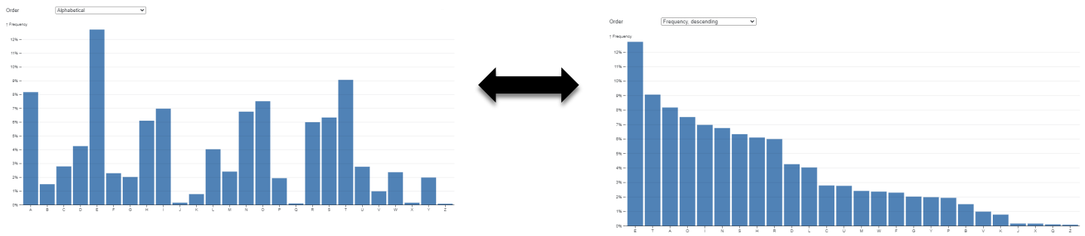


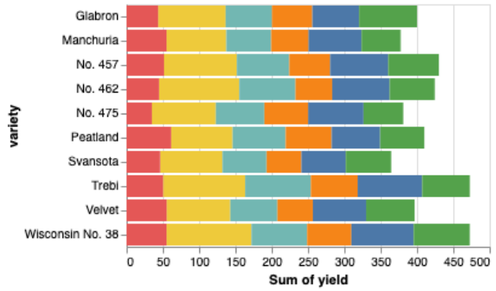


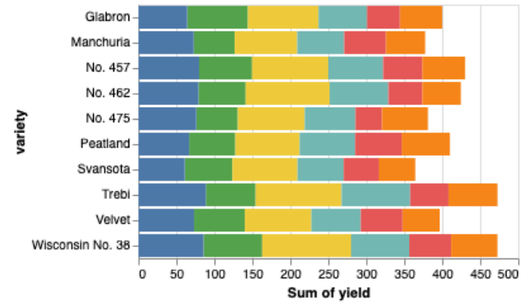


Manipulate by changing

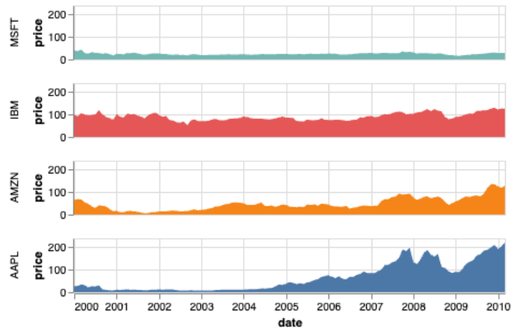
The order

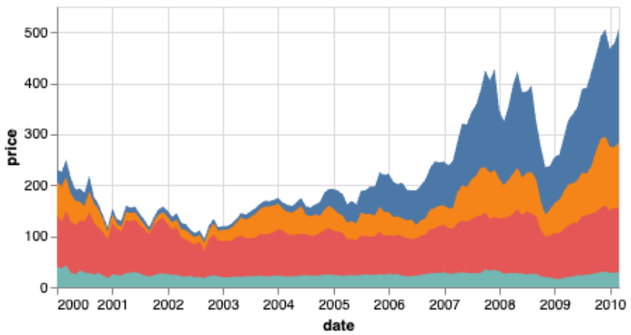


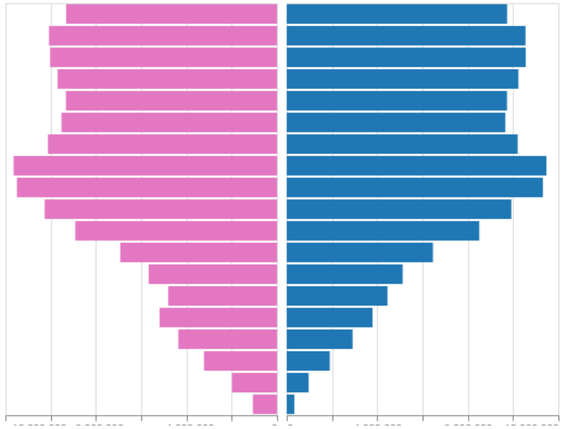


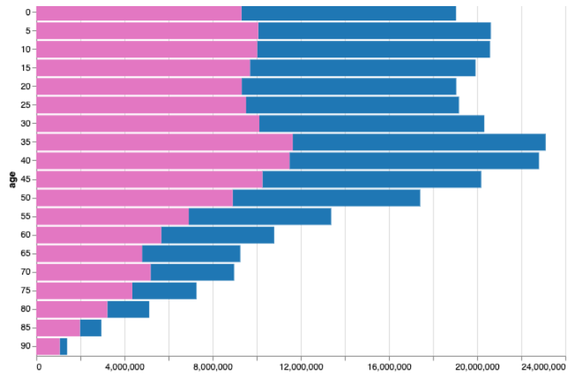


The alignment









Manipulate by changing the viewpoint/visibility

- change viewpoint
  - changes which items are visible within view
- camera metaphor
  - pan/translate/scroll
    - move up/down/sideways

Scrollytelling

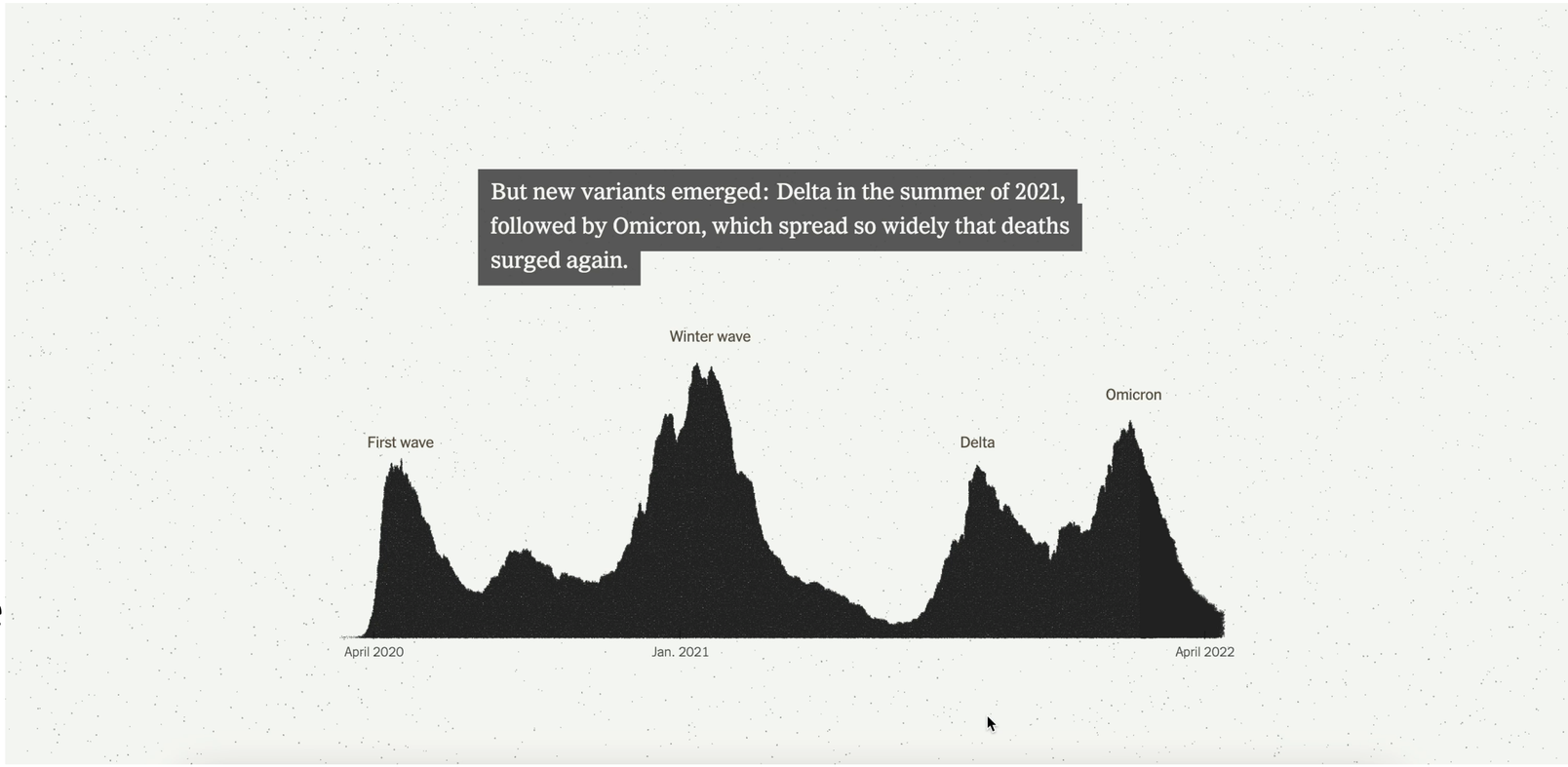
how: navigate page by scrolling (panning down)

