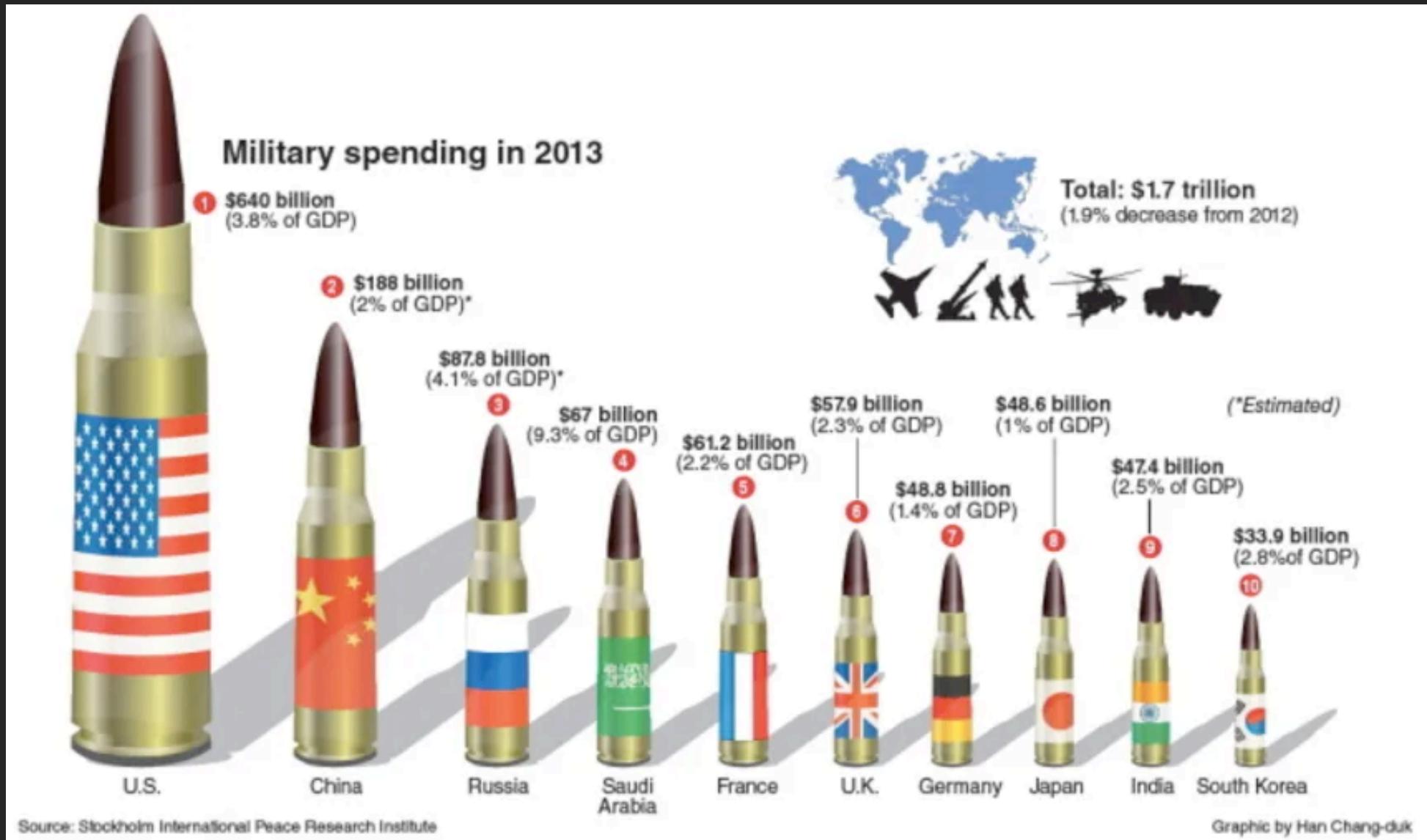


Color and Interaction

Dallas Card

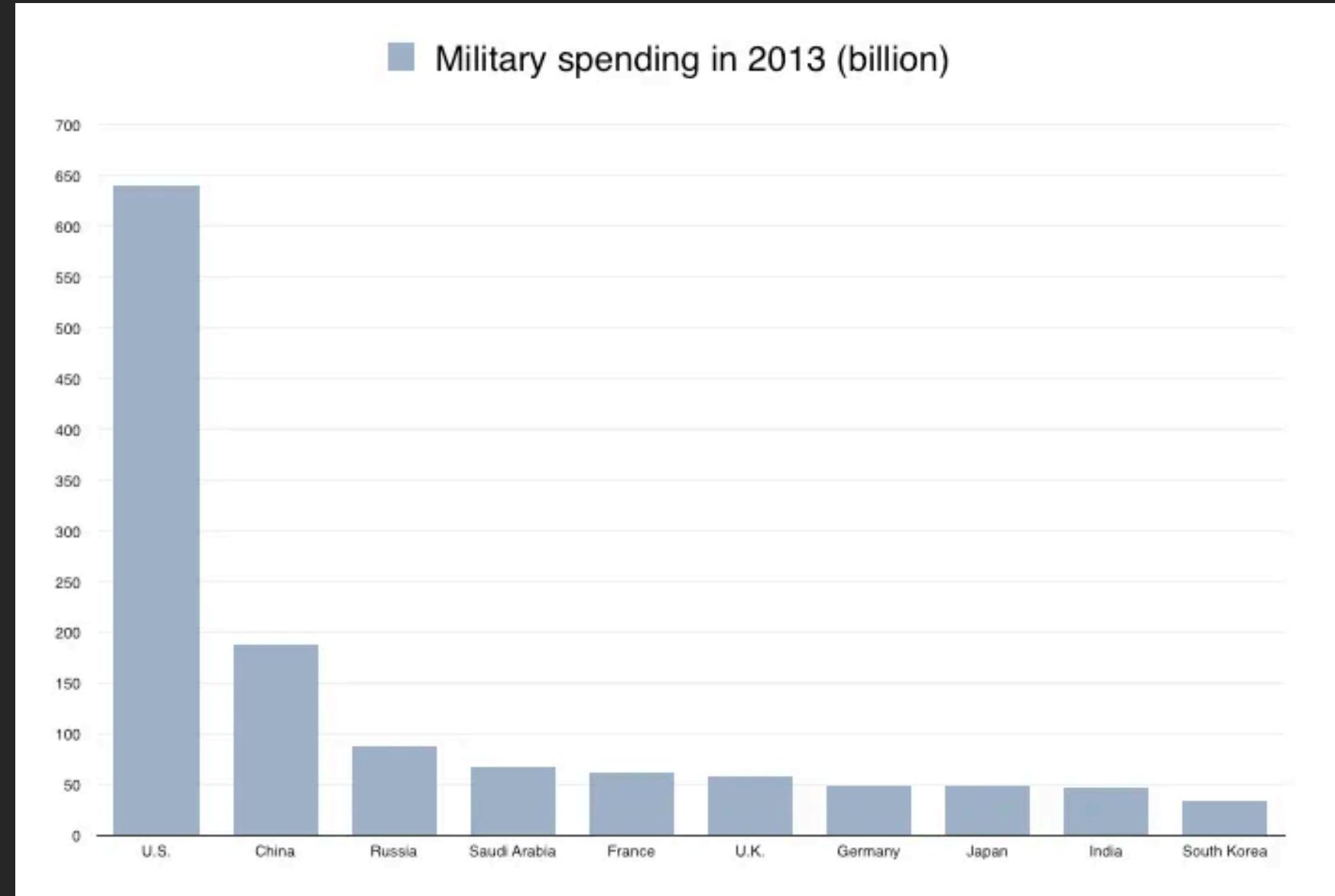
February 13, 2025

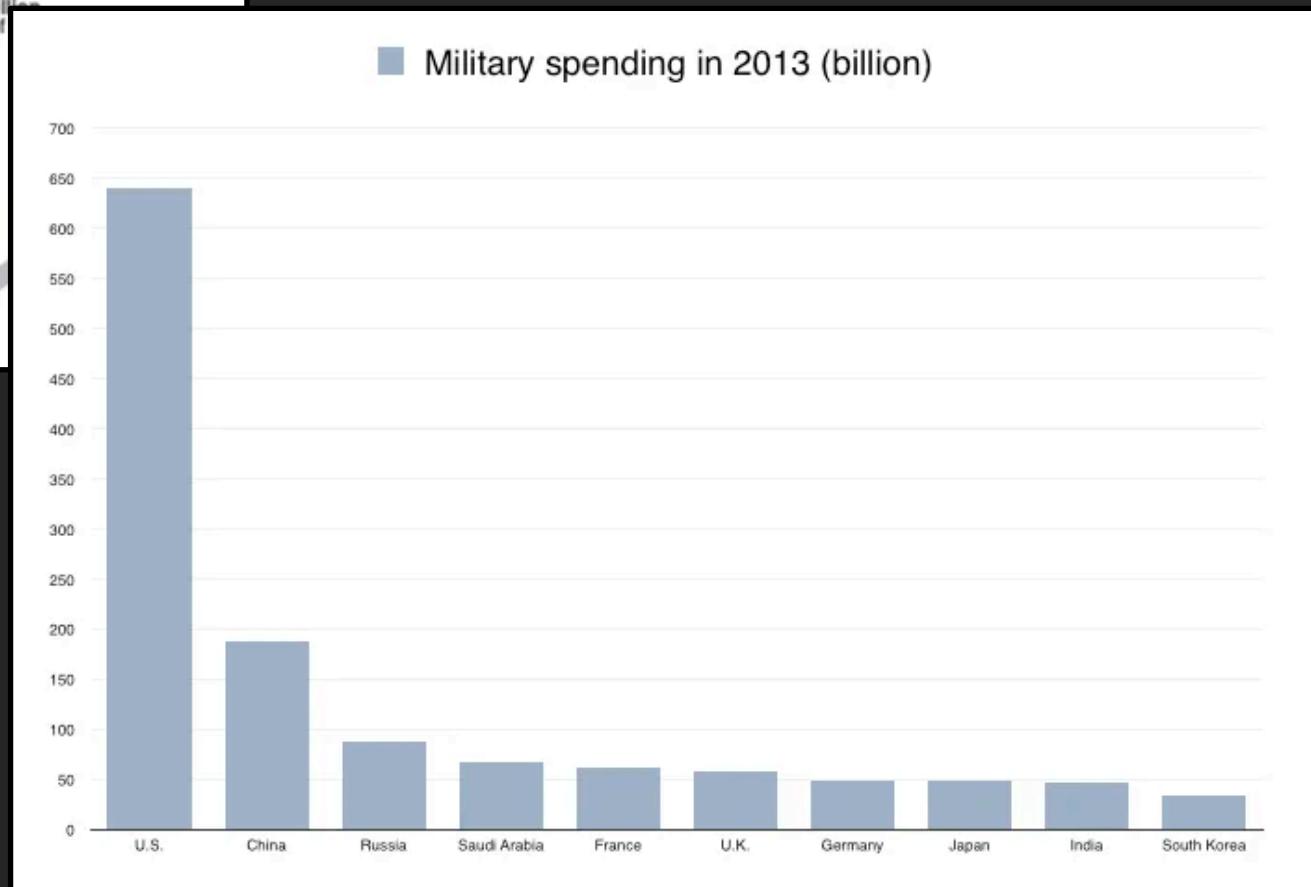
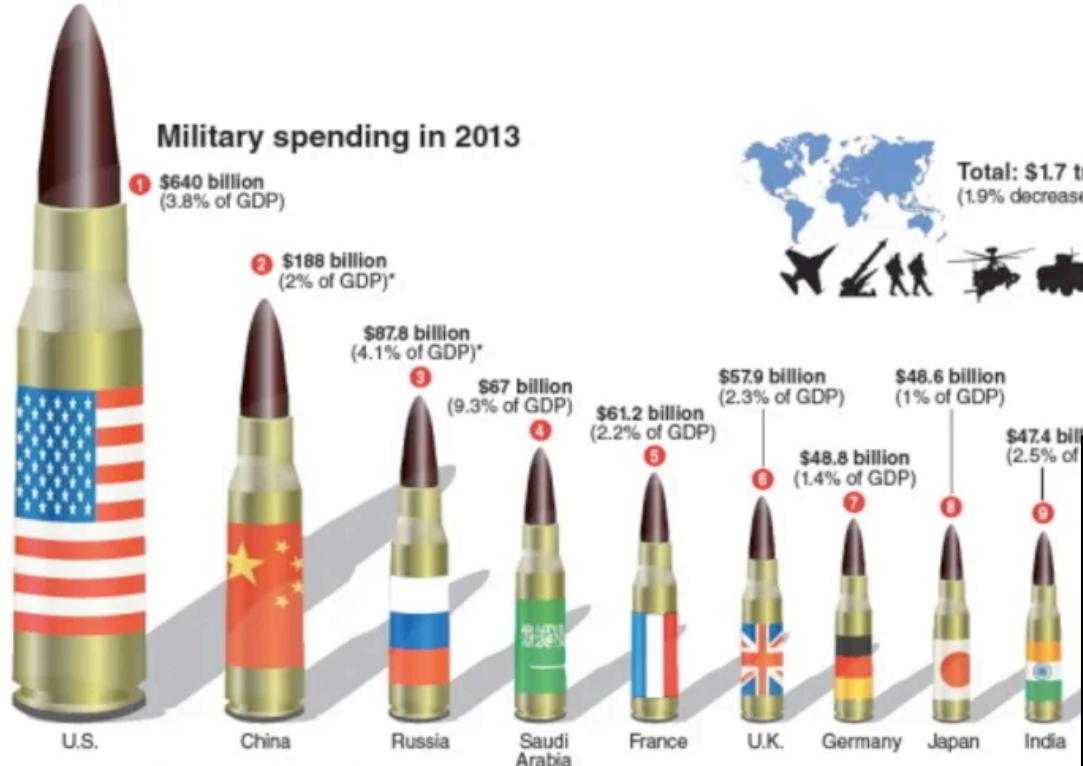
Warmup: What's wrong with this visualization?



A Cleaner Alternative?

<https://medium.com/@migle.rusteikaite/the-above-graph-shows-the-military-spending-in-2013-in-various-countries-54a7cbca9b44>





Color and Interaction

Dallas Card

February 13, 2025

Today

- Logistics
- Brief Recap of Design and Perception
- Evaluation
- Color
- Interaction (first part)
 - Selection
 - Labeling
 - Exploration

Logistics: scheduling

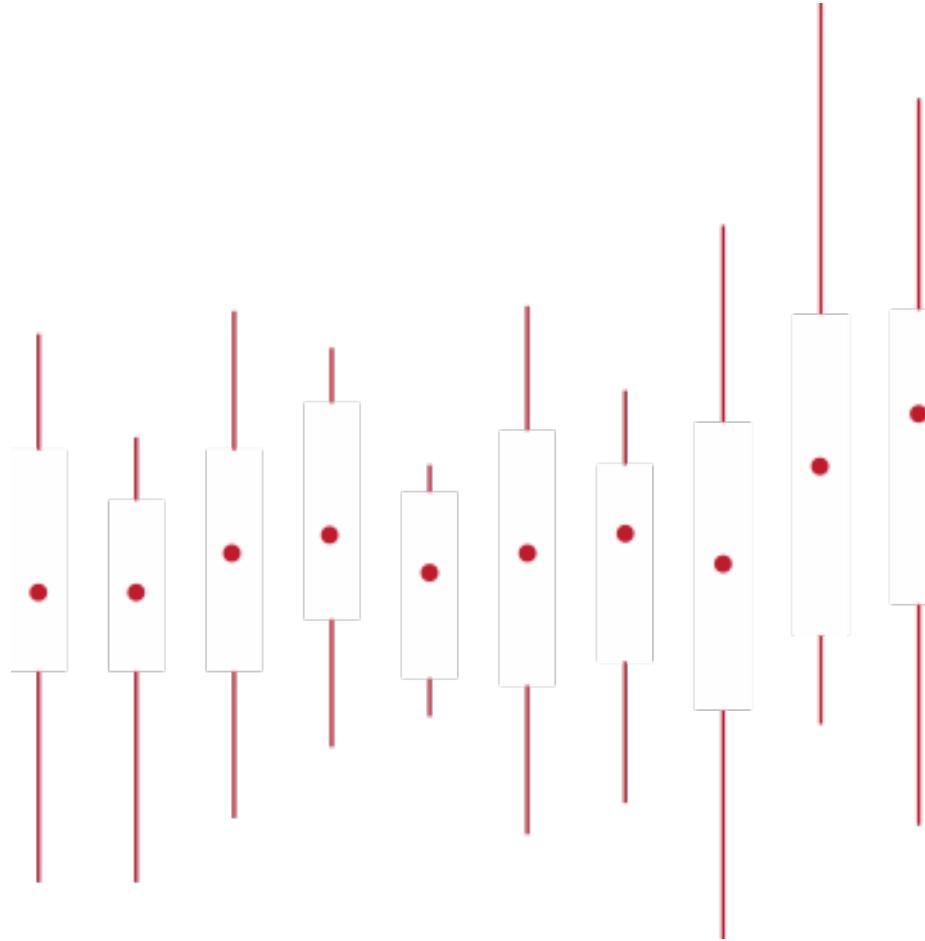
- Apologies for having to cancel class last week
- Schedule has been adjusted somewhat to compensate
- Any questions on logistics?