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://www.nytimes.com/interactive/2014/06/20/sports/worldcup/how-world-cup-players-are-connected.html

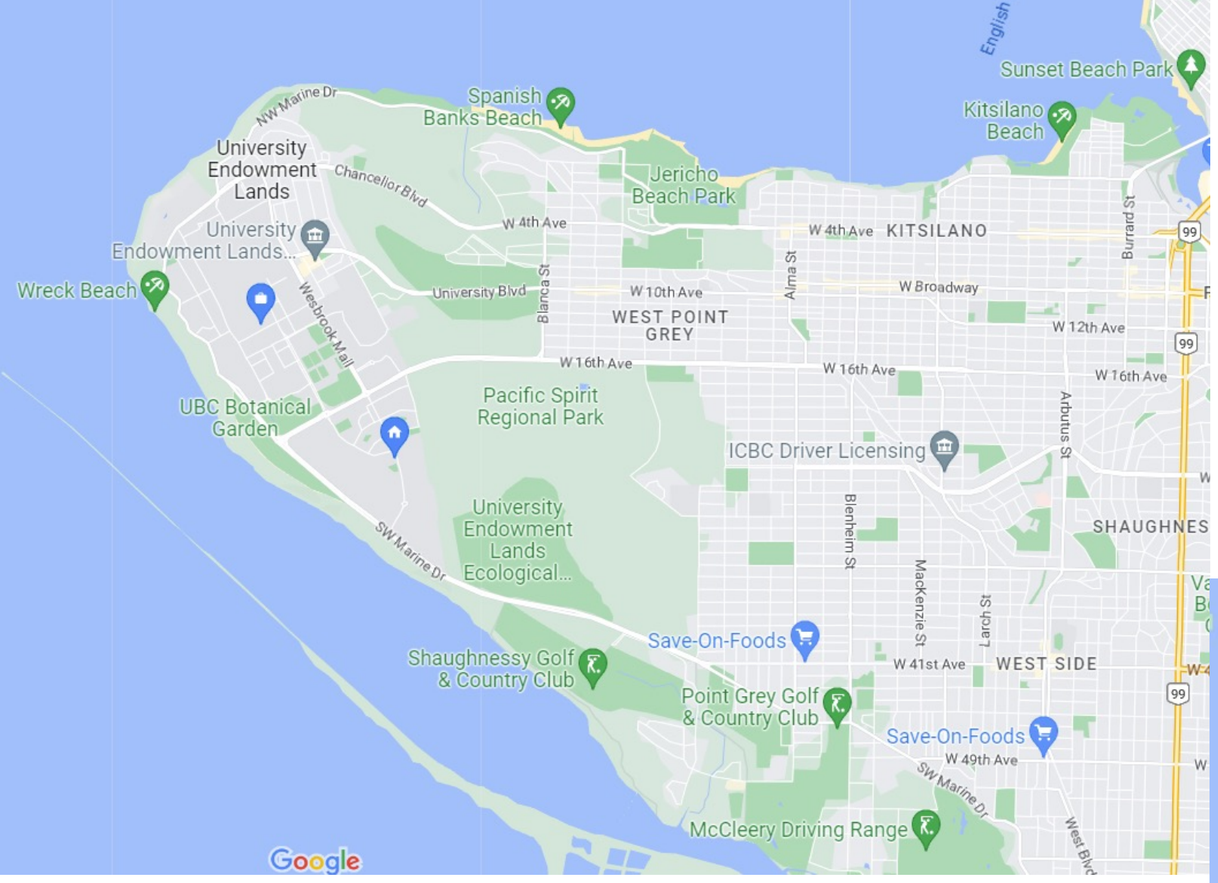
https://www.bloomberg.com/graphics/2015-auto-sales/

https://www.nbcnews.com/specials/detroit-segregation-wall/

https://nikkei.shorthandstories.com/road-to-nowhere-china-s-belt-and-road-initiative/

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


Sunset Beach Park
Spanish Banks Beach
Kitsilano Beach
NW Marine Dr
University Endowment Lands
Chancellor Blvd
Jericho Beach Park
W 4th Ave
KITSILANO
University Endowment Lands...
Wreck Beach
Alma St
Burrard St
University Blvd
W 10th Ave
W Broadway
WEST POINT GREY
Blanca St
Westbrook Mall
W 12th Ave
W 16th Ave
Pacific Spirit Regional Park
UBC Botanical Garden
ICBC Driver Licensing
Arbutus St
SHAUGHNES
University Endowment Lands Ecological...
SW Marine Dr
Blenheim St
Mackenzie St
Larch St
Save-On-Foods
Shaughnessy Golf & Country Club
W 41st Ave
WEST SIDE
Point Grey Golf & Country Club
Save-On-Foods
W 49th Ave
SW Marine Dr
McCleery Driving Range
West Blvd
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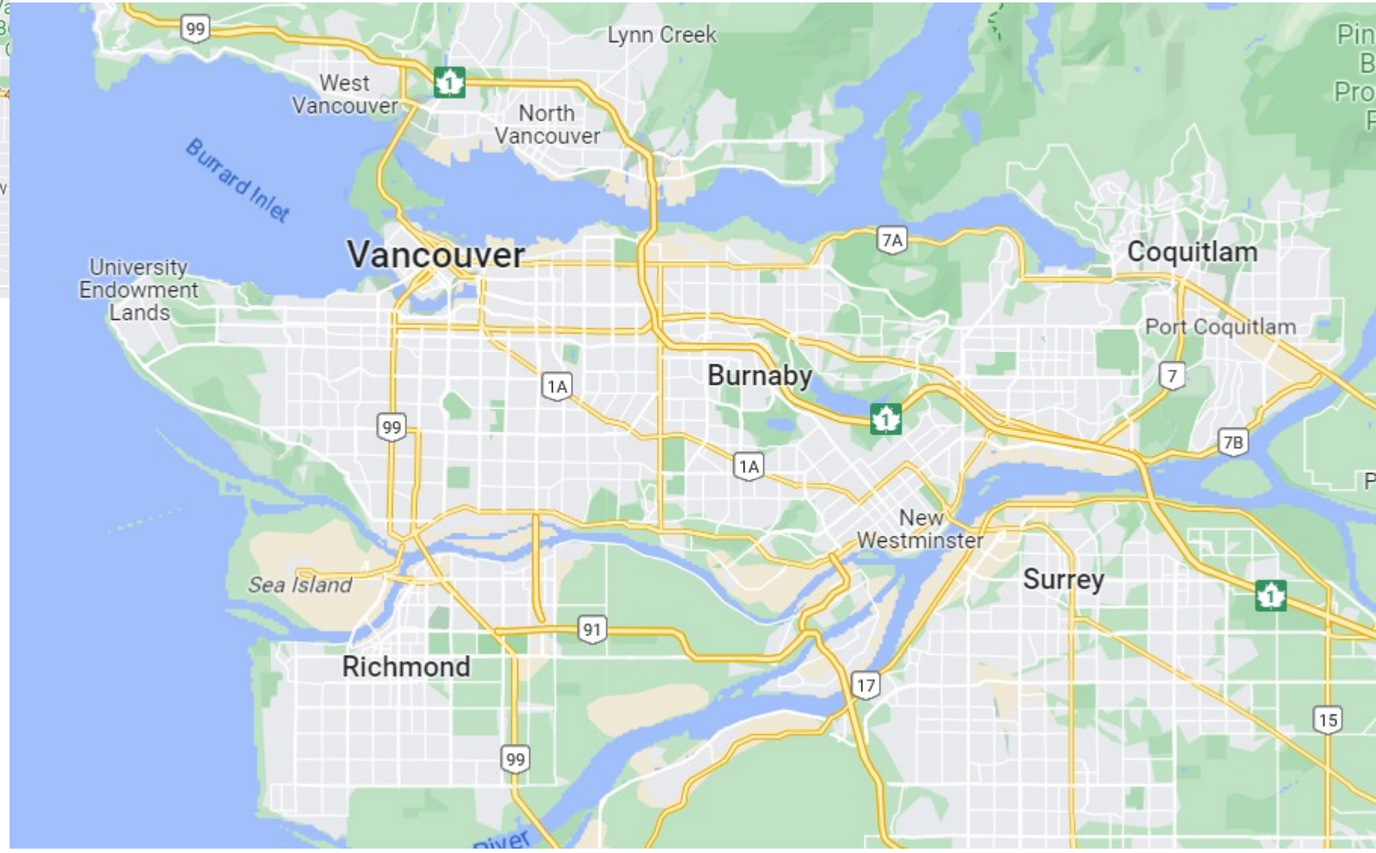
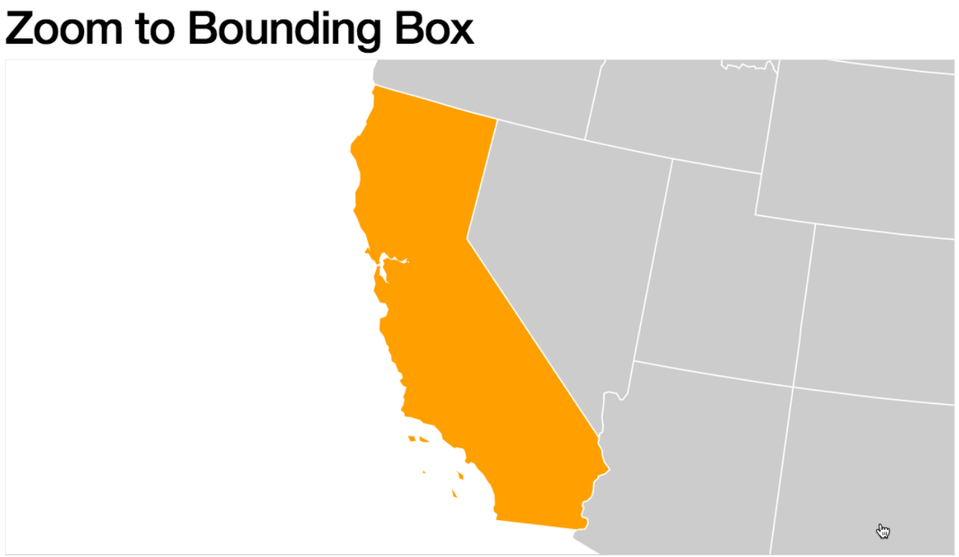

99
Lynn Creek
West Vancouver
North Vancouver
Burrard Inlet
Vancouver
University Endowment Lands
7A
Coquitlam
Port Coquitlam
Burnaby
1A
7
99
7B
New Westminster
Sea Island
Surrey
91
Richmond
17
15
99

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

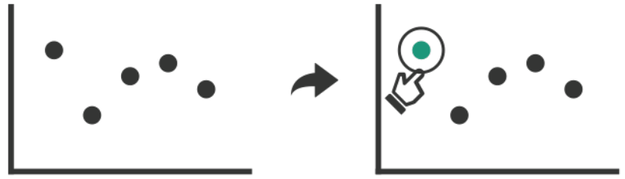
Idiom: **Animated transition + constrained navigation**

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



https://observablehq.com/@d3/zoom-to-bounding-box

Selection



Atomic Interactions (Direct Manipulation)

Single, indivisible user actions that directly target visual elements. Each occurs as one discrete event—click, hover, key press, scroll. The user directly manipulates marks in the visualization with immediate response. These are the building blocks of all interaction.

Composite Interactions (Direct Manipulation)

Multi-step gestures built from sequences of atomic actions. Examples: drag (mousedown → mousemove → mouseup), brush (click + drag to select region). Still direct manipulation, but unfolds over time as a coordinated sequence. The system tracks state across events to understand intent.

Input Bindings (Indirect Manipulation)

External UI controls that set visualization parameters. Sliders, dropdowns, radio buttons, checkboxes sit outside the main view and control *what* or *how* data displays. User manipulates the control → visualization updates. Trades immediacy for precision and exploration of parameter spaces.