Labs next week (Feb 18th and 20th)

- First design workshops
- In-person attendance is required
- Bring drawing implements (pens, markers, etc.)
- We will start by walking you through the exercise (no preparation required)

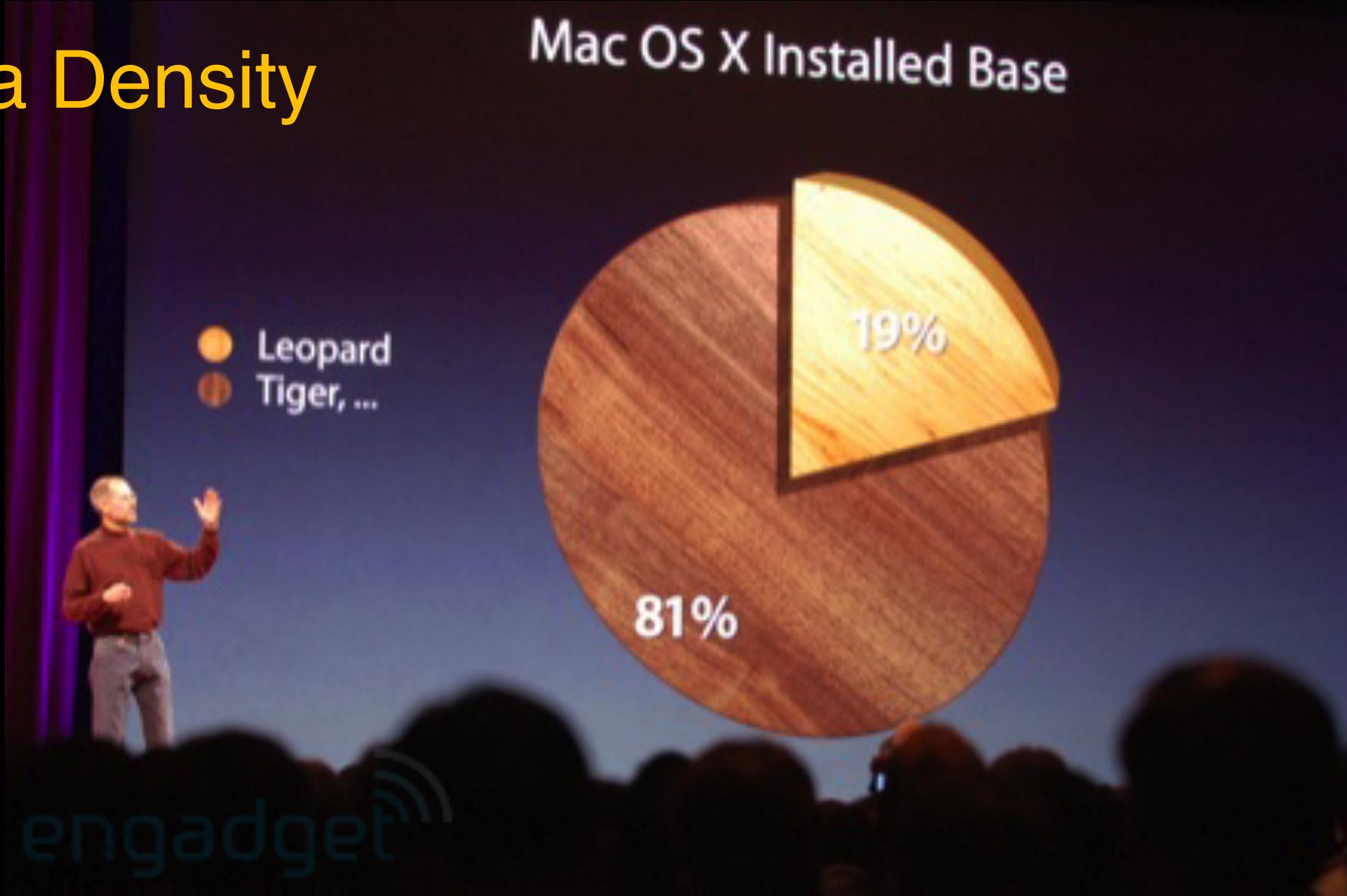
Recap of Design and Perception

Data-ink Ratio



Data Density

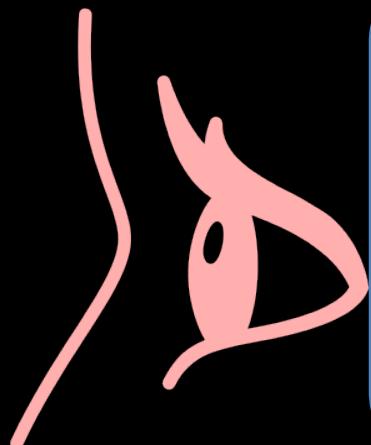
Mac OS X Installed Base



Subjectivity in Perception



Visual Information Processing



Stage 1
Parallel
Processing

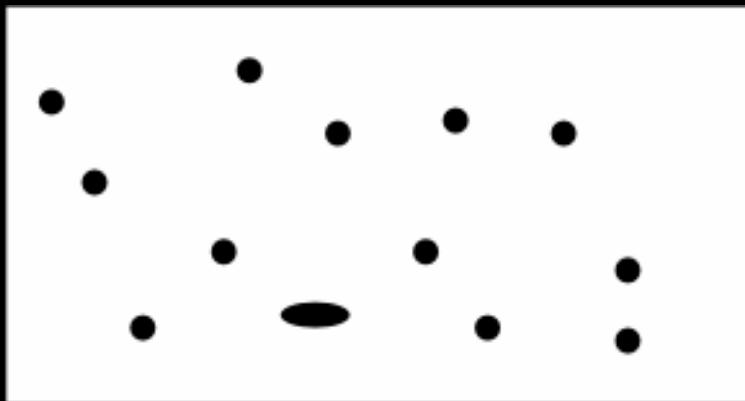
Stage 2
Pattern
Perception

Stage 3
Sequential
Processing

From Ware, 2004

Preattentive Processing

Shape



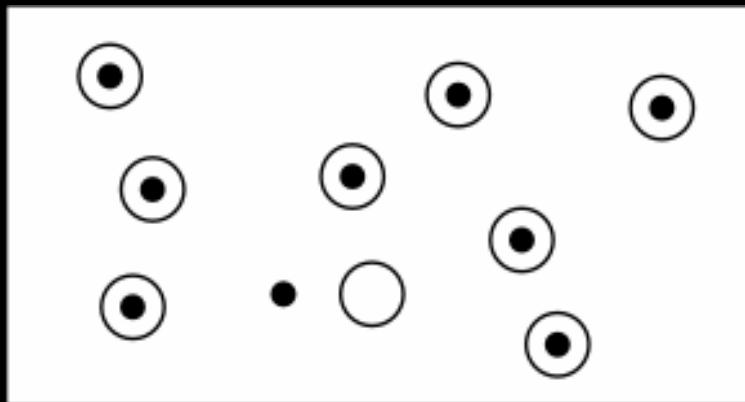
Length



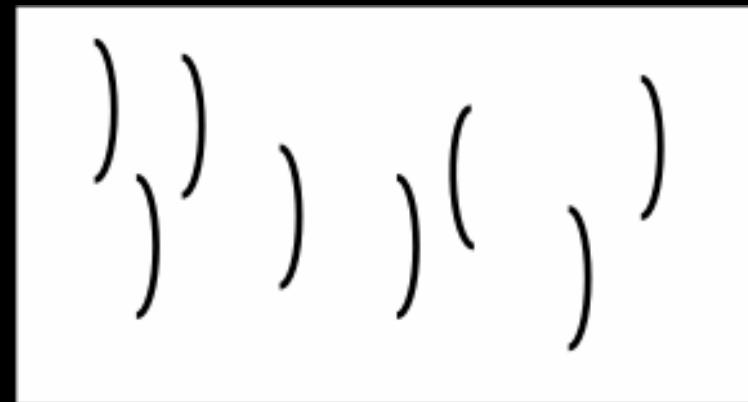
Width



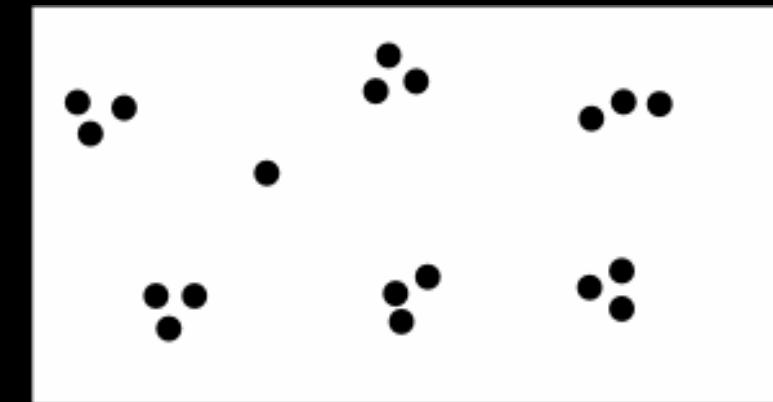
Enclosure



Curvature



Number



Just Noticeable Difference

Weber's law: $k = \frac{\Delta I}{I}$

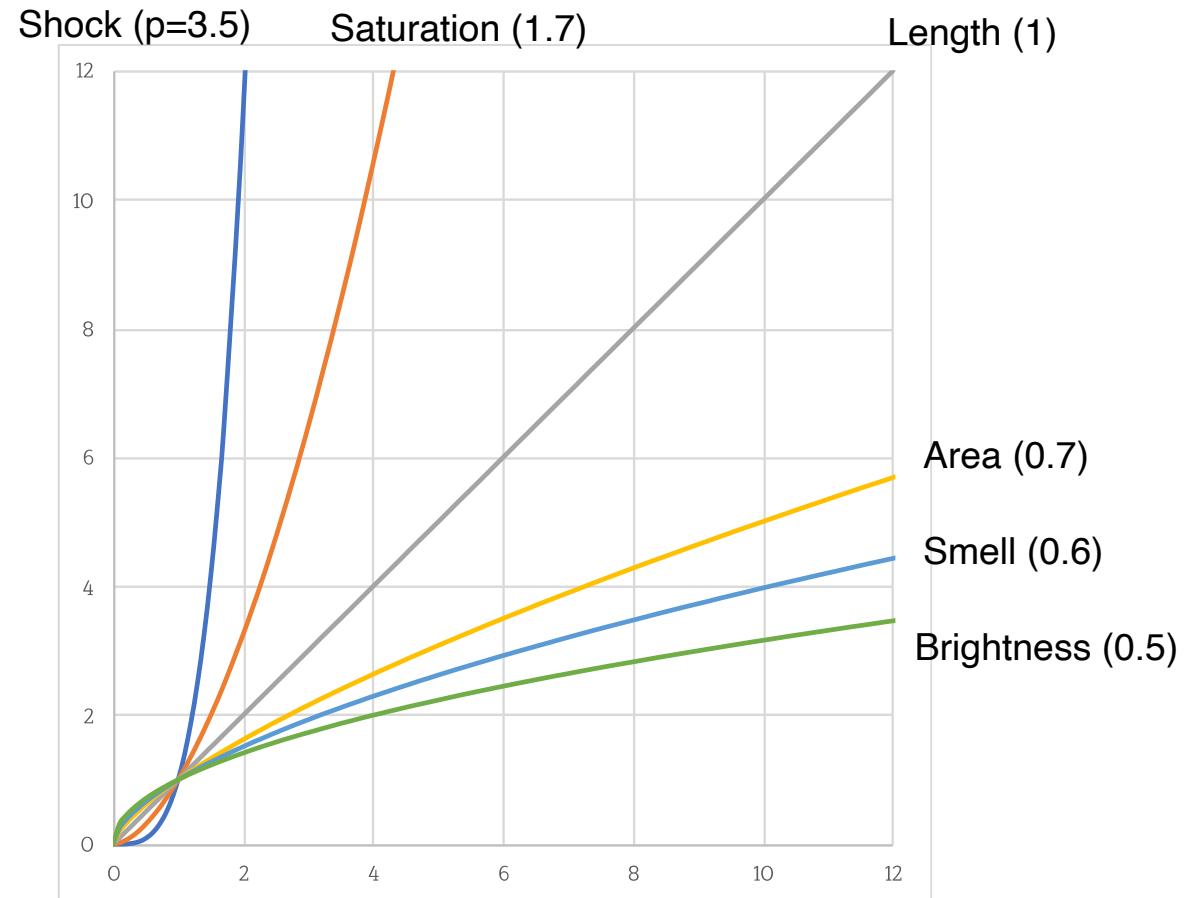
If $k = 1$ and $I = 100$ (loud)
then $\Delta I = 100!$



Stevens' Power Law

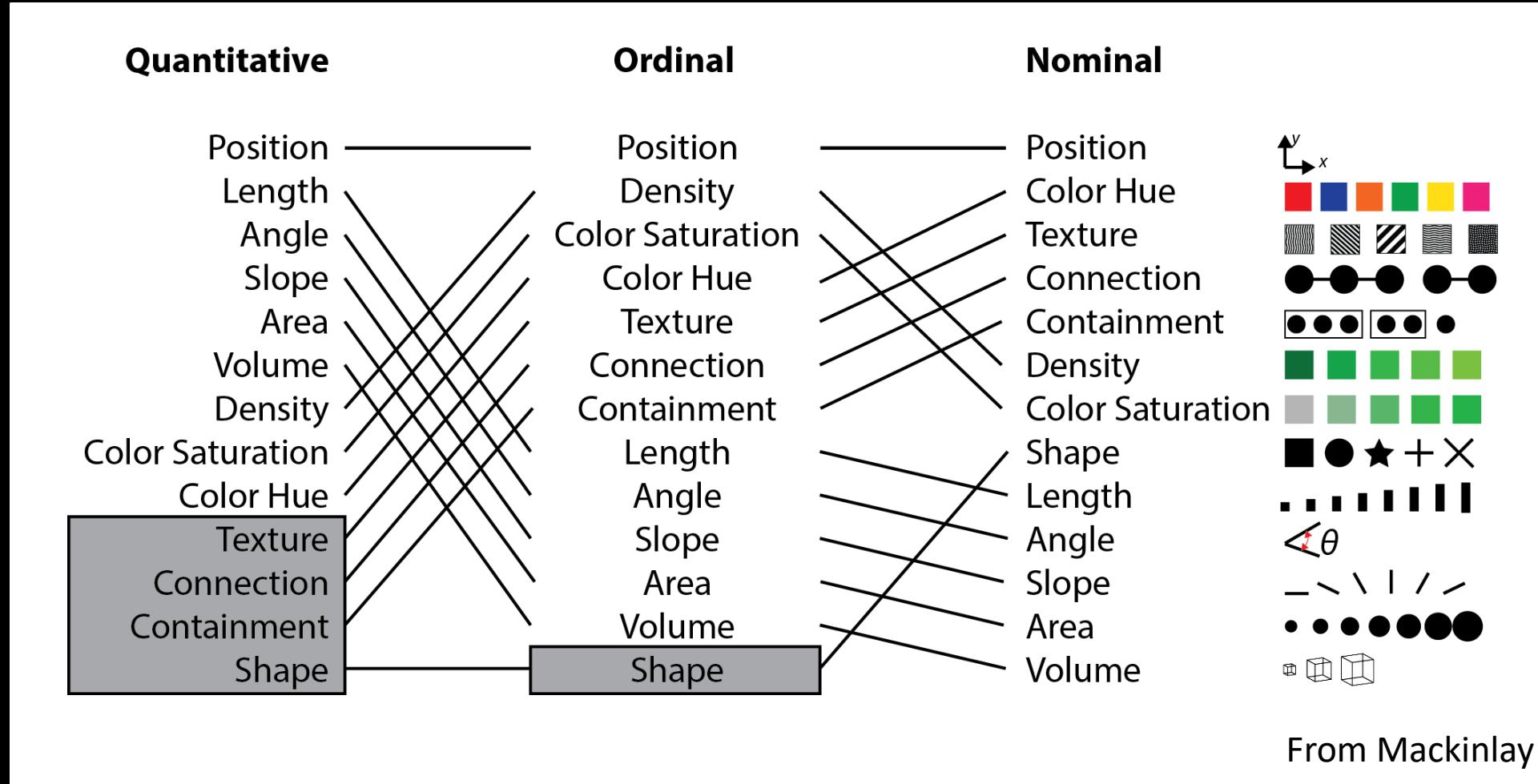
Intensity = Sensation^{Power}

$$I = S^P$$

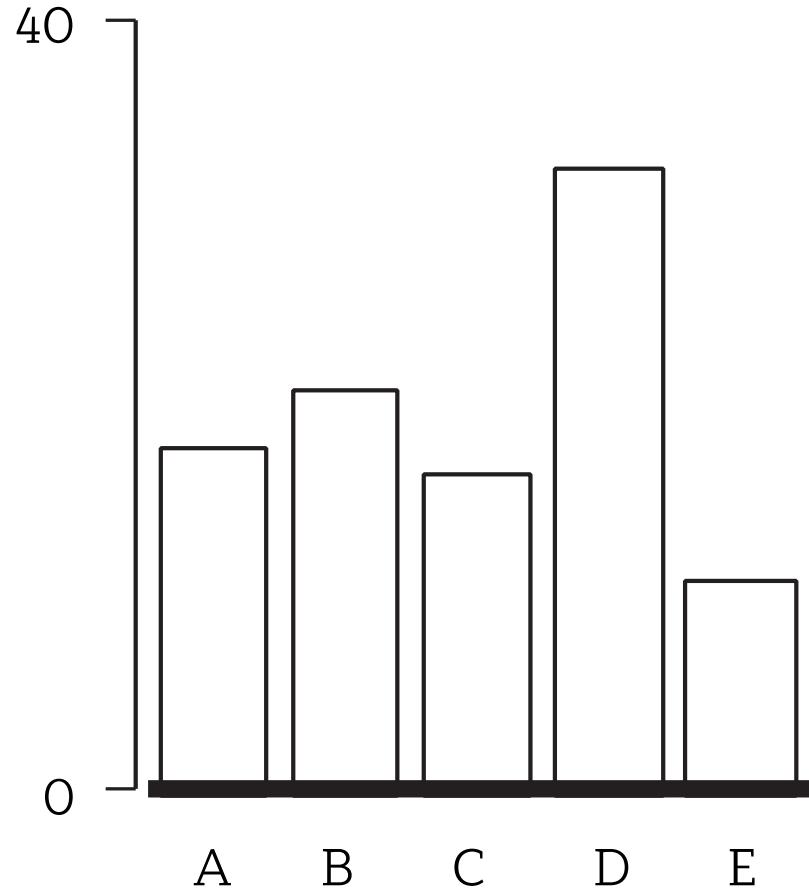
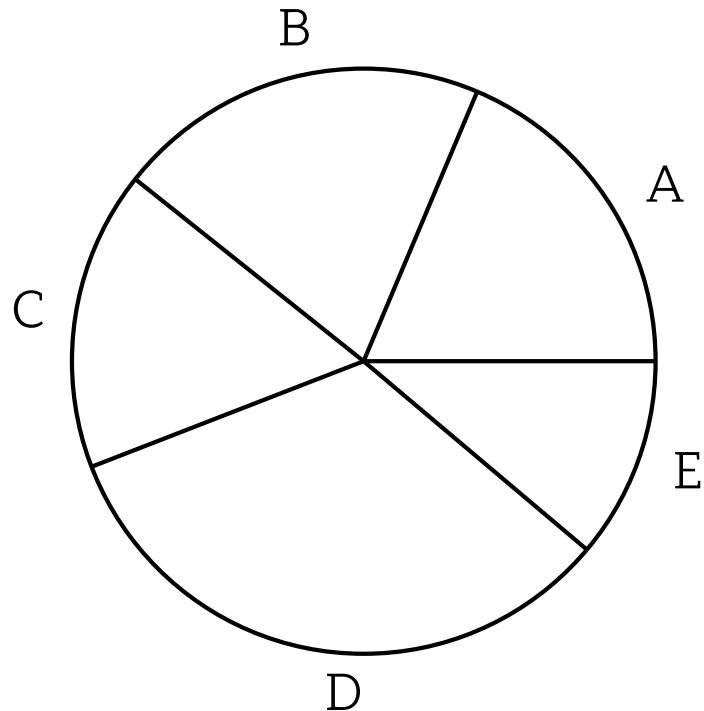