Selection – Action Type & Category

Direct Manipulation – Atomic	Direct Manipulation – Composite	Indirect Manipulation
Click/Touch/Tap	Drag	Sliders
Hover	Brush/Interval Selection	Dropdowns
Scroll/Wheel	Zoom	Radio buttons
Proximity (rare)	Multi-Selection (modifier + click)	Checkboxes
Double-click	Pan	Text inputs
Key Press	Pinch	

Selection – Action's Semantics

Semantic	Description
Null/Empty	Selection set is empty: nothing is selected. Initial state or after clearing selection. Note that for hover the default in Altair is NOT empty
Single (Replace)	Selecting an item replaces previous selection; max one item at a time.
Toggle	Clicking same item switches between selected/deselected
Multiple (Add)	Items accumulate in selection set; often Shift+Click or Ctrl+Click
Remove	Deselect specific items from an existing selection
Clear/Reset	Remove all items from selection set
Interval	Multiple items selected based on contiguous region

Highlight

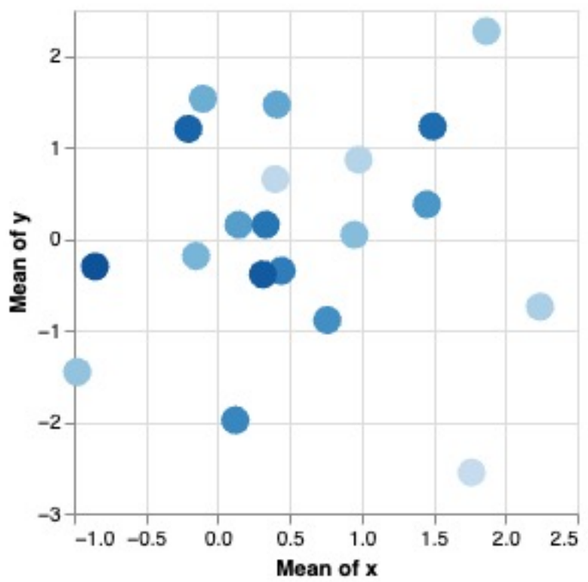
Technique	Description
Color	Change to a distinct highlight color. Very salient with immediate popout effect, but hides existing color encoding.
Opacity	Make selected opaque and others transparent (or inverse). Doesn't interfere with other channels but can reduce readability.
Outline/ Stroke	Add outline or change stroke color. Preserves existing color encoding but not effective for small marks.
Stroke Width	Thicker borders or line width. Works well for lines and preserves color, but can cause overlap issues.
Size	Increase mark size. Very noticeable but can cause occlusion and change spatial layout.
Shape	Change mark shape (e.g., solid → dashed line). Preserves other channels but has limited shape options.
Connection Lines	Draw lines between selected items. Shows relationships explicitly but adds visual clutter.
Drill	Additional Details on Demand

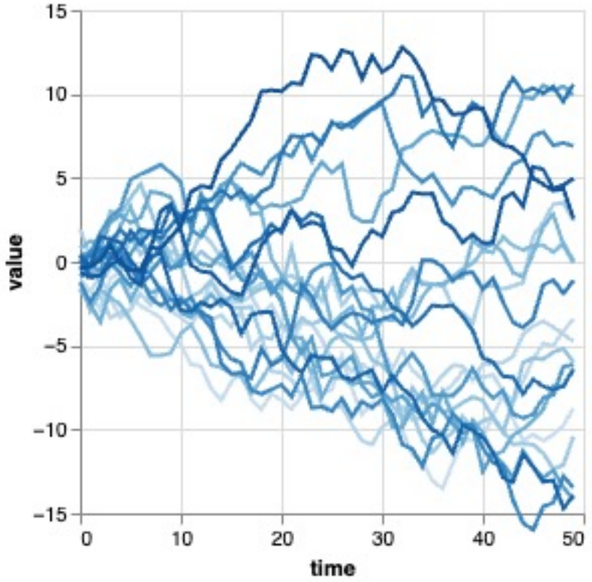
Highlight Considerations

- **Popout Effect:** Need sufficient contrast (hue, luminance, or saturation) for visual popout. Highlight should be immediately distinguishable.
- **Preservation vs. Replacement:** Color change replaces existing encoding (destructive); outline, stroke width, and opacity preserve original encoding (preservative).
- **Combining Techniques:** Multiple channels can be combined for stronger effect (e.g., strokeWidth + color for links). Be careful not to overwhelm.
- **Context Matters:** Small marks work better with size/color than outlines. Large marks work well with outlines. Lines work well with stroke width, dash pattern, color. Many items benefit from opacity or desaturation of non-selected.

Deconstruct the Interactions

- Selection (action type + semantics)
  -
- Highlight (effect of change on vis)



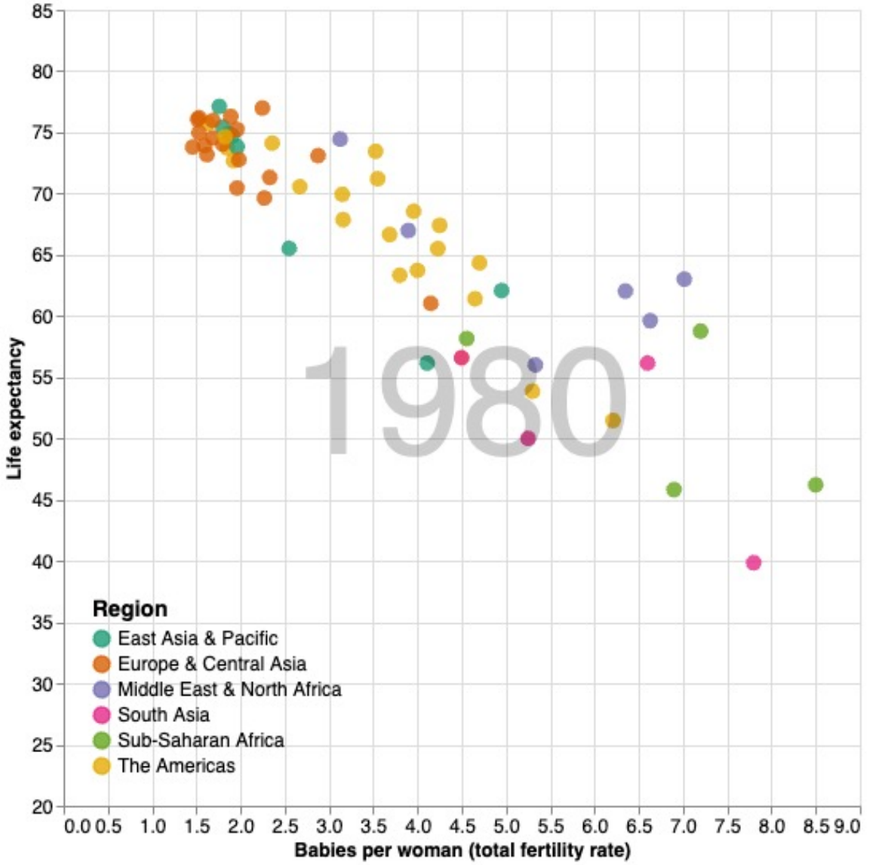


https://altair-viz.github.io/gallery/select_detail.html

Exercise: Deconstruct the Interactions

- Selection (action type + semantics)
  –

- Highlight (effect of change on vis)