Measuring Effectiveness

Ranking of Perceptual Tasks



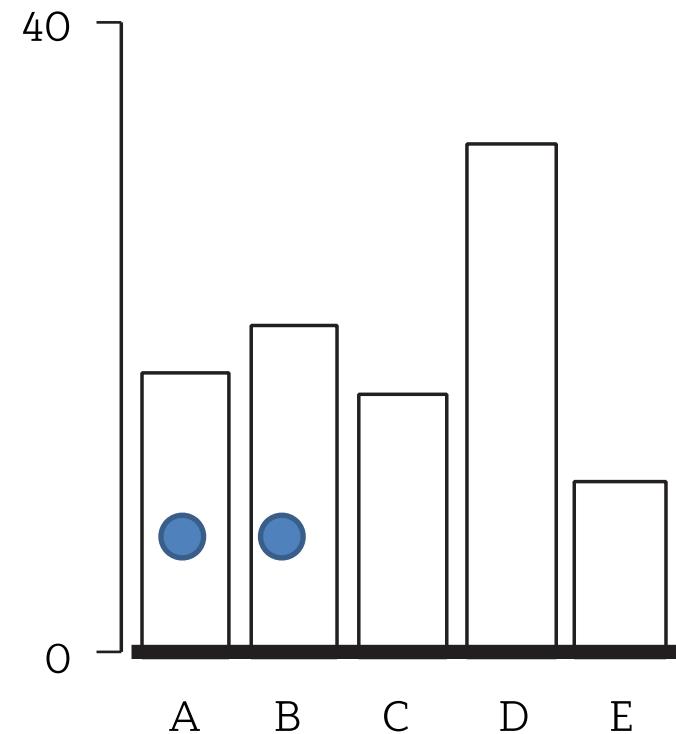
Cleveland/McGill (1984)



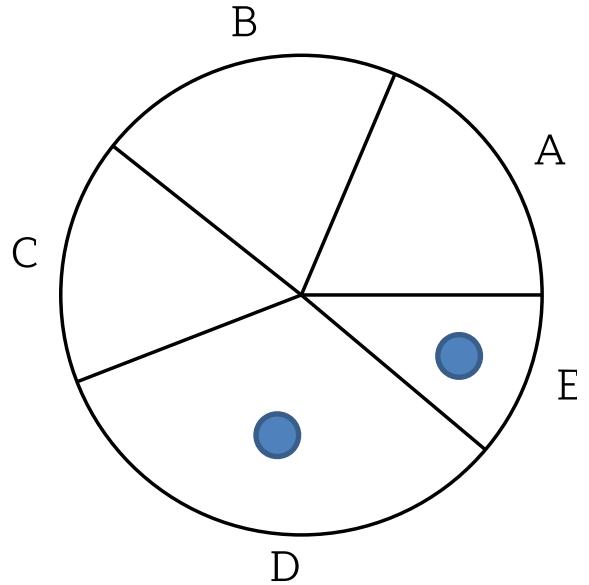
Cleveland/McGill (1984)

Q1: Which is bigger, A or B?

Q2: How much bigger?

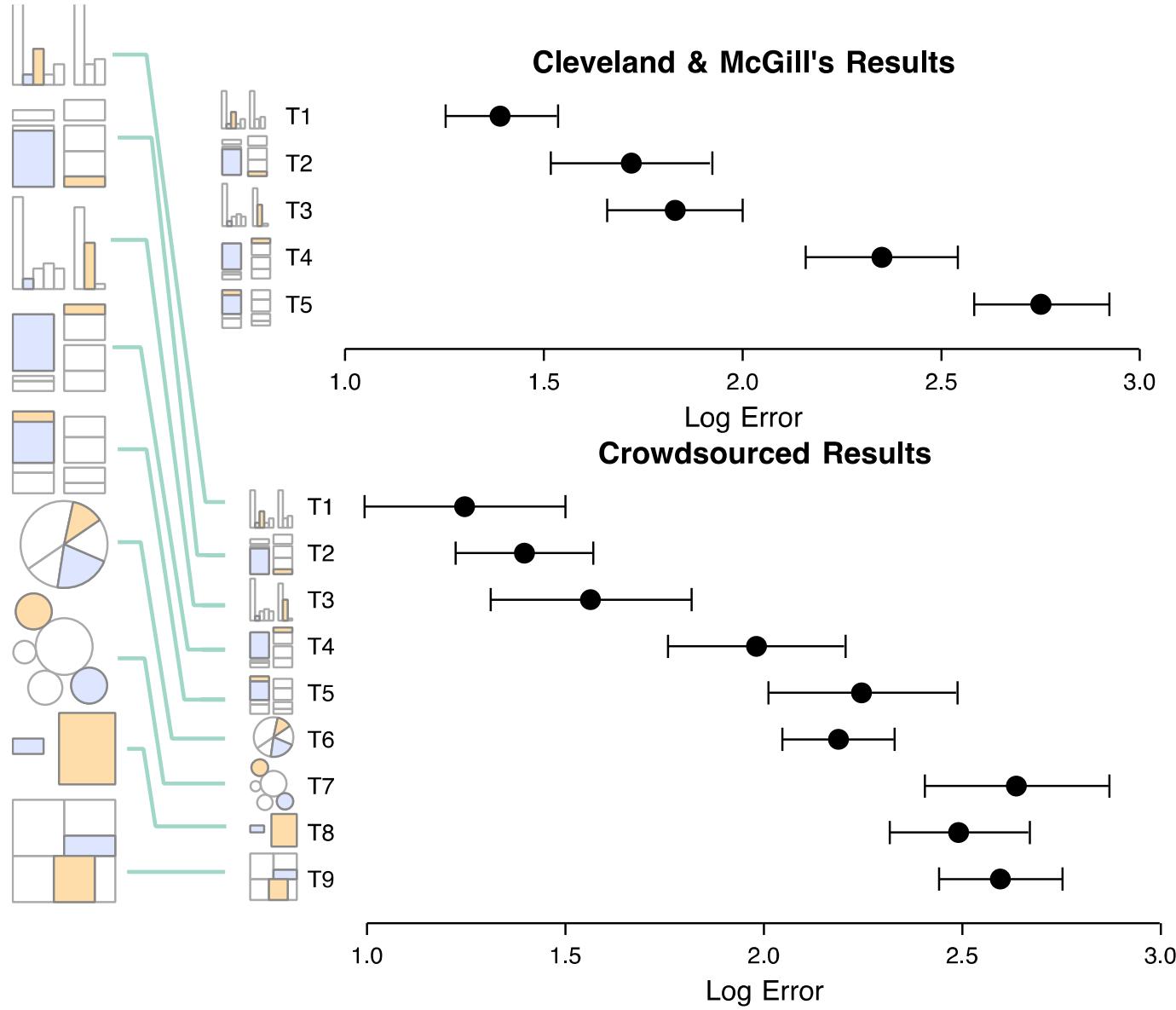


Cleveland/McGill (1984)

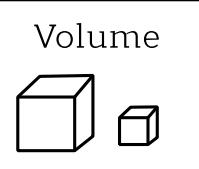
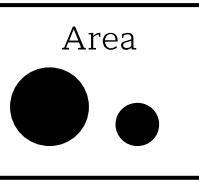
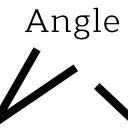
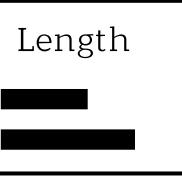
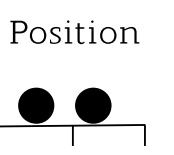


Q1: Which is bigger, E or D?

Q2: How much bigger?



More accurate



Less accurate

The real world

- Different implementations/solutions
 - Wicked problem
- Different people
- Different contexts
- Different tasks
- Different ...

Most Important Takeaway

- Rarely is there a single, simple answer like A > B
- Things like effectiveness depend on
 - Task
 - User
 - Context
 - Etc.
- But, many ways to make evaluation rigorous
- And many evaluations can be complementary

Controlled Experiments

- Good for performance or comparing multiple techniques
- What do we measure?
 - Performance, time, errors, etc.



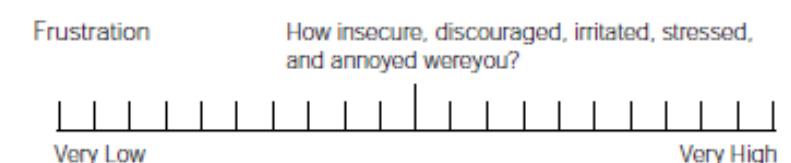
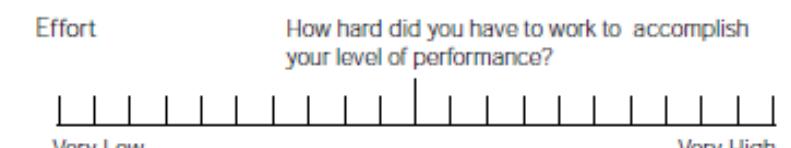
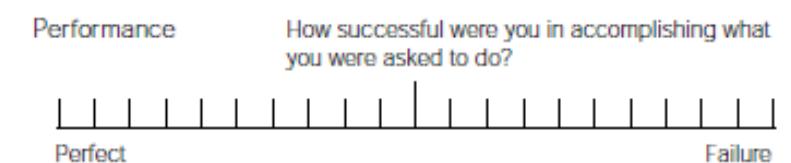
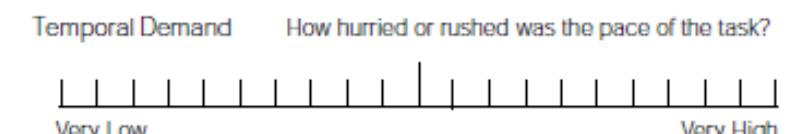
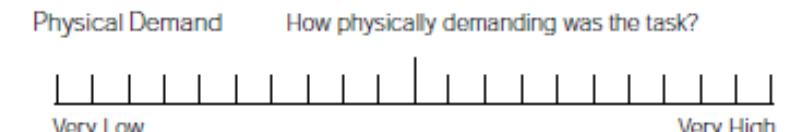
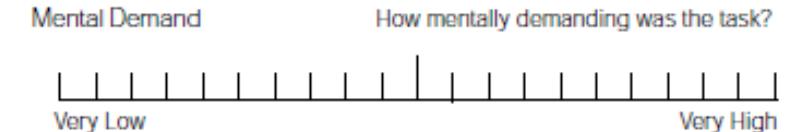
Subjective Assessments / Structural Analysis

- Find out people's subjective views on tools
 - Was it enjoyable, confusing, fun, difficult, ...?
 - NASA-TLX
- Strengths/Weaknesses?
 - This kind of personal judgment strongly influence use and adoption, sometimes even overcoming performance deficits

NASA Task Load Index

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

Name	Task	Date
------	------	------



Observational Studies

- Watch systems being used (you can learn a lot)
- Is it being used in the way you expected?
 - Ecological validity
 - Can suggest new designs and improvements



Post-deployment Evaluation



Figure 3. Settings used in the study. Left and top right: the atrium. Bottom right: the usability lab.

White Rooms
and Morphing
don't mix:
Setting and the
Evaluation of
Visualization
Techniques.
Derek Reilly
and Kori
Inkpen, CHI'07

Makings of a good experiment

- Matching tools with users, tasks and real problems
- Good user-testing
 - Tasks should be believable
 - Training time sufficient
 - Tasks complex enough
 - Look at data over a long time
 - Answering questions you didn't know you had
 - Chance of discovery and benefits of awareness
- Addressing universal usability

Evaluation Summary

- Need to evaluate effectiveness with respect to specific tasks
- Various approaches available, including experiments, observational studies, etc
- Can develop general principles, but contextual factors may still matter
- Ultimately, need to evaluate utility in situ

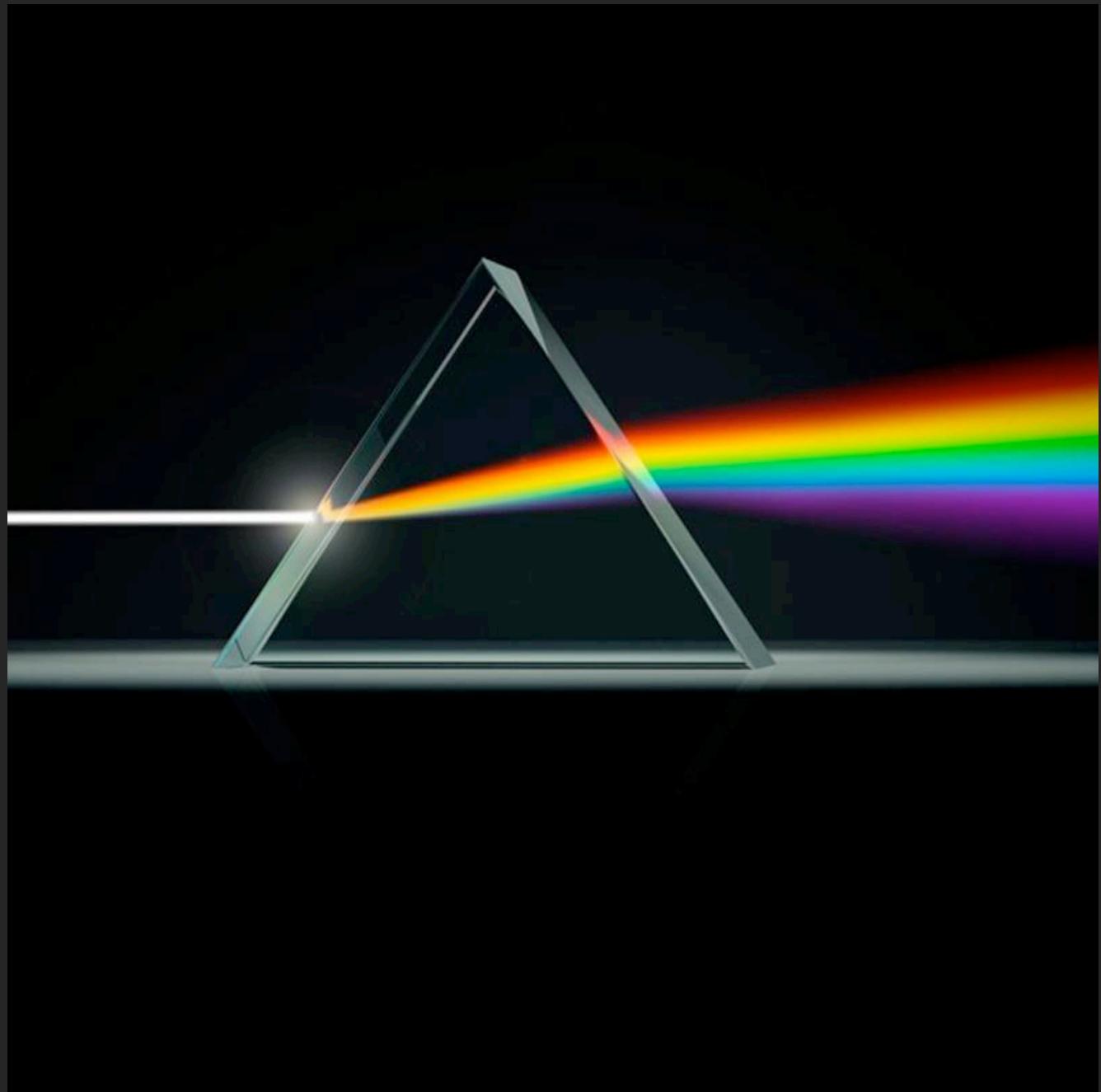
The background features a circular color wheel composed of numerous concentric rings. Each ring is filled with a gradient of colors, transitioning smoothly from one hue to the next. Starting from the top and moving clockwise, the colors follow the standard primary and secondary color sequence: yellow, orange, red, magenta, blue, and green. The colors are bright and saturated, creating a visually appealing and dynamic pattern.

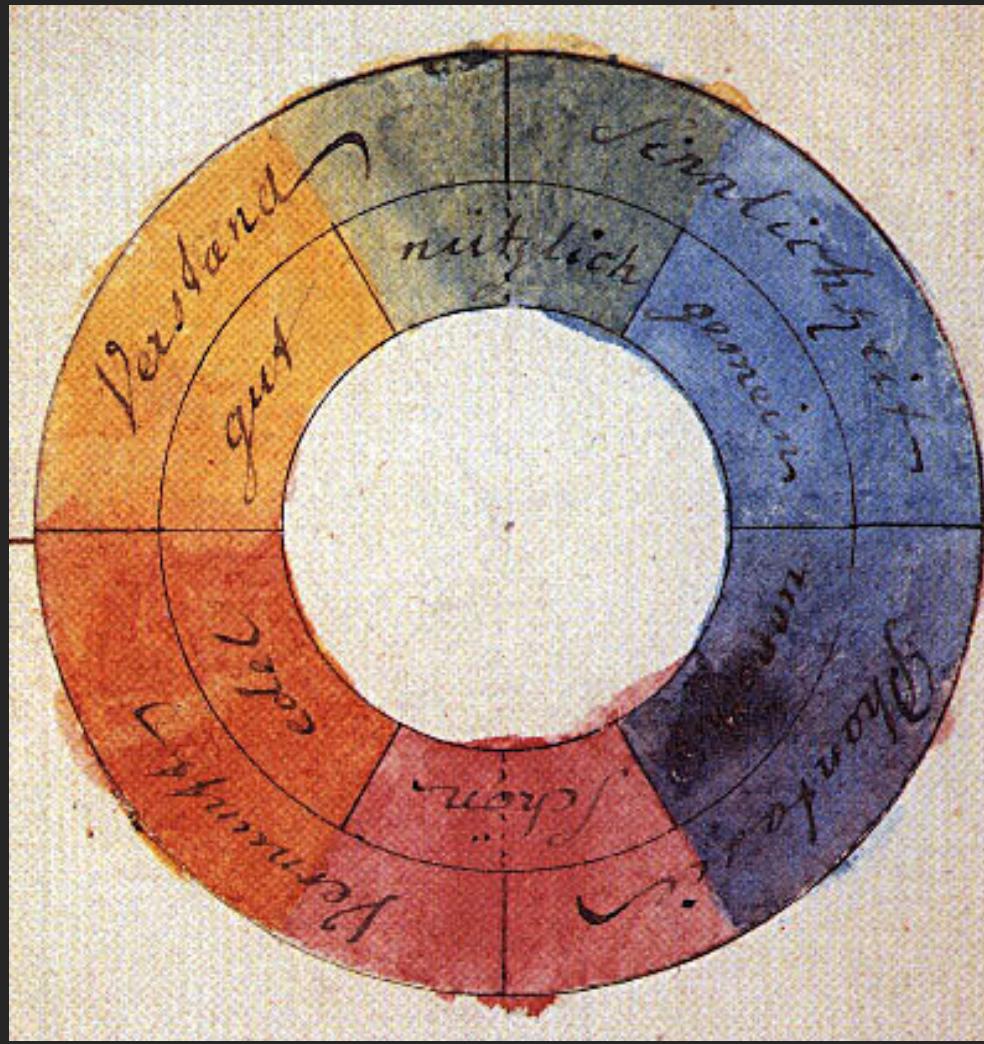
Color

Quotes on Color

- "Even putting a good color in a good place is a complex matter. Indeed, so difficult and subtle that avoiding catastrophe becomes the first principle in bringing color to information" --- Edward Tufte, *Envisioning Information*
- "Position is everything, color is difficult" --- Noah Iliinsky
- "Get it right in black and white" --- Maureen Stone

The Color Spectrum





Goethe, 1810

How many basic (named) colors are there?

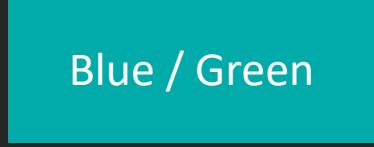
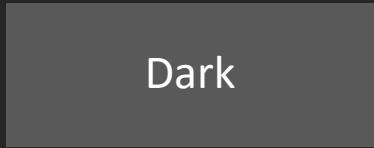
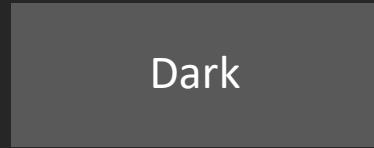
Cultural Differences in Color Naming and Perception

Dark

Light

Red

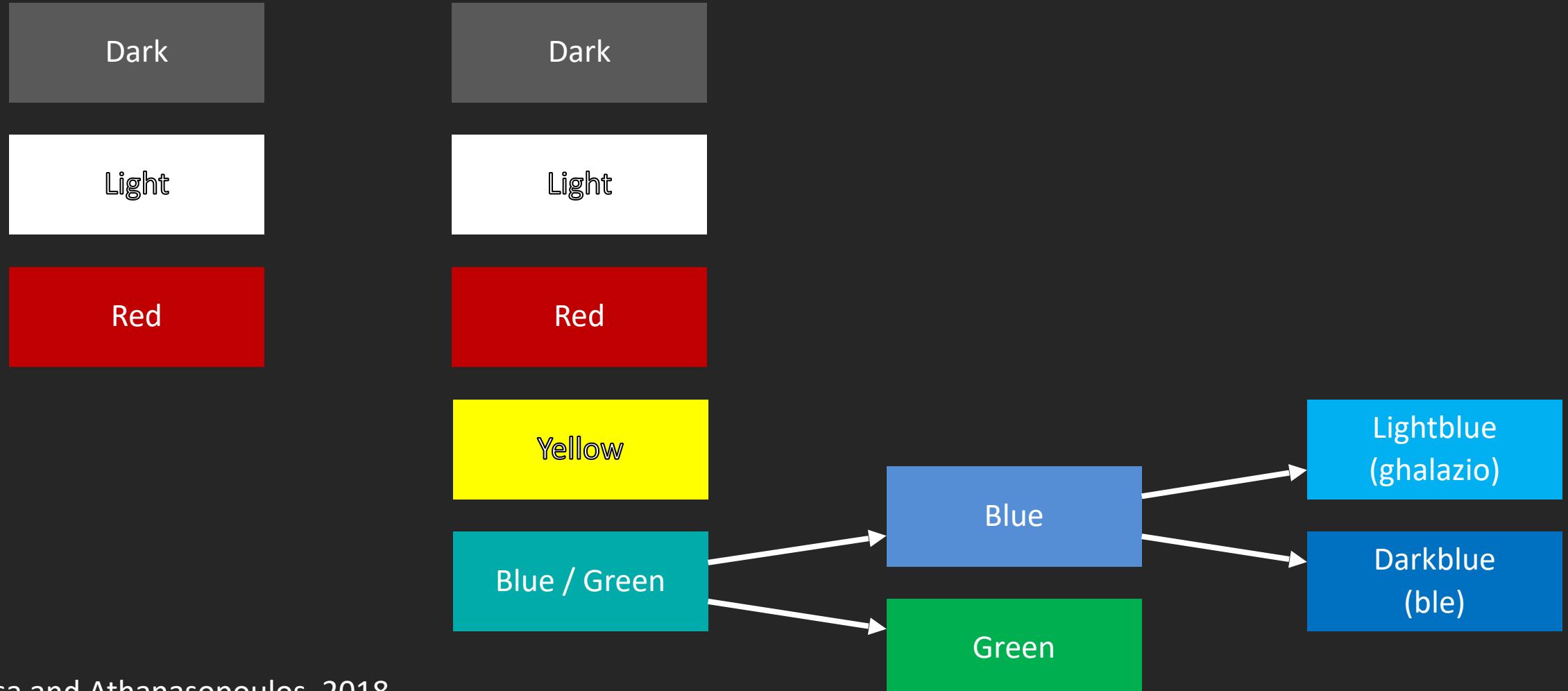
Cultural Differences in Color Naming and Perception



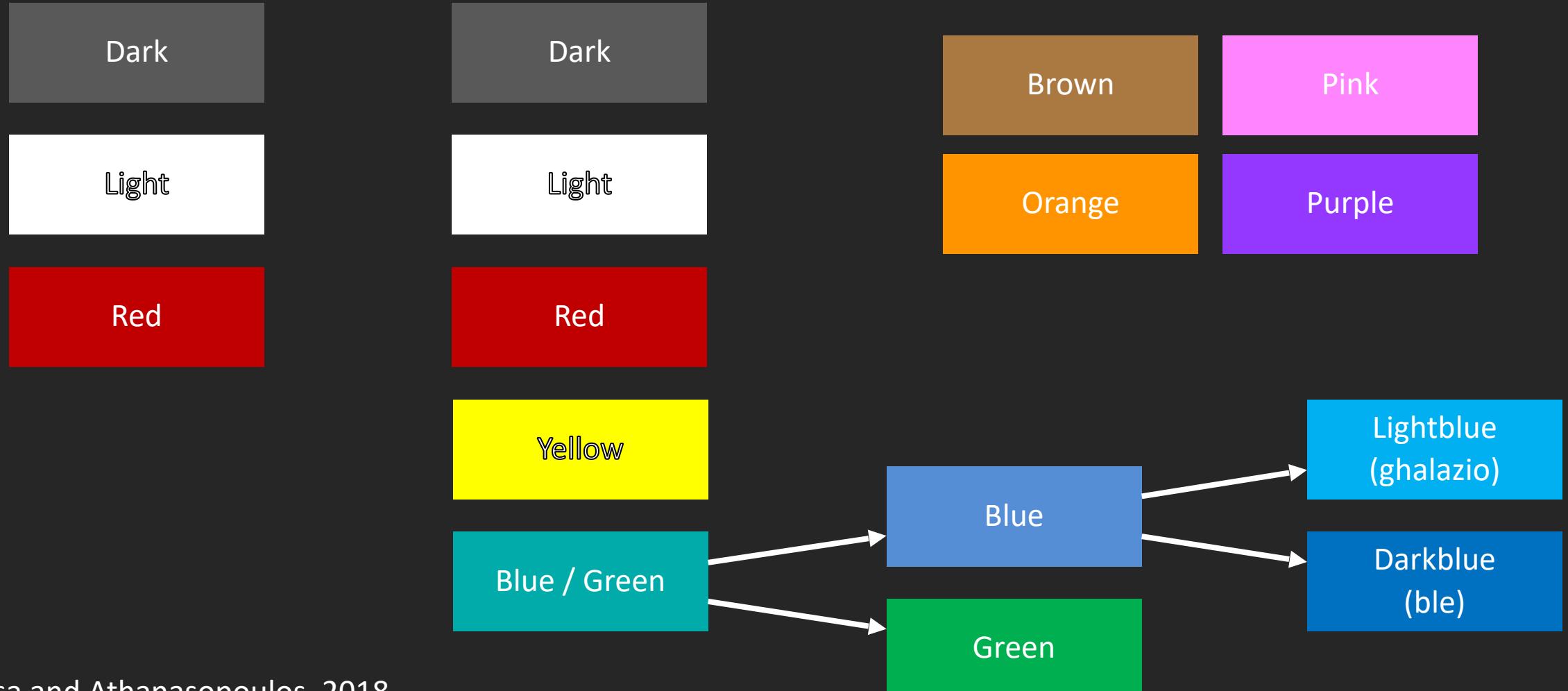
Cultural Differences in Color Naming and Perception



Cultural Differences in Color Naming and Perception



Cultural Differences in Color Naming and Perception



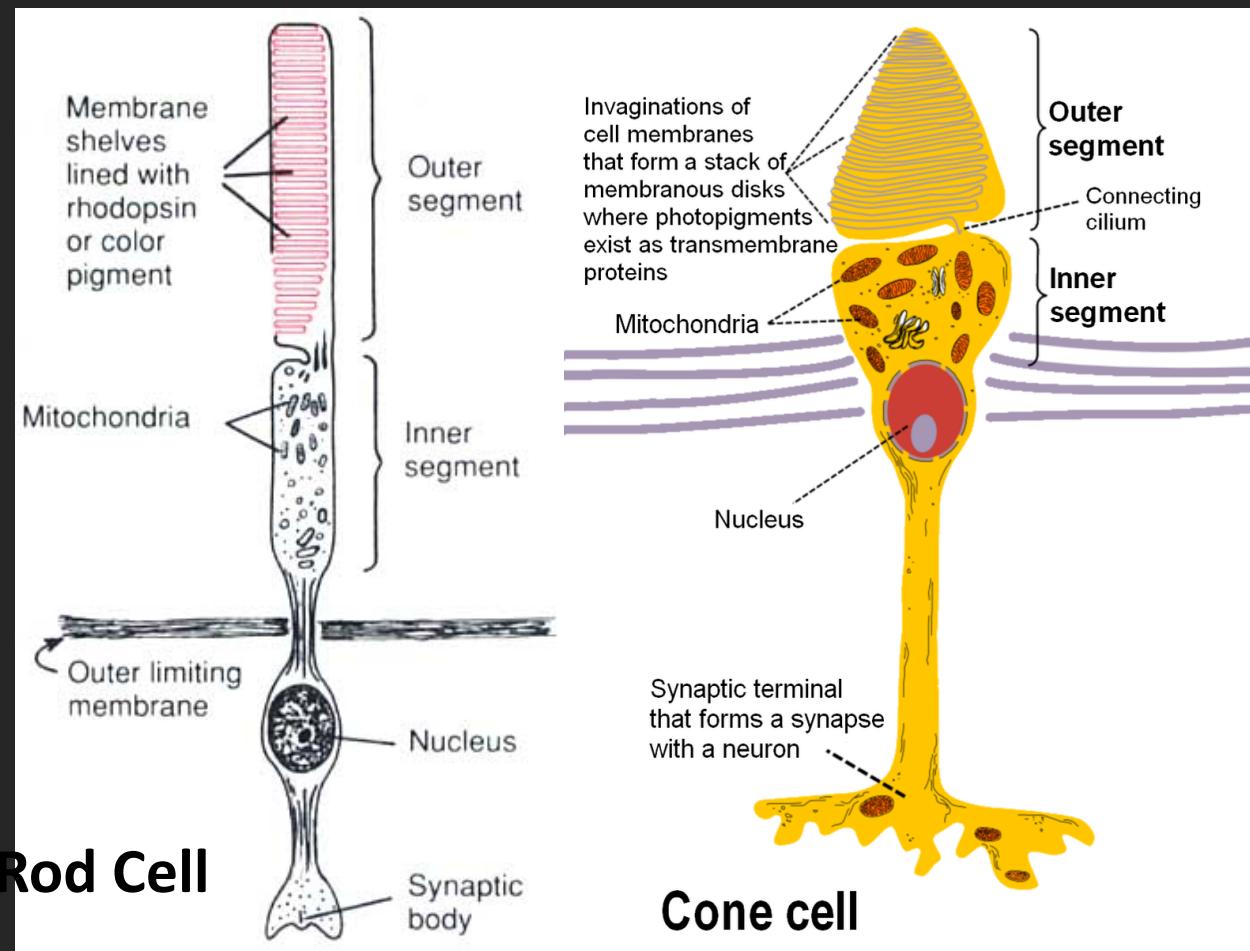
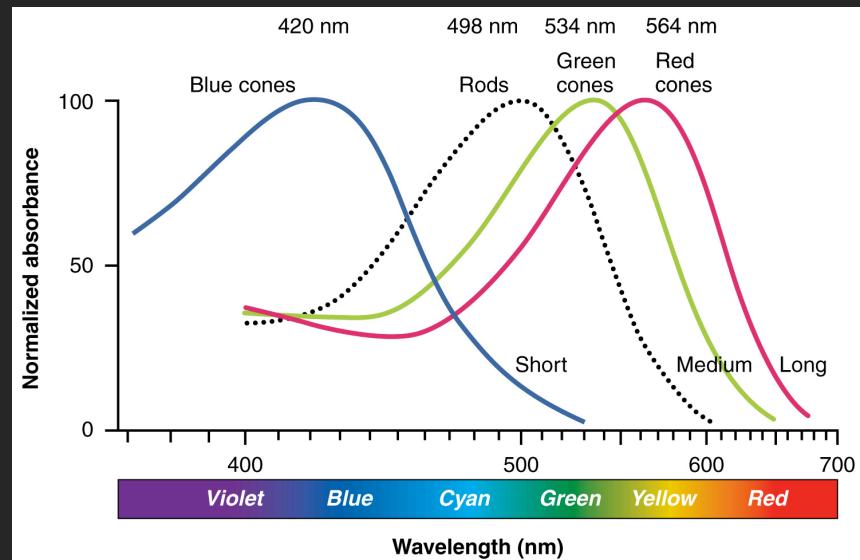
Is my blue your blue?