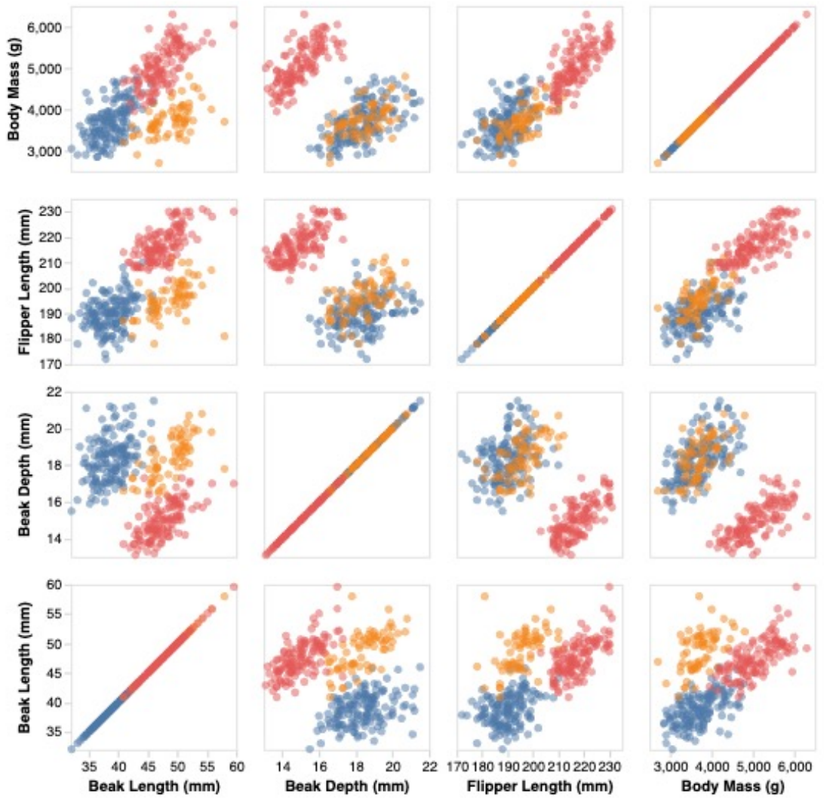


https://altair-viz.github.io/gallery/scatter_point_paths_hover.html

Exercise: Deconstruct the Interactions

- Selection (action type + semantics)
  - –

- Highlight (effect of change on vis)



https://vega.github.io/vega/examples/brushing-scatter-plots/

Interaction benefits

- 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
- be active participants in the analysis of data,
- adjust features of the tool to suit the user's needs,
- visualization of large amounts of data,
- extend/amplifies users' sensemaking abilities,
- increase engagement (vis becomes personal to user),

Interaction limitations

- Requires human time and attention
- Increases perceptual and exploration costs
- Limited performance gains
  - studies find no increase in performance (Moscaet al., 2021)
  - users may not interact as planned by designer
    - NYTimes logs show ~90% don’t interact beyond scrollytelling - Aisch, 2016
- 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)

Weigh the tradeoffs when designing!

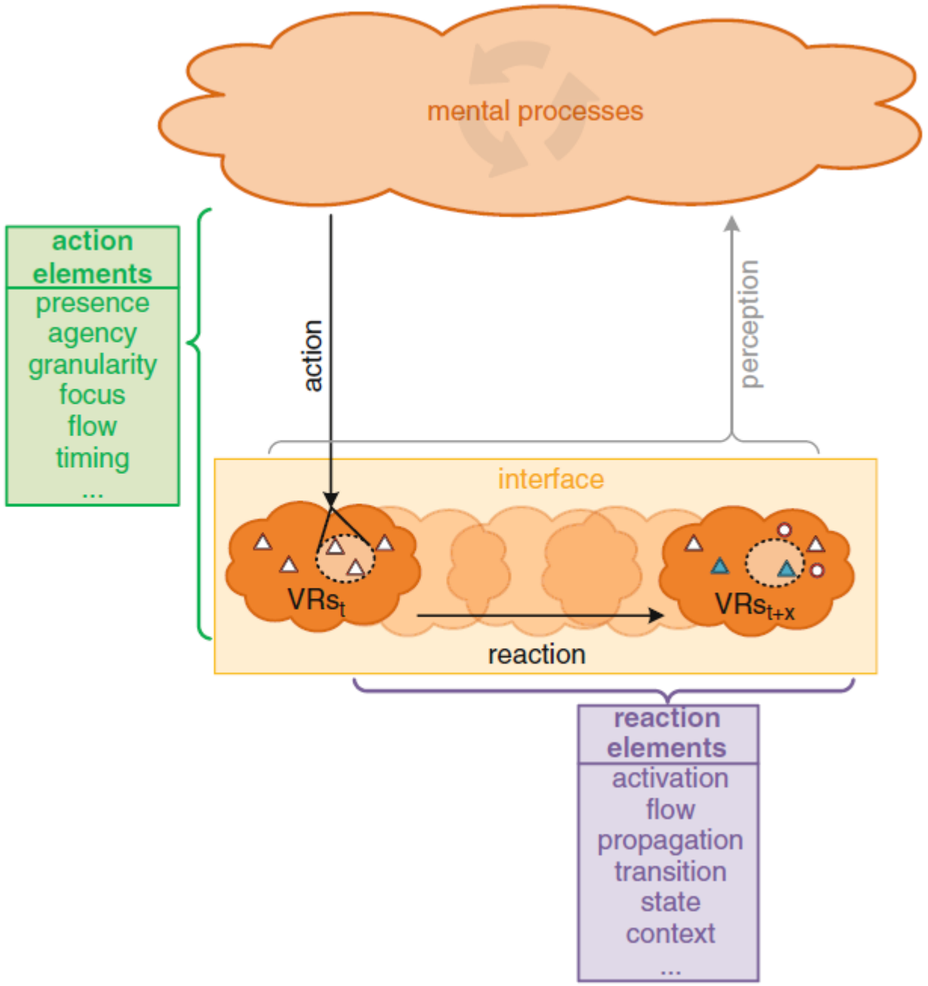
Benefits

Costs

Eyes beat memory

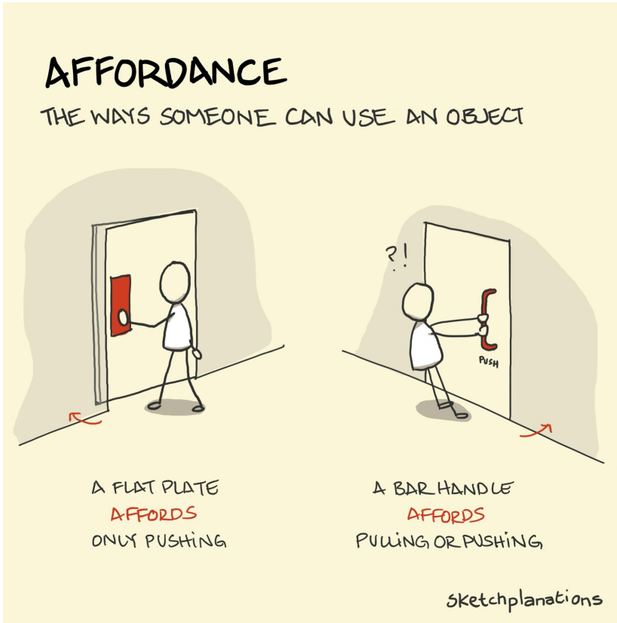
- principle: external cognition vs. internal memory
  - easy to compare by moving eyes between side-by-side views
  - harder to compare visible item to memory of what you saw
- implications for animation
  - great for choreographed storytelling
  - great for transitions between two states
  - poor for many states with changes everywhere
    - consider small multiples instead

Human-Computer Interaction Considerations

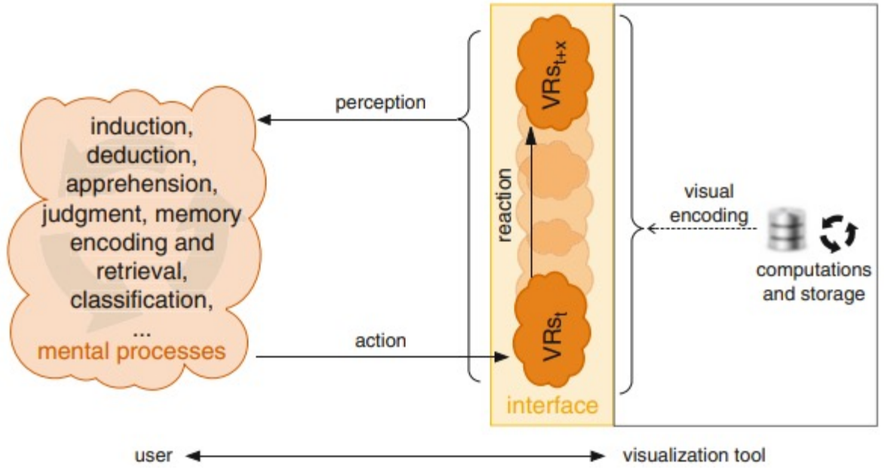


– Action – the action/event the user engages in
– Reaction - the effects of an action that are visually perceptible at the interface

HCI Principle of Affordance
The relationship between what something looks like and how it should be used.

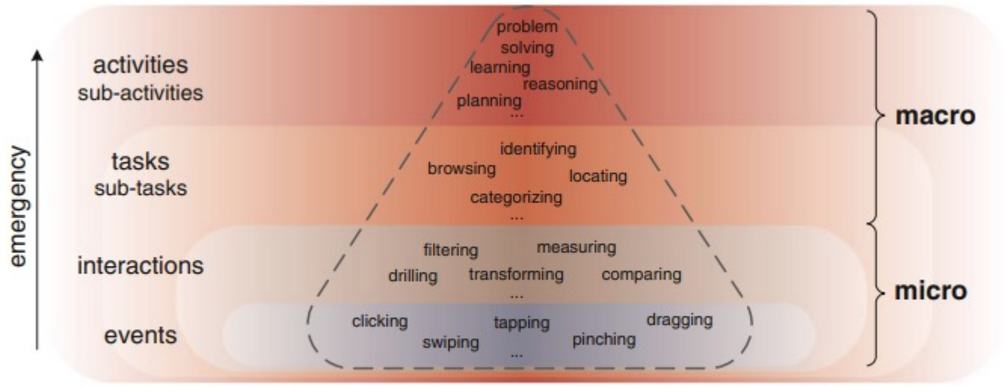


Interactivity: The quality of interaction



Interaction emerges from lower-level events

Interaction – is comprised of action, reaction and perception



Interactivity is dependent upon a series of elements relating to action, reaction and the user's perception.

Sedig et. al

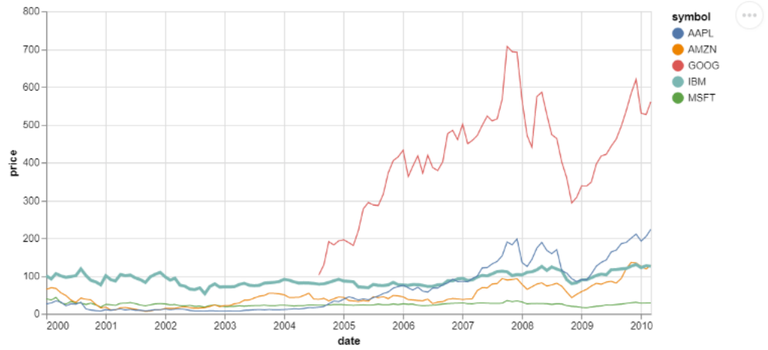
Interactivity: Action - Focus

The focal point of an action

- Direct focus of an action is expressed by the user directly acting upon the visual representation
- Indirect the action is expressed by the user operating on other intermediary interface representations in order to communicate with and cause a change in the visual representation of interest

Multi-Line Highlight

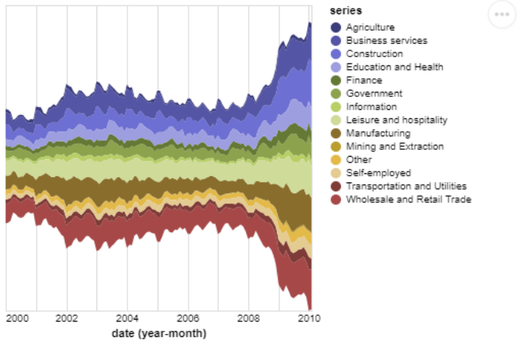
This multi-line chart uses an invisible Voronoi tessellation to handle mouseover to identify the nearest point and then highlight the line on which the point falls. It is adapted from the Vega-Lite example found at https://bl.ocks.org/amitkaps/fe4238e716db53930b2f1a70d3401701



https://altair-viz.github.io/gallery/multiline_highlight.html

Interactive Legend

The following shows how to create a chart with an interactive legend, by binding the selection to `"legend"`. Such a binding only works with `selection_point` when projected over a single field or encoding.