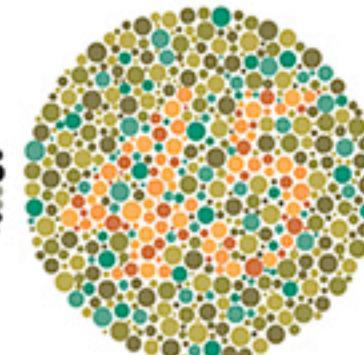
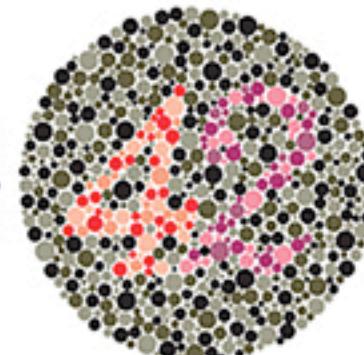
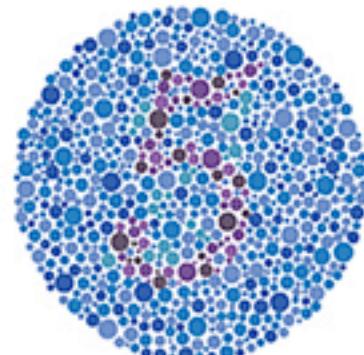
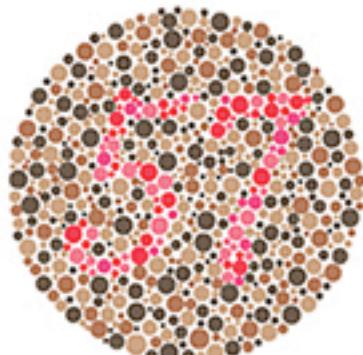
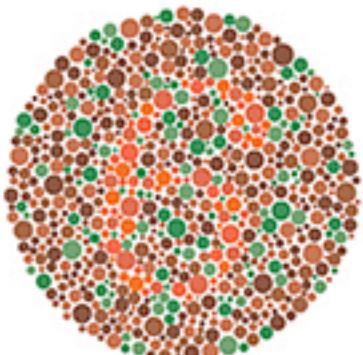
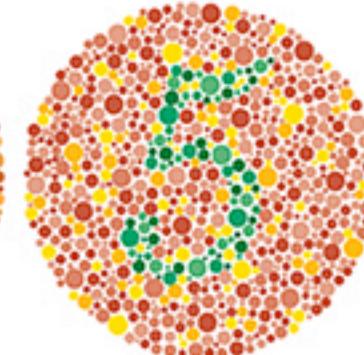
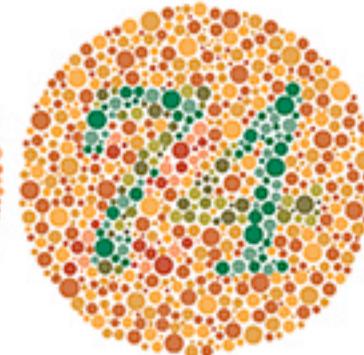
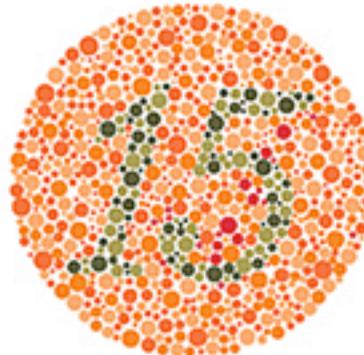
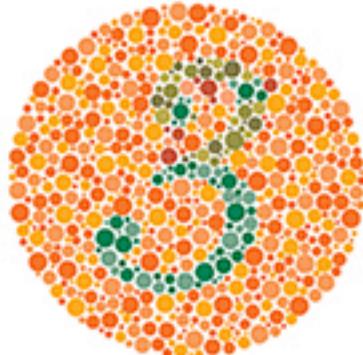
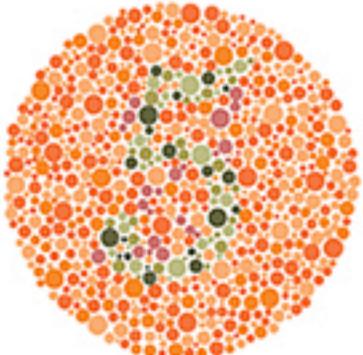
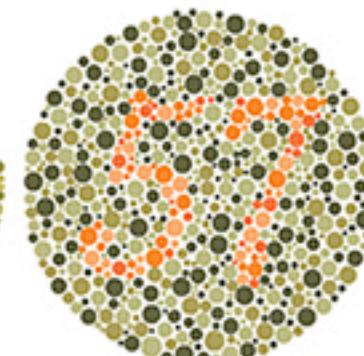
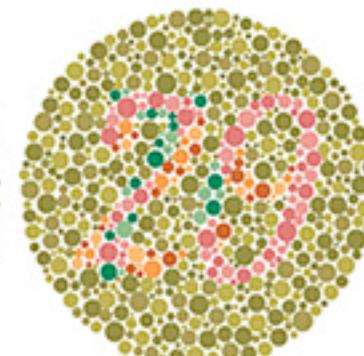
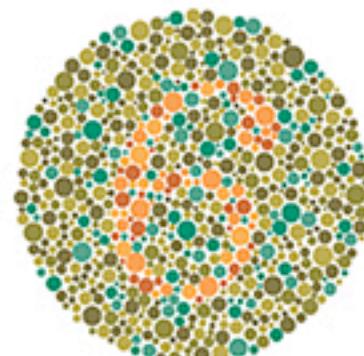
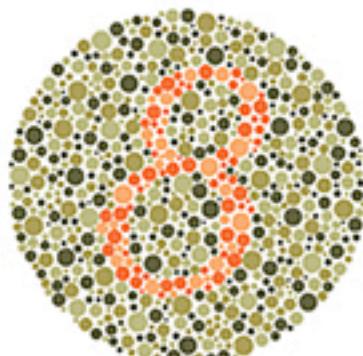
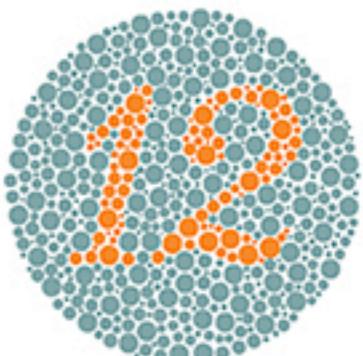
This is blue

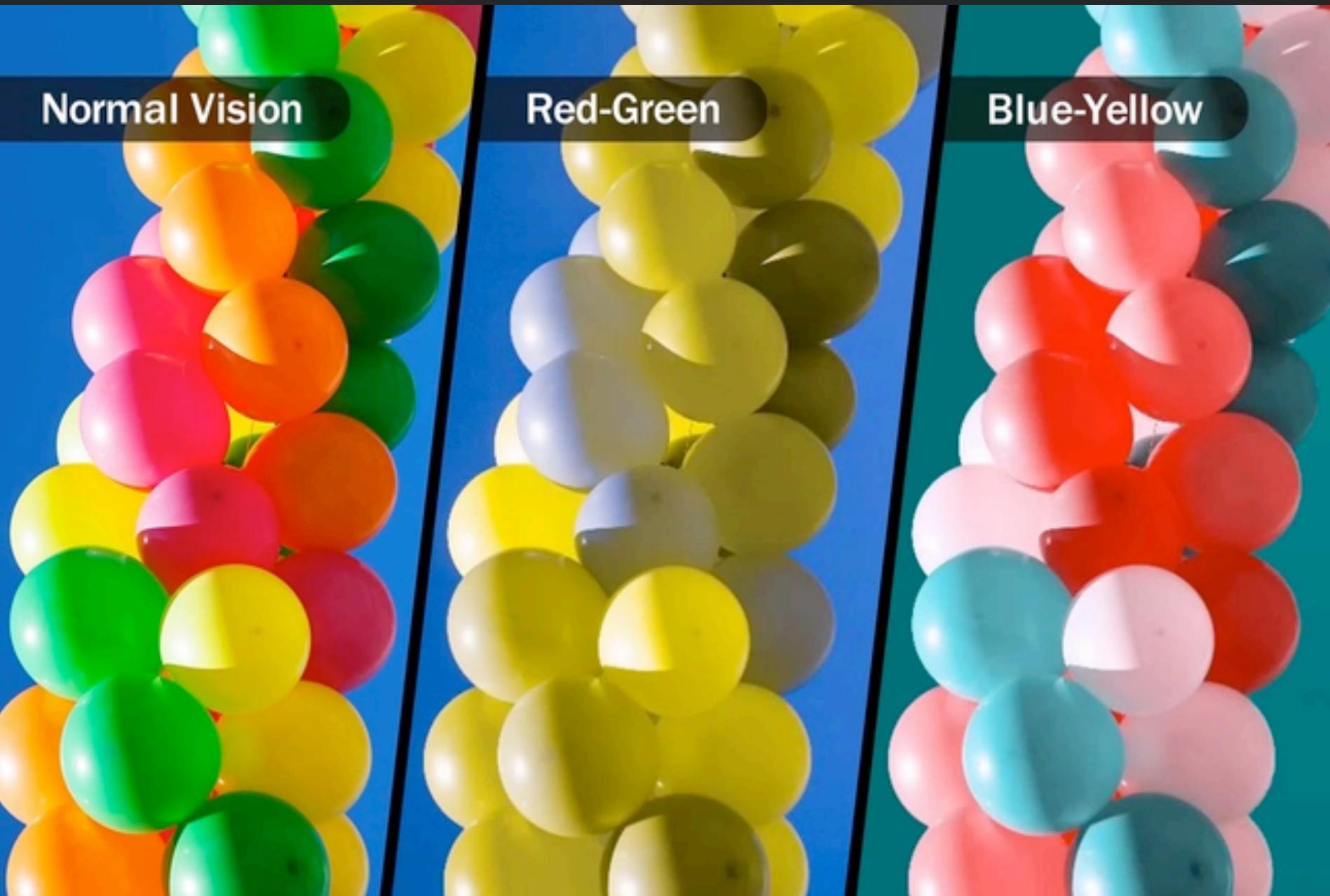
Reset

This is green

<https://ismy.blue/>

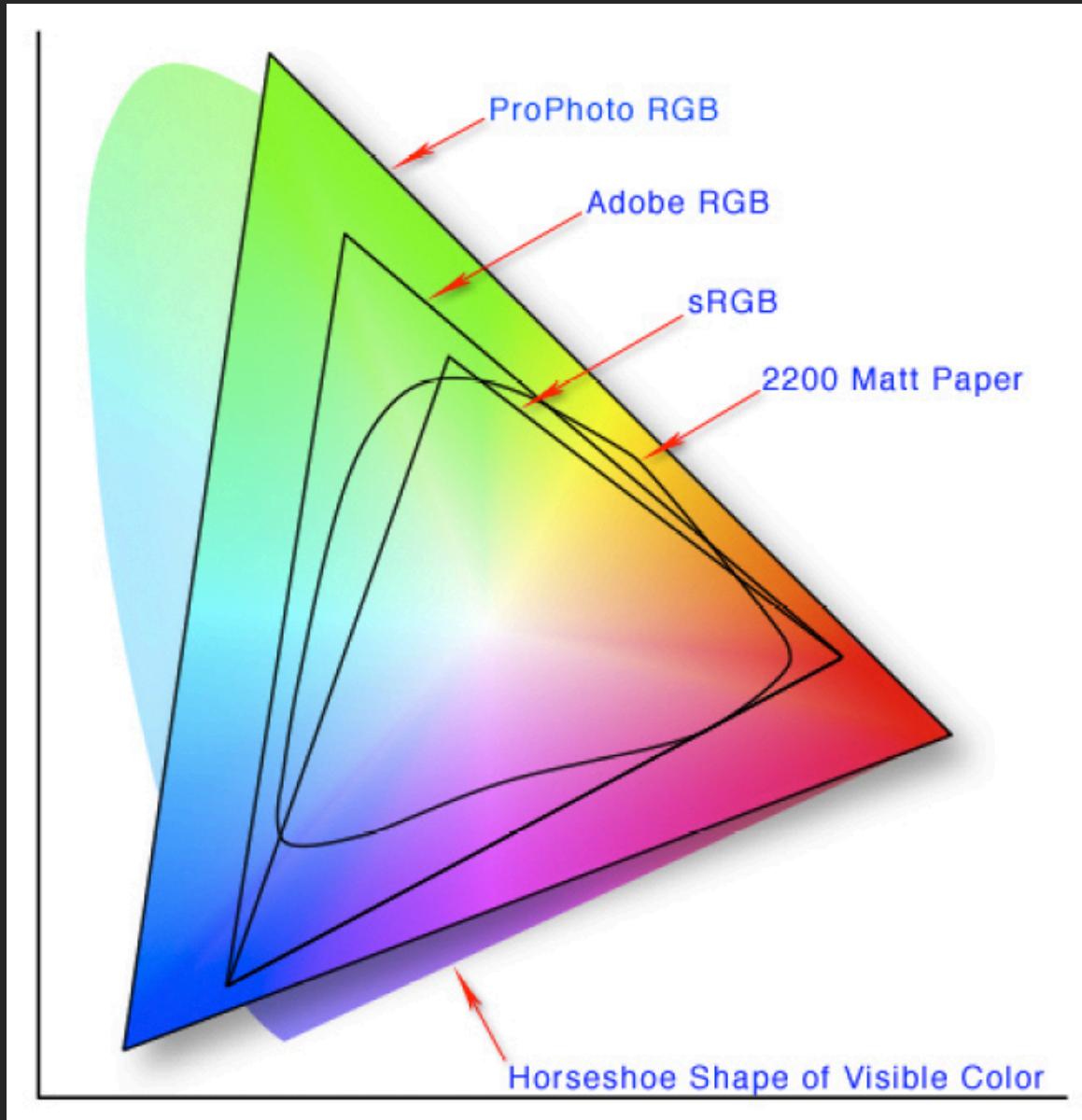






<https://www.webmd.com/eye-health/ss/slideshow-color-blindness>

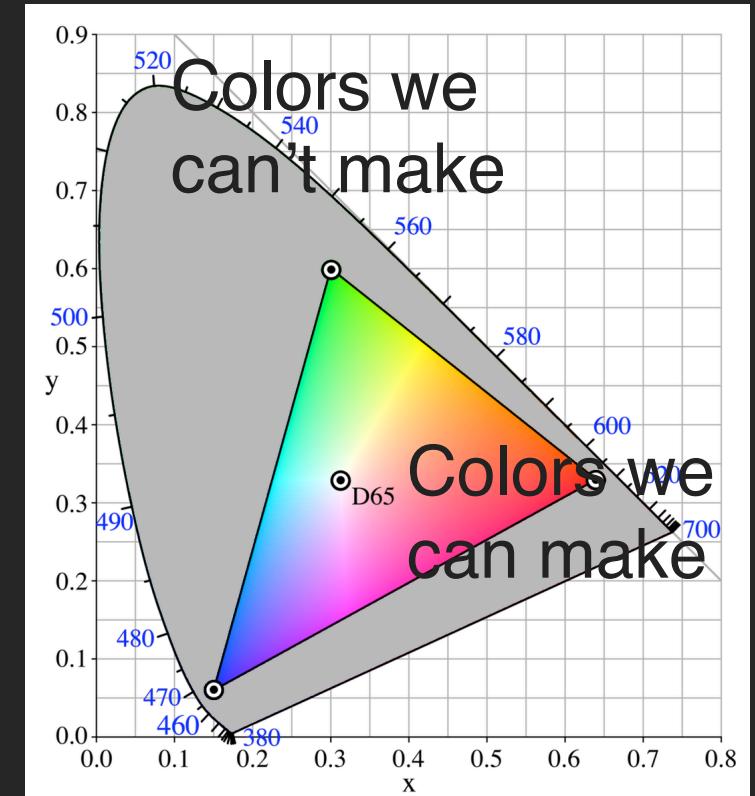
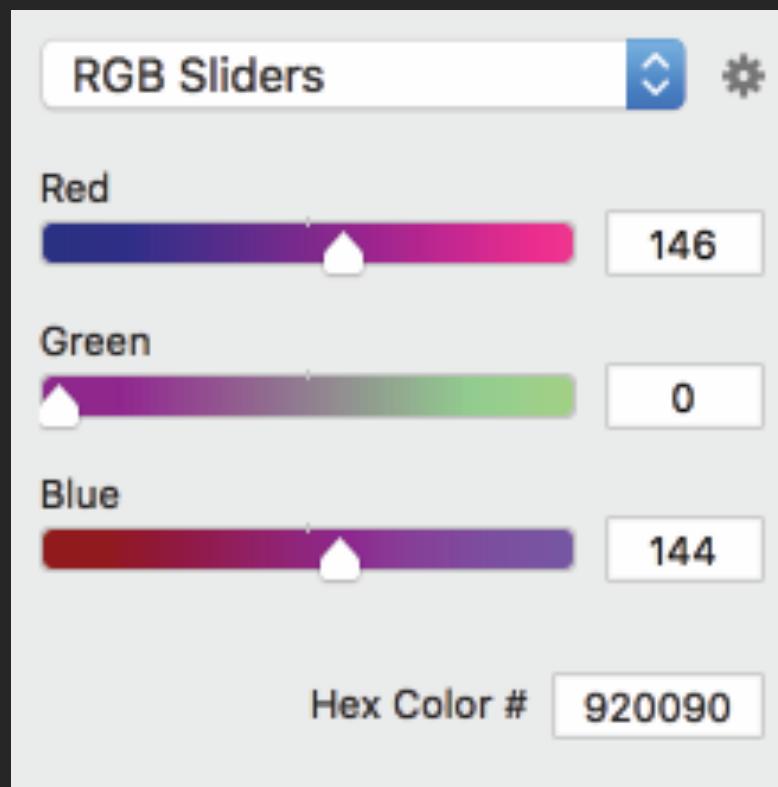
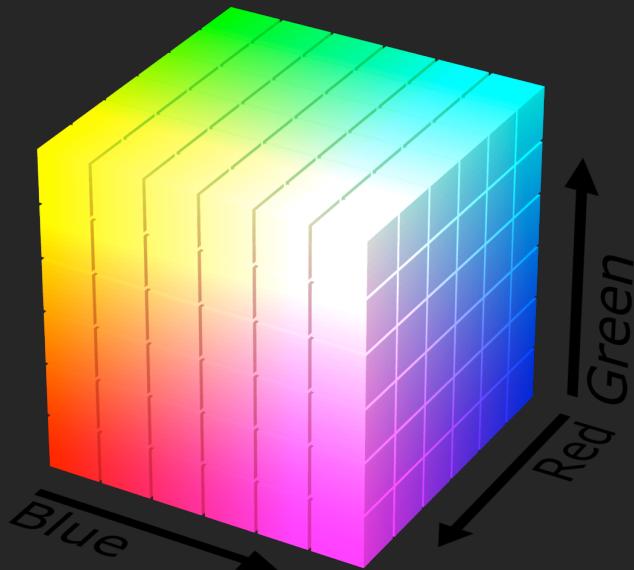
Computational representation of color



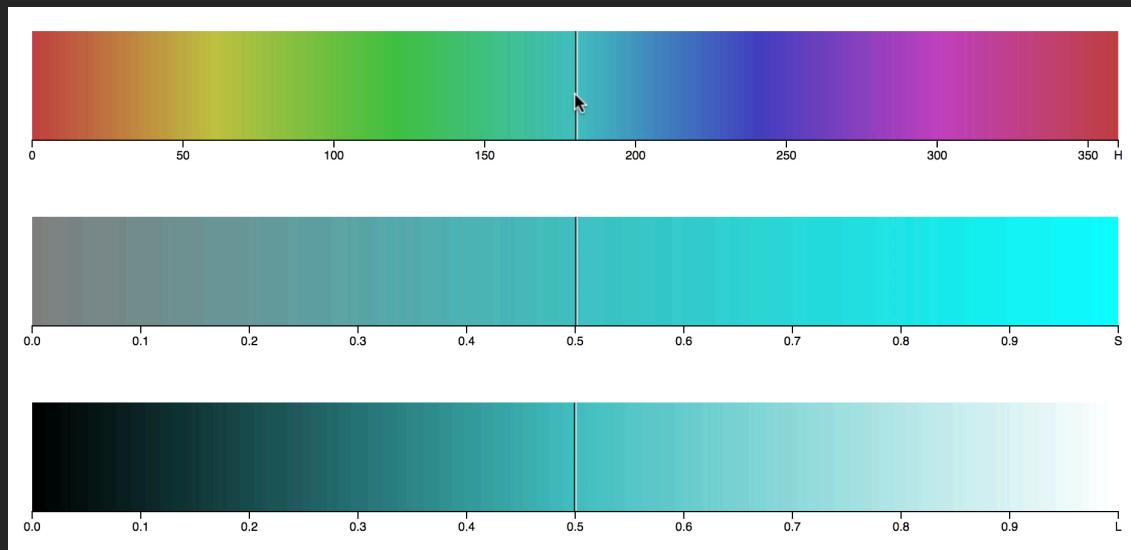
CMYK Color Space



RGB Color Space

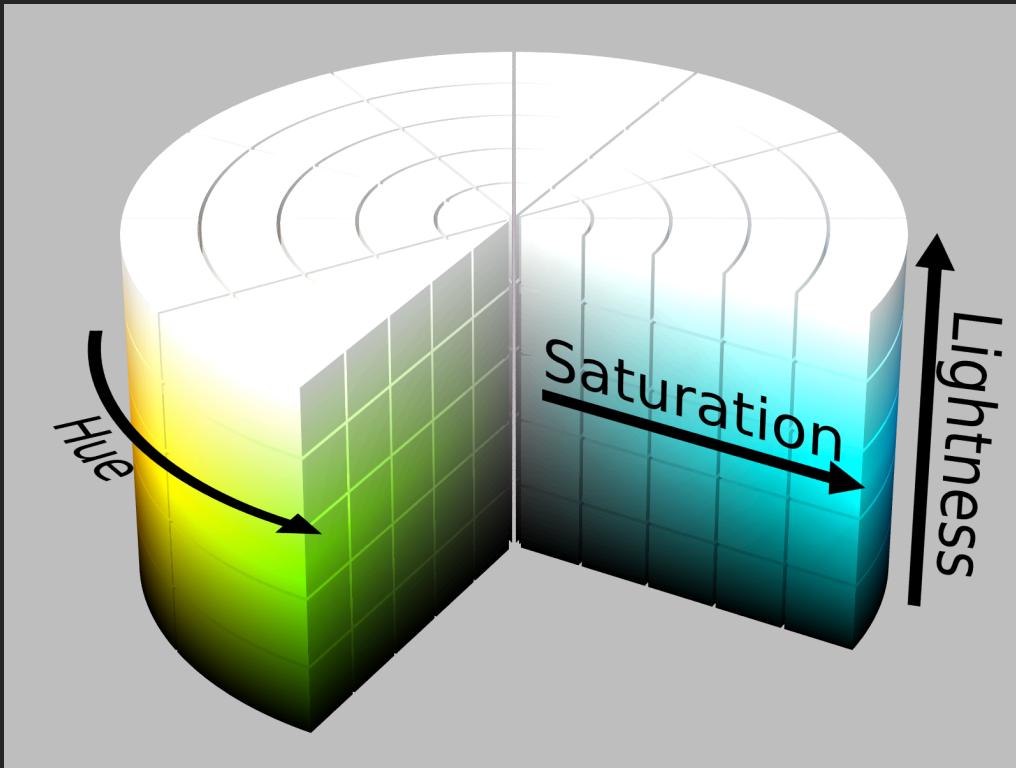


HSL Color Space



- H – Hue (the color, 0-360)
- S – Saturation (from neutral gray to full saturation – muted to vivid)
- L – Lightness (from black to white)

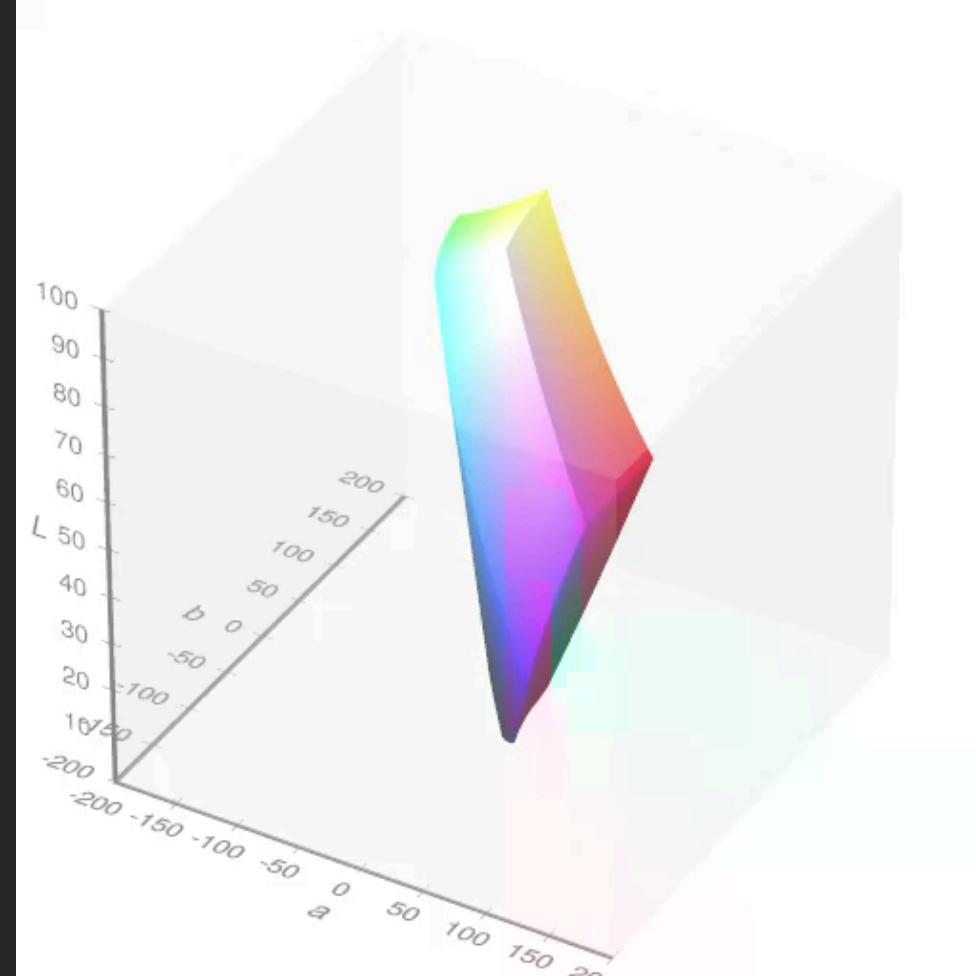
HSL Color Space



- H – Hue (the color, 0-360)
- S – Saturation (from neutral gray to full saturation)
- L – Lightness (from black to white)

CIELAB Color Space

- Better models perception
- l^* - lightness (0 to 100)
- a^* - red to green (negative to positive)
- b^* - yellow to blue (negative to positive)
- Non-linear, 3D but *perceptual* distances preserved



Which one to work with

- RGB/CMYK – easier to think about but device dependent
- Lab – hard to reason about, but more accurate to human perception
- HSL – designed to be aligned to perception but distances inaccurate

Color schemes for visualization

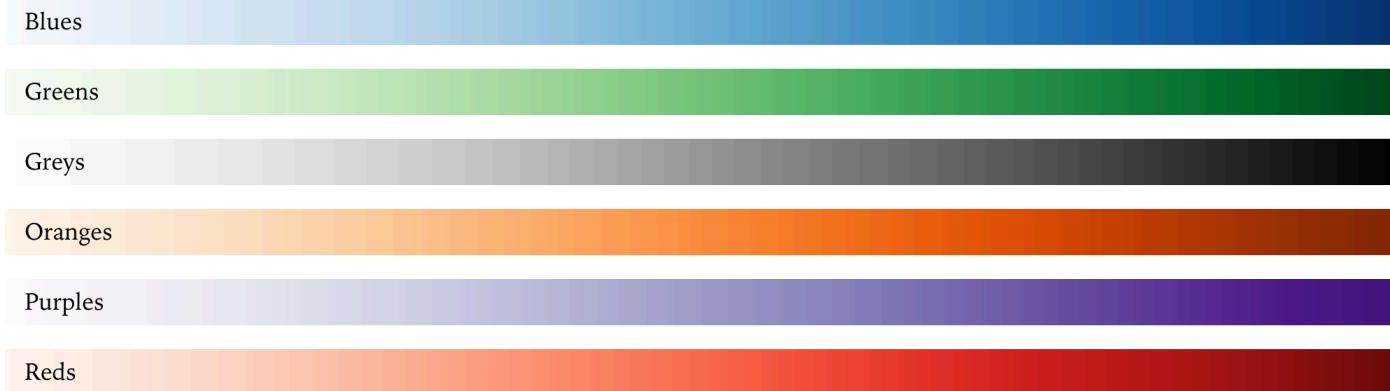
Picking colors

- For ordered data –
 - Luminance in HSL space
 - (Possibly not grayscale)
 - Saturation can work
 - not as easily discernible and interacts
- For nominal data
 - Hue

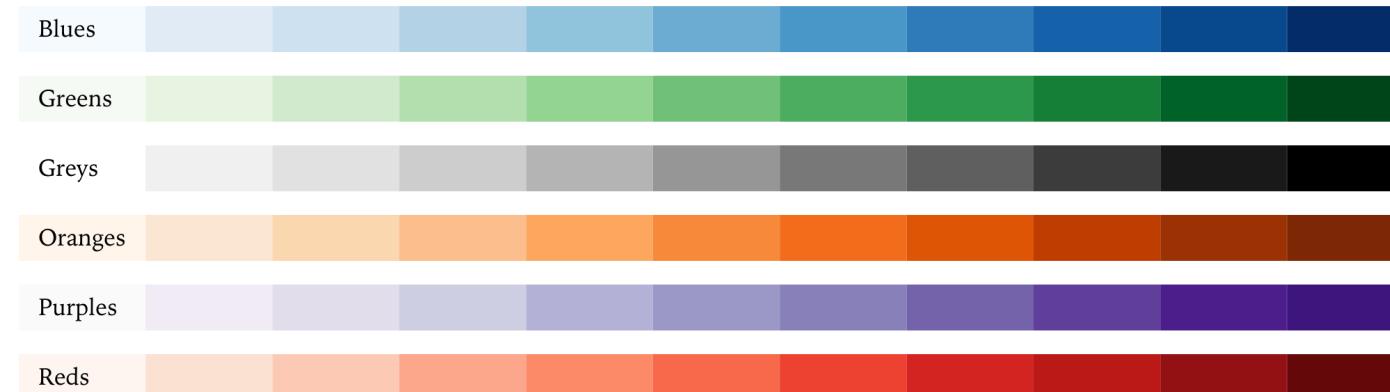


Segmented Versus Contiguous

Contiguous

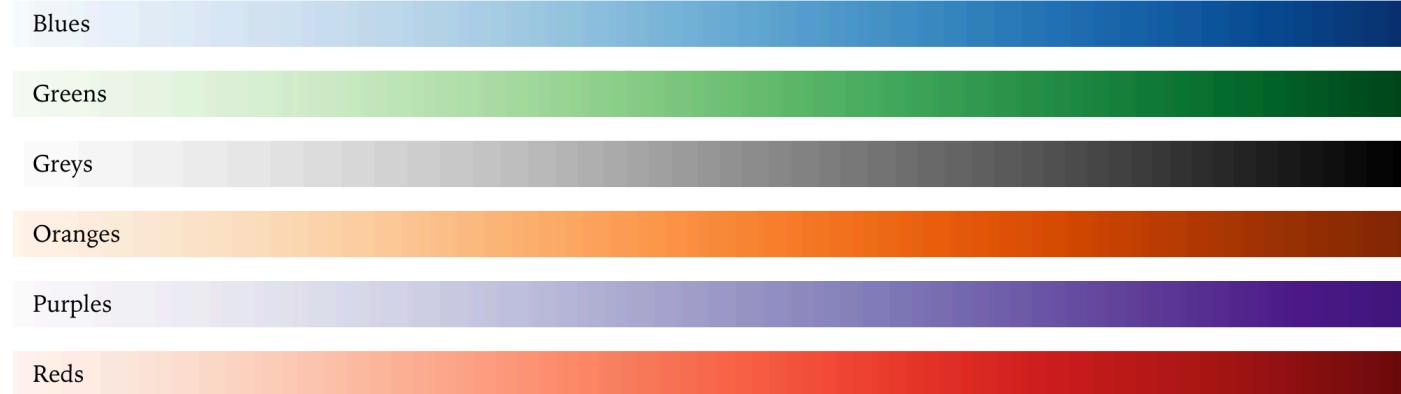


Segmented



Sequential versus Diverging

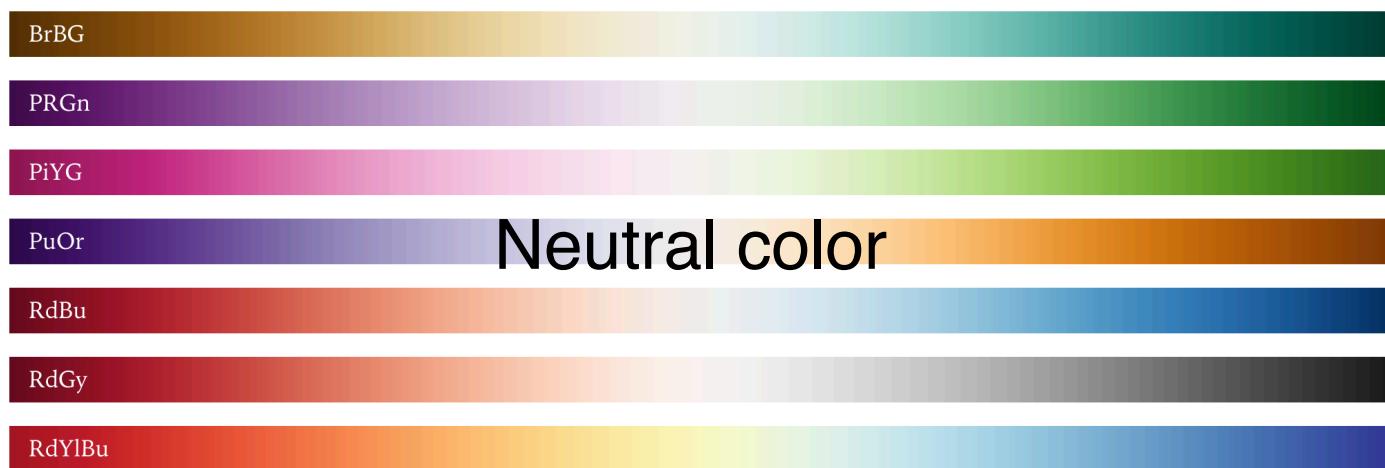
Sequential



Start color

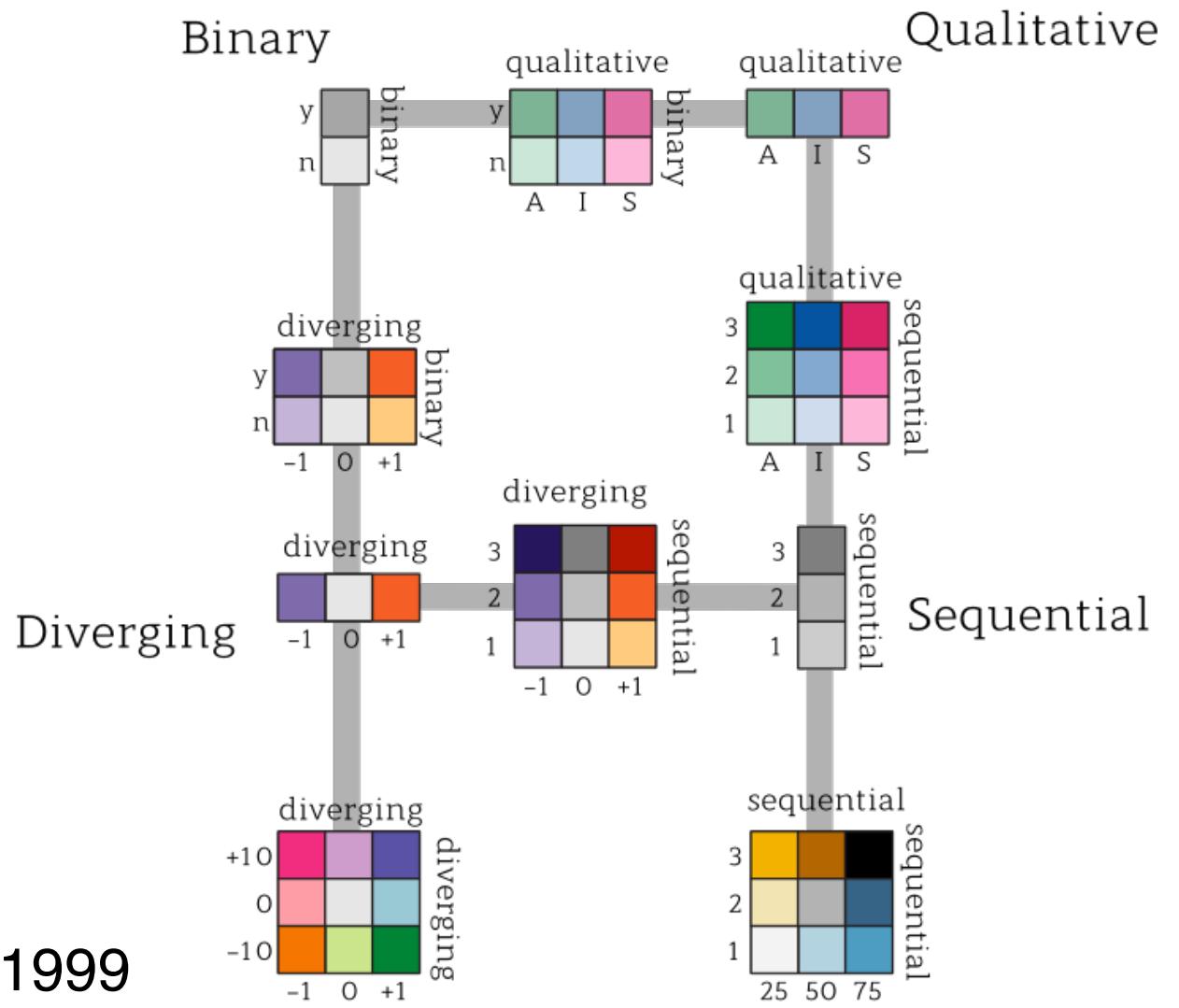
End color

Diverging



Bivariate

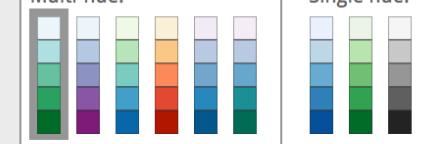
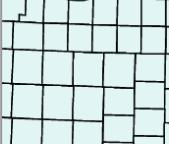
Brewer, 1999