https://altair-viz.github.io/gallery/interactive_legend.html

Sedig et. al

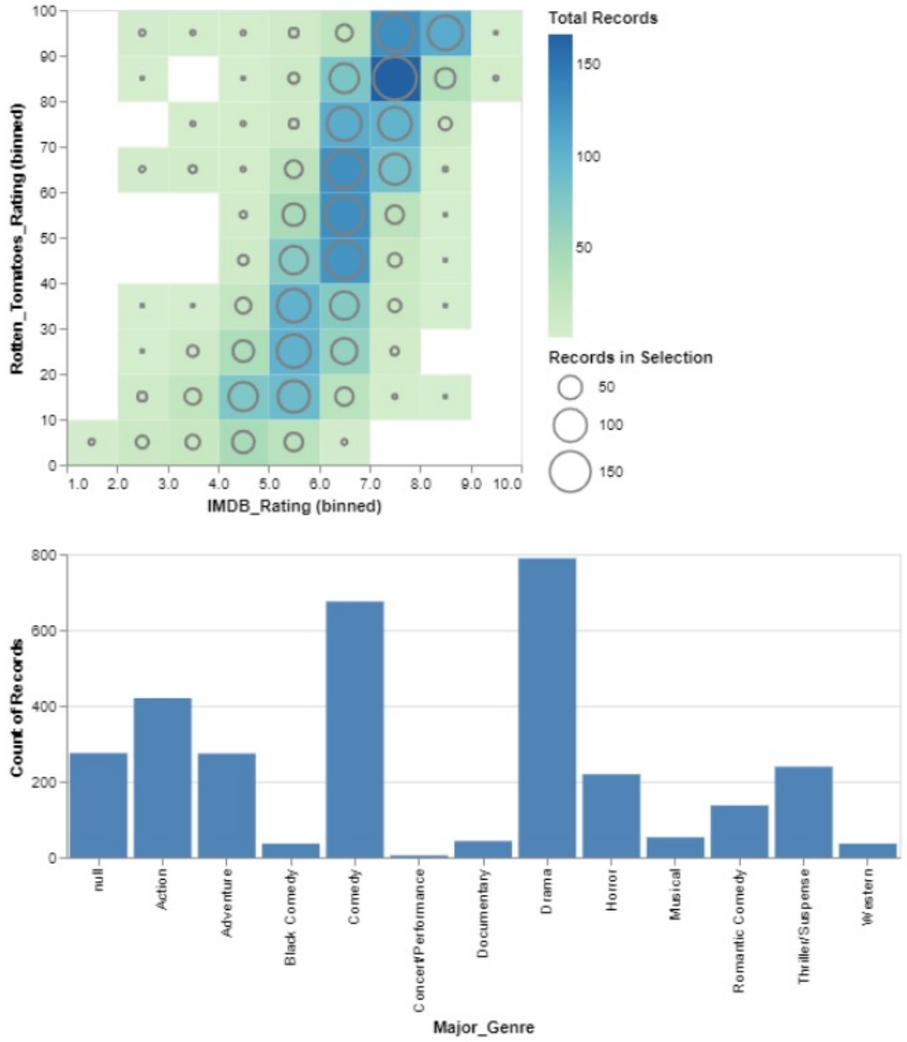
Interactivity: Action - Presence

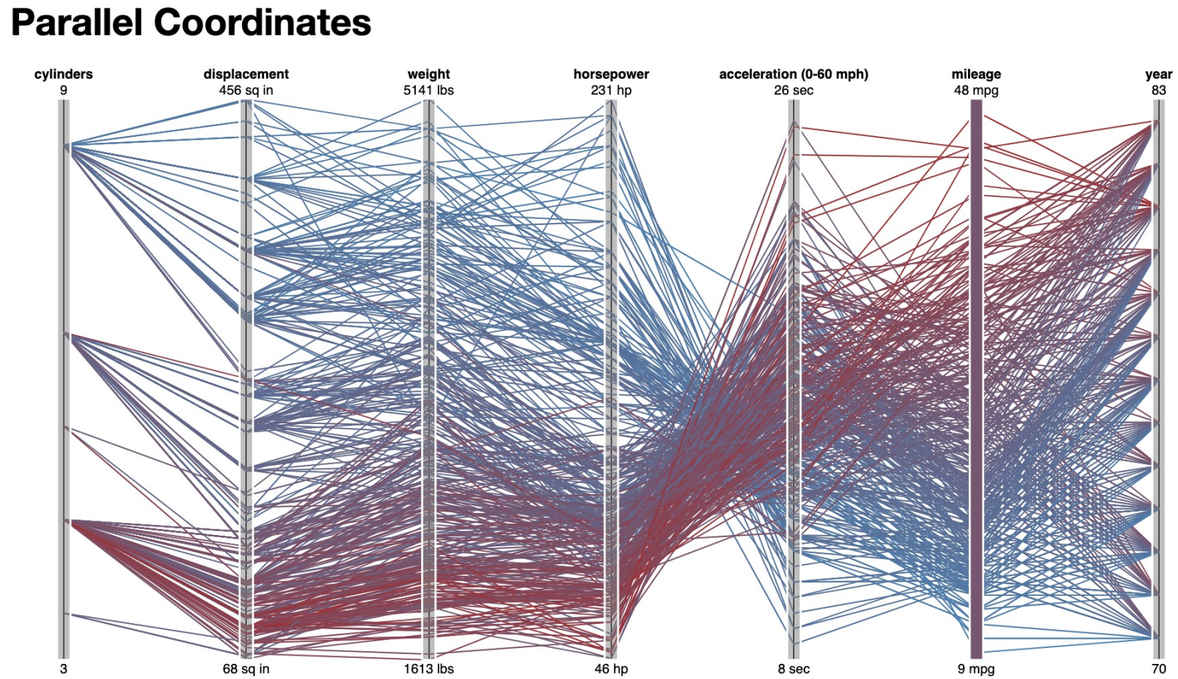
The advertisement of an action. So is there a clear signal from the visualization that let's us know we should interact with it in a certain way?

- Explicit: the availability, existence, or provision of the interaction is clearly advertised by the tool. For example when a label or tool tip is used to let the user know that the interaction exists.
- Implicit: the action's availability is either not easily perceptible by the user, or it is not visible at the interface level. This ties in to the user's expectation of what should happen (e.g. hover, click)

Sedig et. al

Implicit Presence vs Explicit Presence





https://altair-viz.github.io/gallery/interactive_cross_highlight.html

https://mbostock.github.io/protovis/ex/cars.html

Interactivity: Reaction - Activation

The point at which the reaction begins.

- Immediate – the vis reacts to the user's action instantaneously.
- Delayed - there is a delay between the user's action and the reaction.
- On-demand - the reaction does not take place until requested by the user.

Sedig et. al

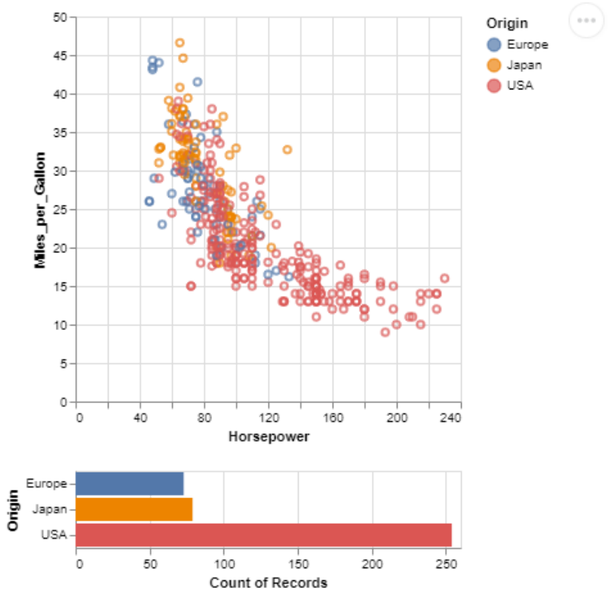
Rule of thumb: **Responsiveness is required**

- *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)

Interactivity: Reaction - Spread

the effect that an action causes. Is it contained to one viz, or does it impact other visualizations

- Self-contained form - the viz of interest is the only viz that is affected by the action.
- Propagated form - the effect of the action propagates to other viz in the interface.