Tools

Number of data classes: 3

Nature of your data:
 sequential diverging
 qualitative

Pick a color scheme:
 Multi-hue:  Single hue: 

Only show: colorblind safe print friendly photocopy safe

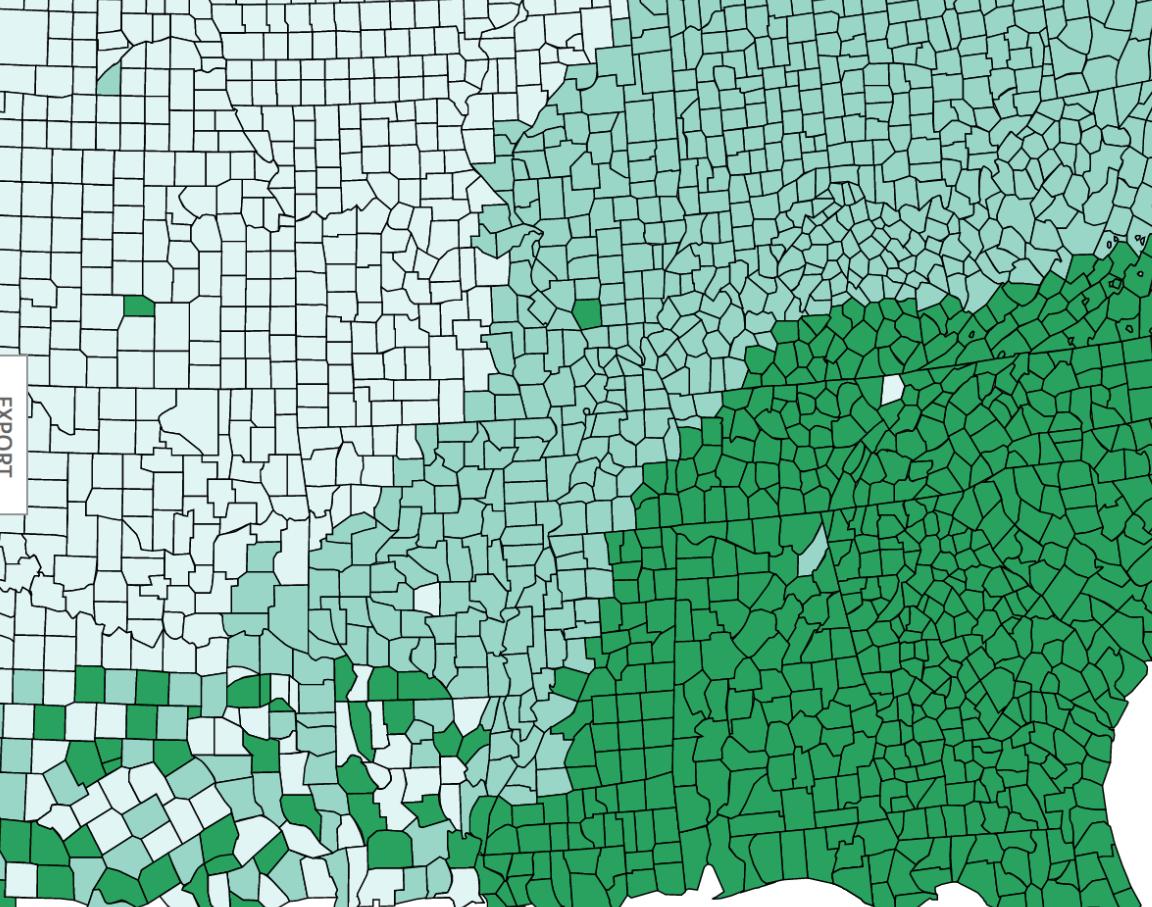
Context: roads cities borders

Background: solid color terrain
 color transparency

how to use | updates | downloads | credits

COLORBREWER 2.0

color advice for cartography



EXPORT

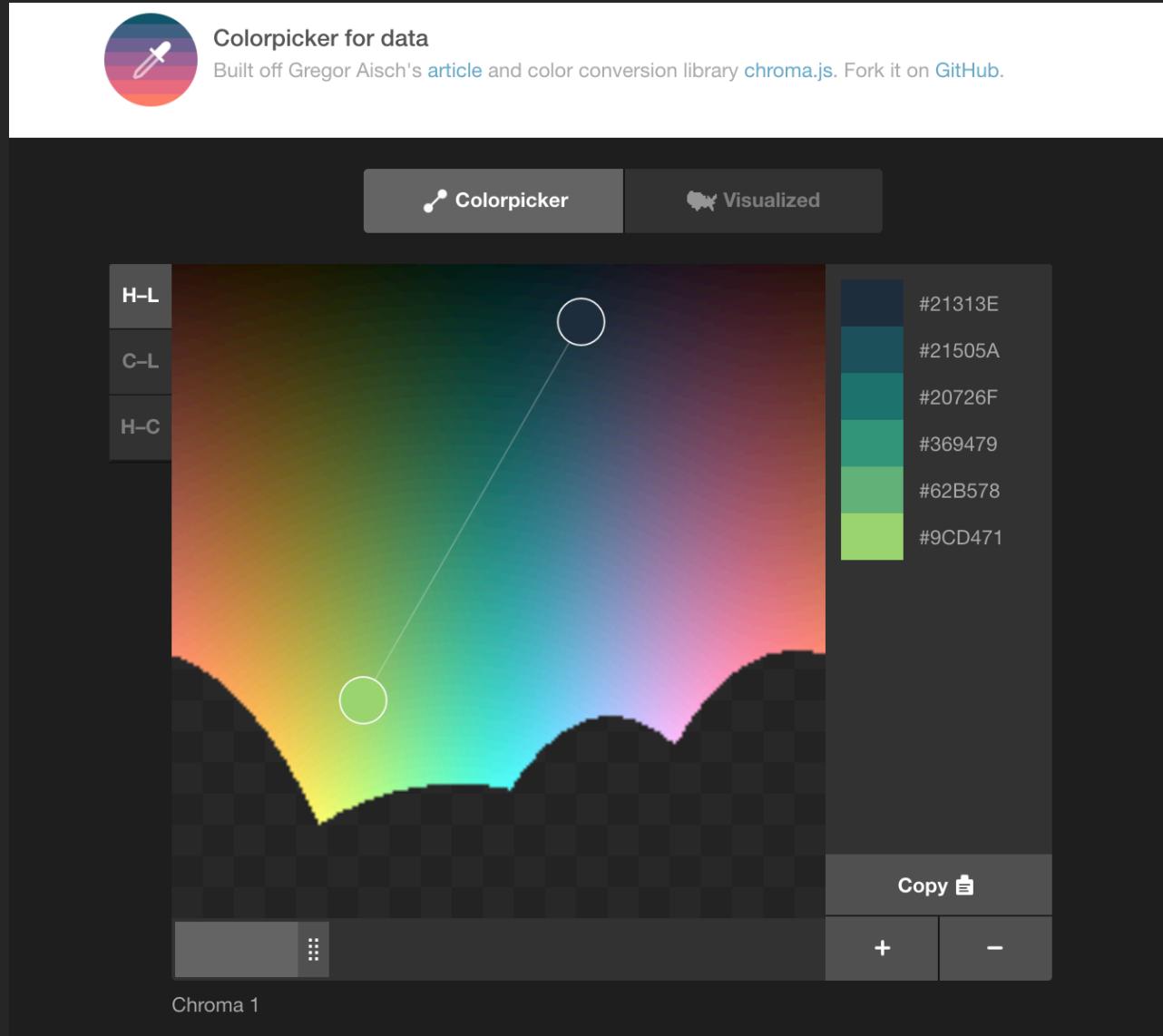
3-class BuGn

HEX

© Cynthia Brewer, Mark Harrower and The Pennsylvania State University



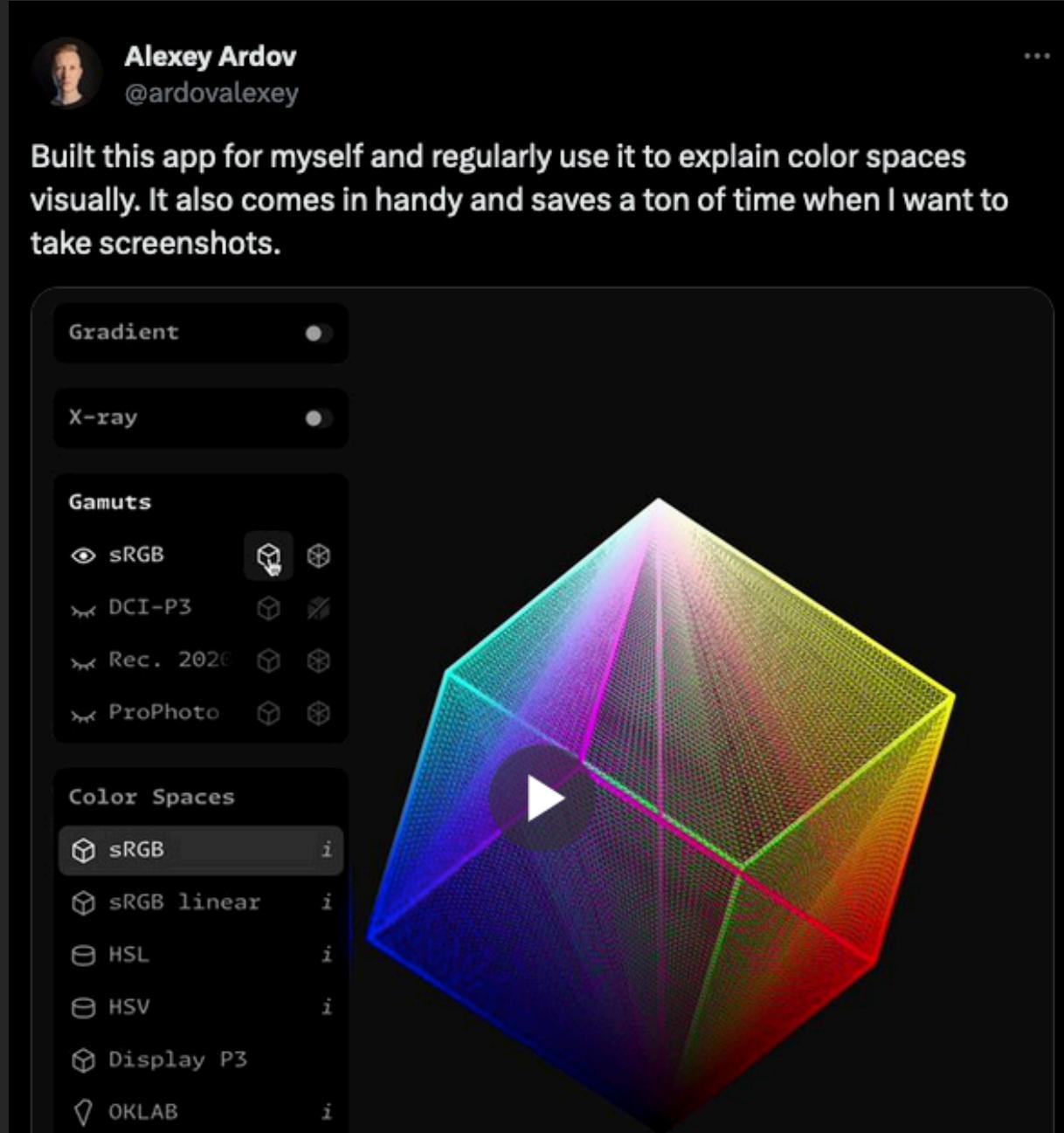
Color Brewer 2.0
<http://colorbrewer2.org>



Color Picker for Data
<http://tristen.ca/hcl-picker/>

Tools for exploration

<https://hueplot.ardov.me/>



Takeaways

- Many ways to model color
- Some better suited to different purposes
- Some better model human perception
- Make use of pre-designed and validated color choices for each task

Breakout:

Why is this
a good or
bad use of
color?

SANFORD AND SELNICK

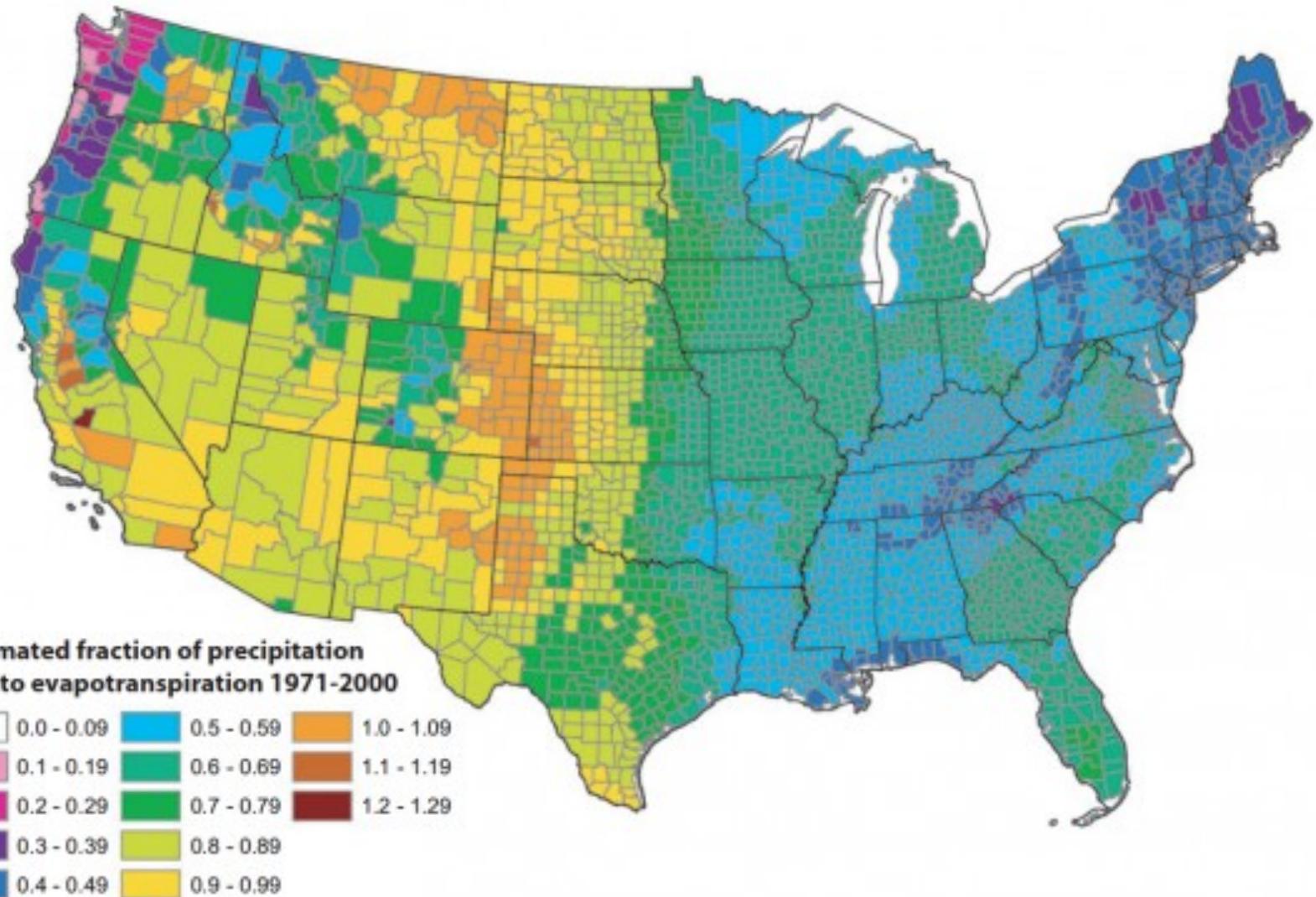


FIGURE 13. Estimated Mean Annual Ratio of Actual Evapotranspiration (ET) to Precipitation (P) for the Conterminous U.S. for the Period 1971-2000. Estimates are based on the regression equation in Table 1 that includes land cover. Calculations of ET/P were made first at the 800-m resolution of the PRISM climate data. The mean values for the counties (shown) were then calculated by averaging the 800-m values within each county. Areas with fractions >1 are agricultural counties that either import surface water or mine deep groundwater.

Breakout:

Why is this
a good or
bad use of
color?