https://altair-viz.github.io/gallery/selection_histogram.html

Interaction Exploration

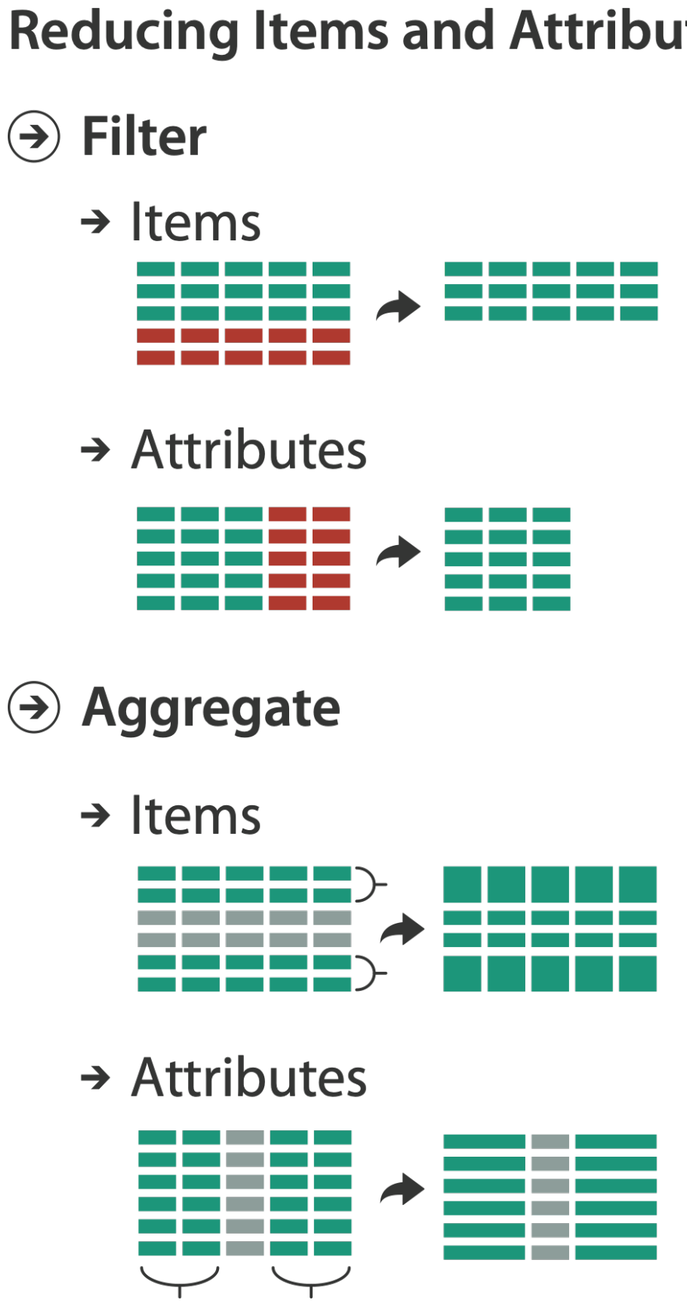
Characterize and critique the viz based on the concepts you have been exposed to this term. Notice the focus is solely on interaction and NOT have the data is visualized.

1. Life Expectancy
2. Global Oil Production and Consumption
3. Obama 2013 Spending
4. Homelessness – The Guardian
5. Gender Pay Gap
6. Demographics of Others

Action event and semantics : click, hover, drag, etc
Reaction type – highlight, change over time (data, encoding, arrangement, alignment)
Views – juxtapose, partition, superimpose
Views data – share encoding, share data, share navigation
Interactivity – Action Elements (Focus, Presence)
Interactivity – Reaction Elements (Spread, Activation)

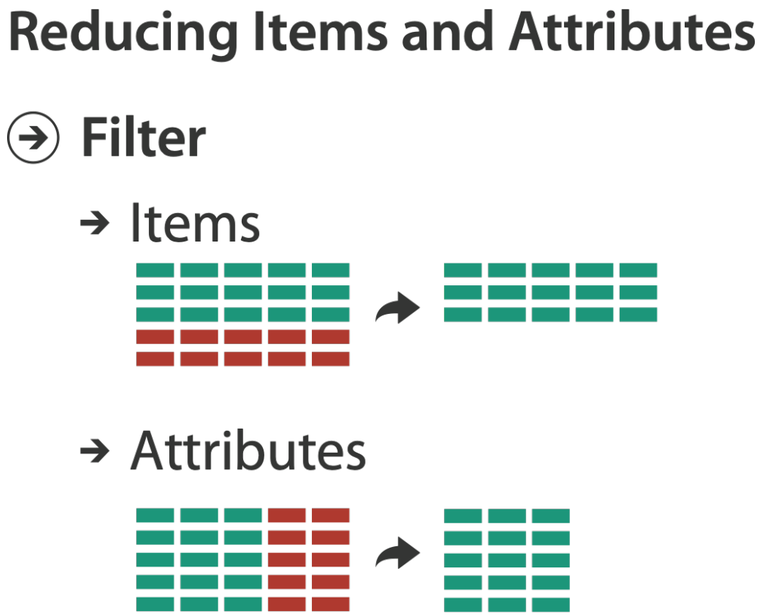
Reduce items and attributes

- reduce/increase: inverses
- filter
  - pro: straightforward and intuitive
    - to understand and compute
  - con: out of sight, out of mind
- aggregation
  - pro: inform about whole set
  - con: difficult to avoid losing signal
- not mutually exclusive
  - combine filter, aggregate
  - combine reduce, change, facet



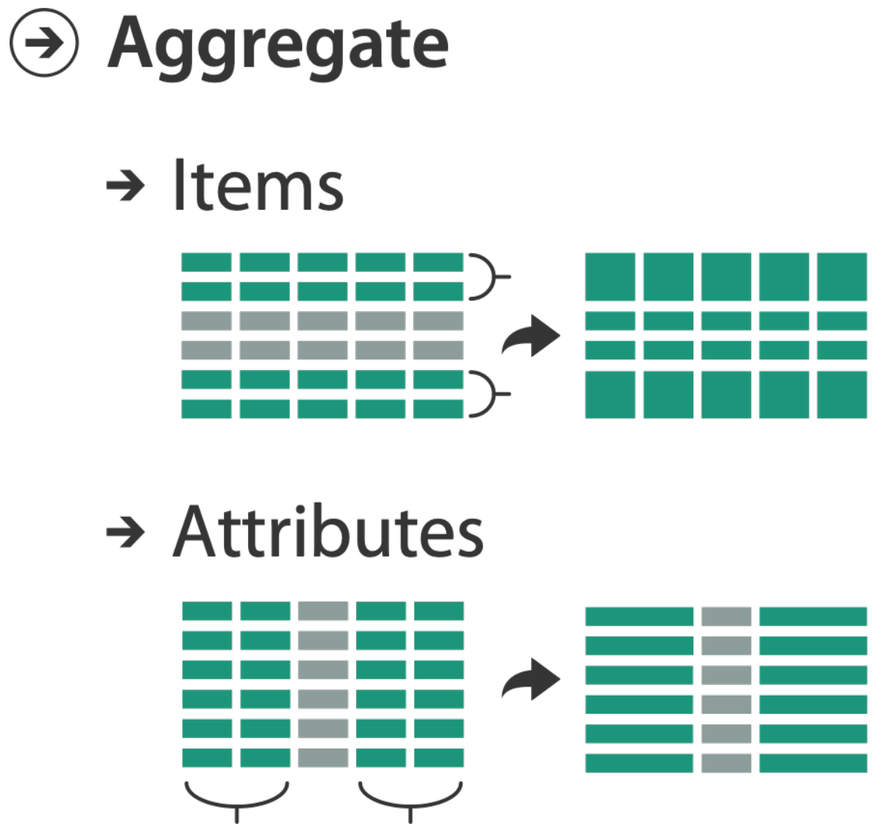
Filter

- eliminate some elements
  - either items or attributes
- What drives filtering?
  - any possible function that partitions dataset into two sets
    - attribute values bigger/smaller than x
    - noise/signal
- filters vs queries
  - query: start with nothing, add in elements
  - filters: start with everything, remove elements
  - best approach depends on dataset size



Aggregate

- a group of elements is represented by a smaller number of derived elements



Recall Tabular Aggregation