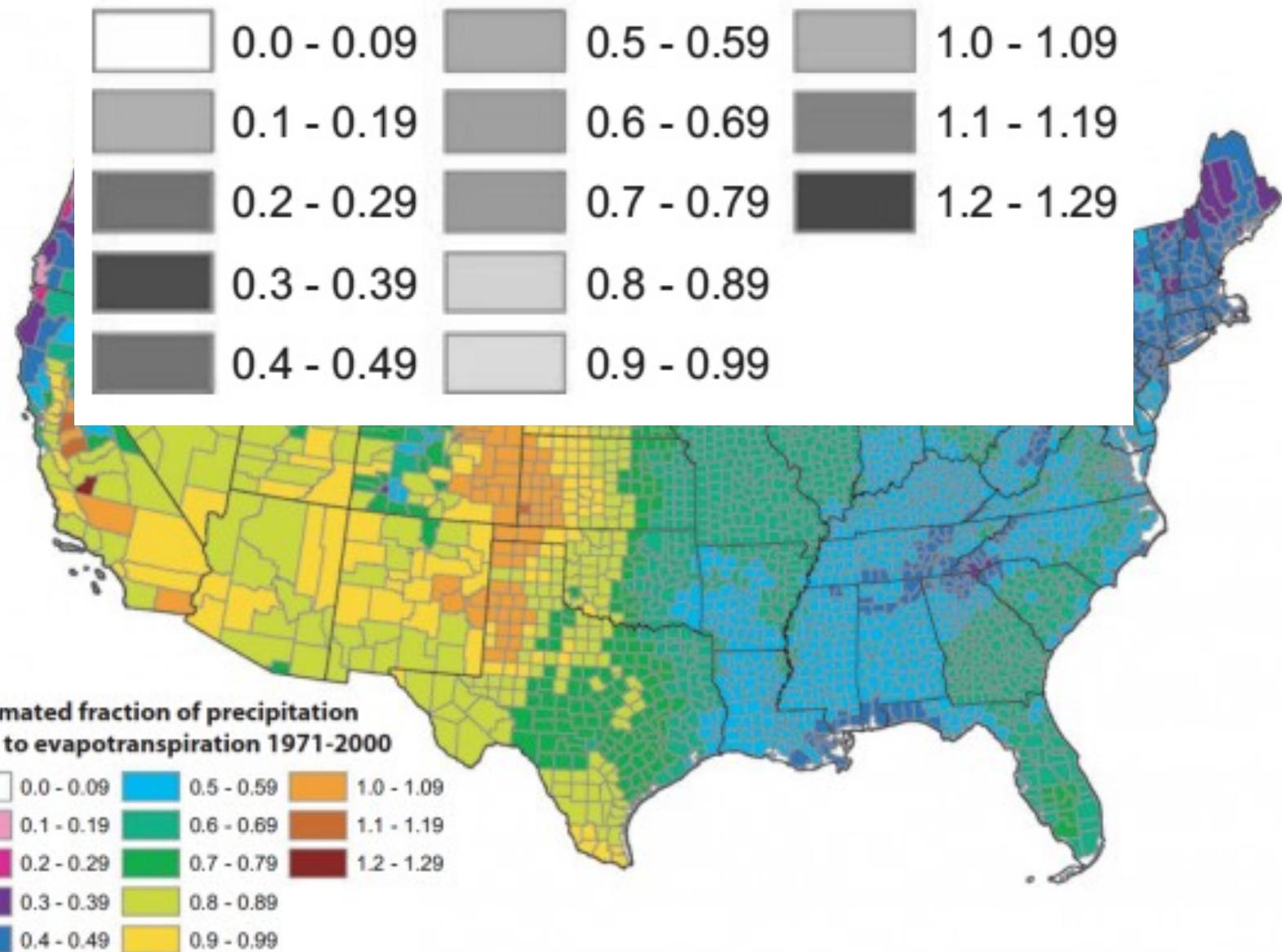
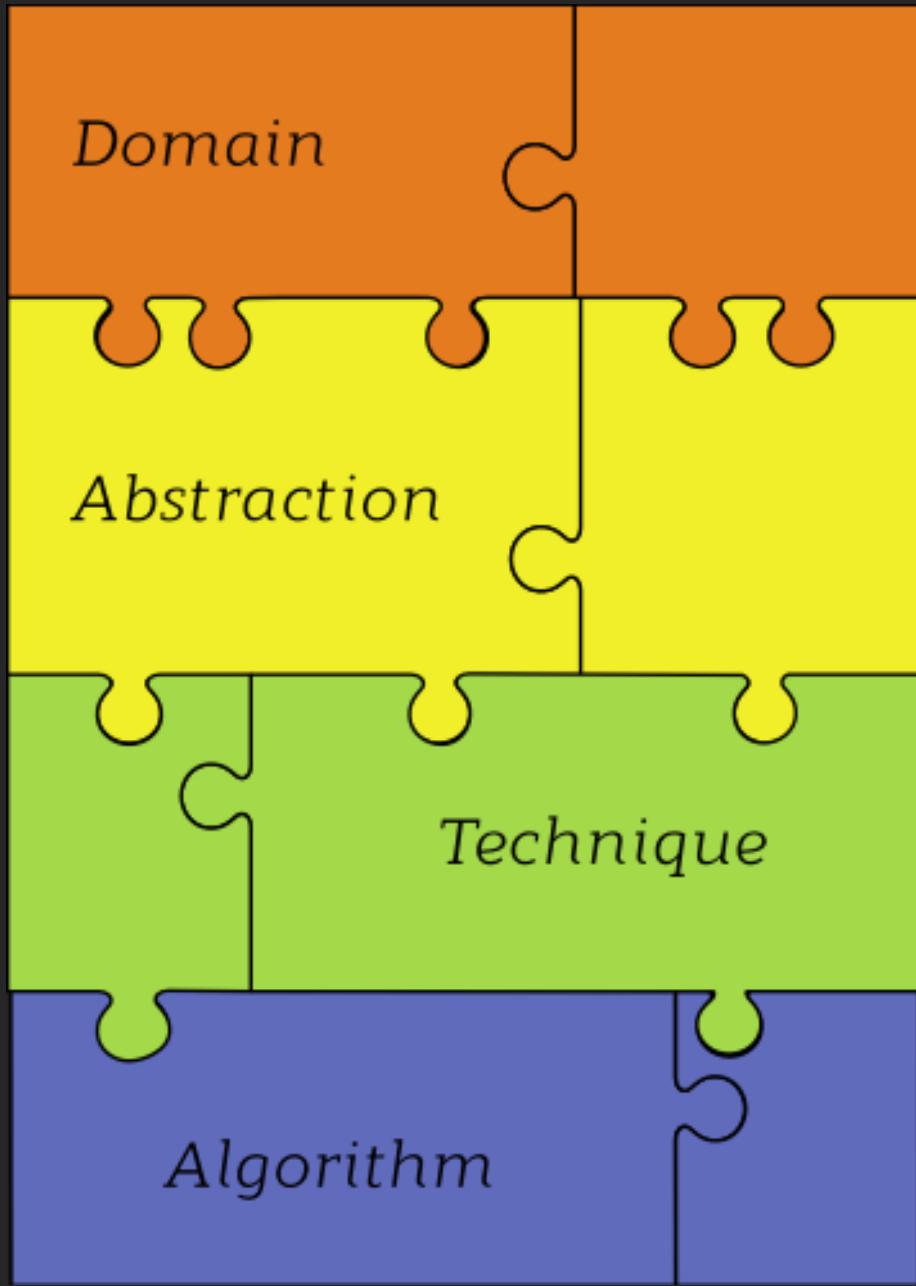


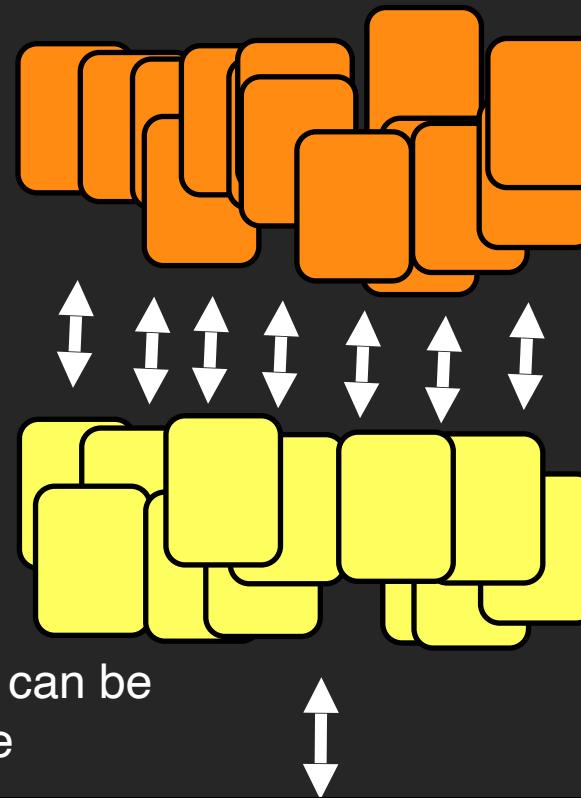
FIGURE 13. Estimated Mean Annual Ratio of Actual Evapotranspiration (ET) to Precipitation (P) for the Conterminous U.S. for the Period 1971-2000. Estimates are based on the regression equation in Table 1 that includes land cover. Calculations of ET/P were made first at the 800-m resolution of the PRISM climate data. The mean values for the counties (shown) were then calculated by averaging the 800-m values within each county. Areas with fractions >1 are agricultural counties that either import surface water or mine deep groundwater.

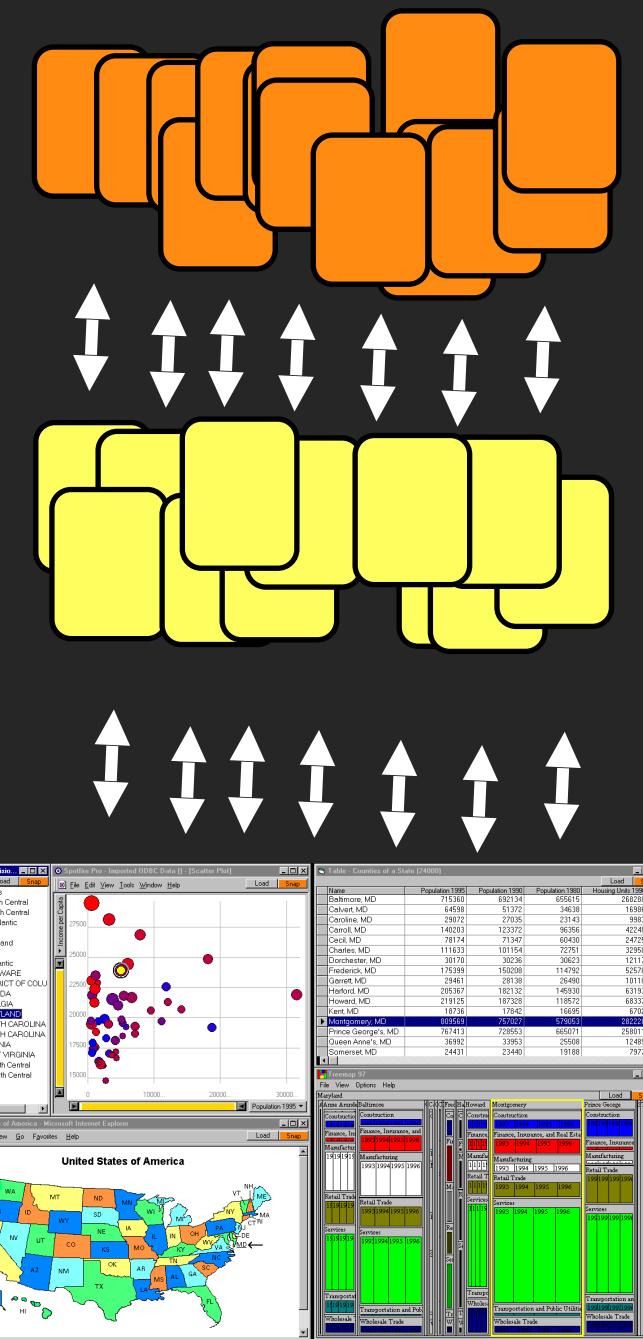
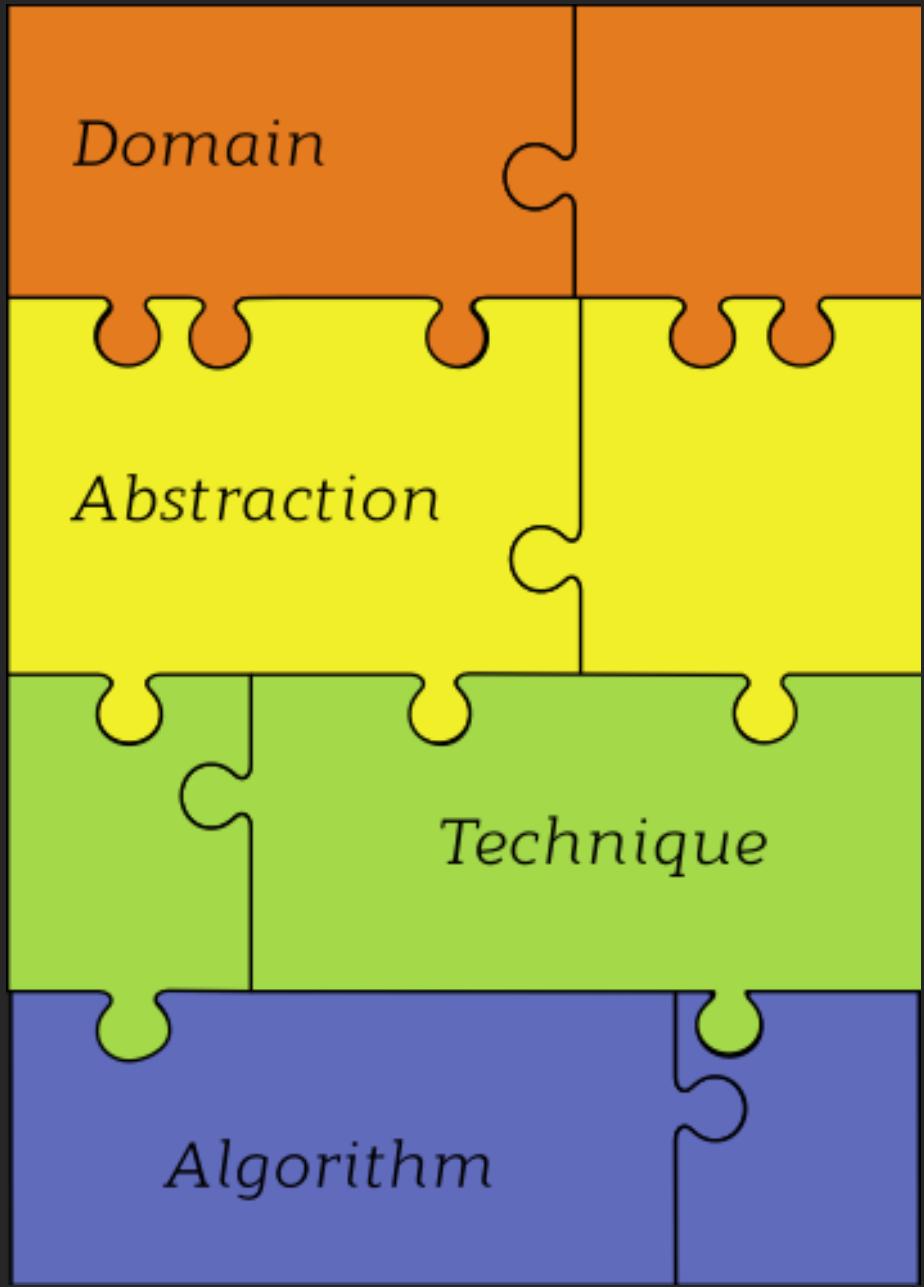
Interaction

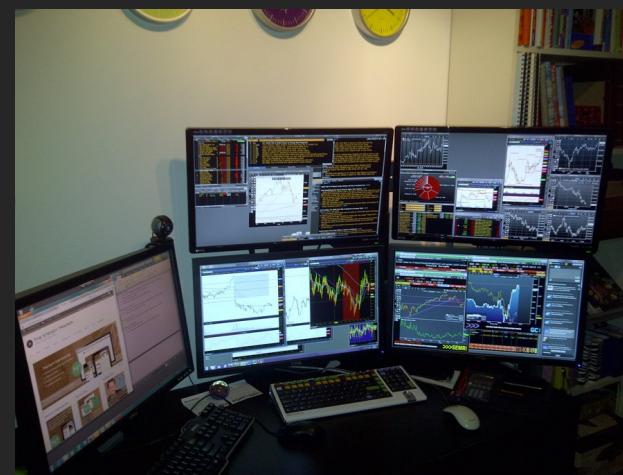
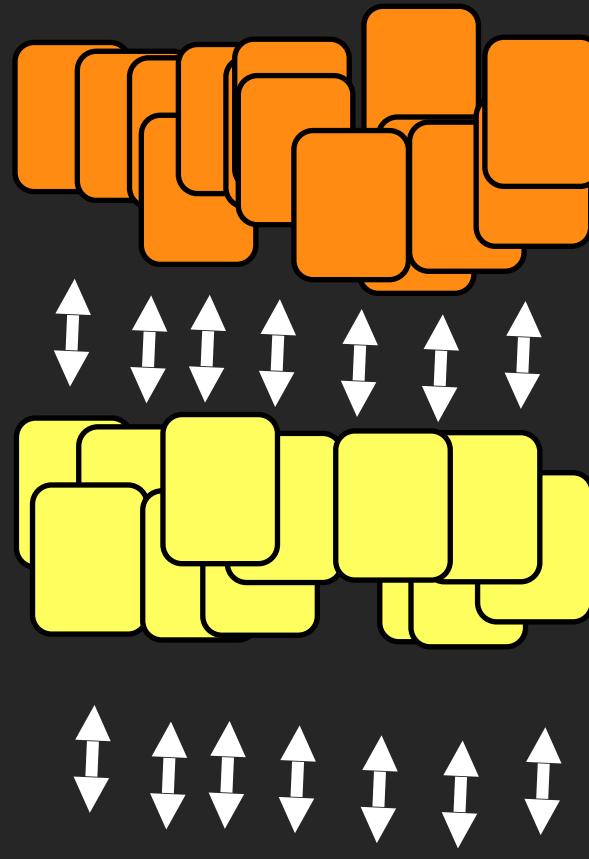
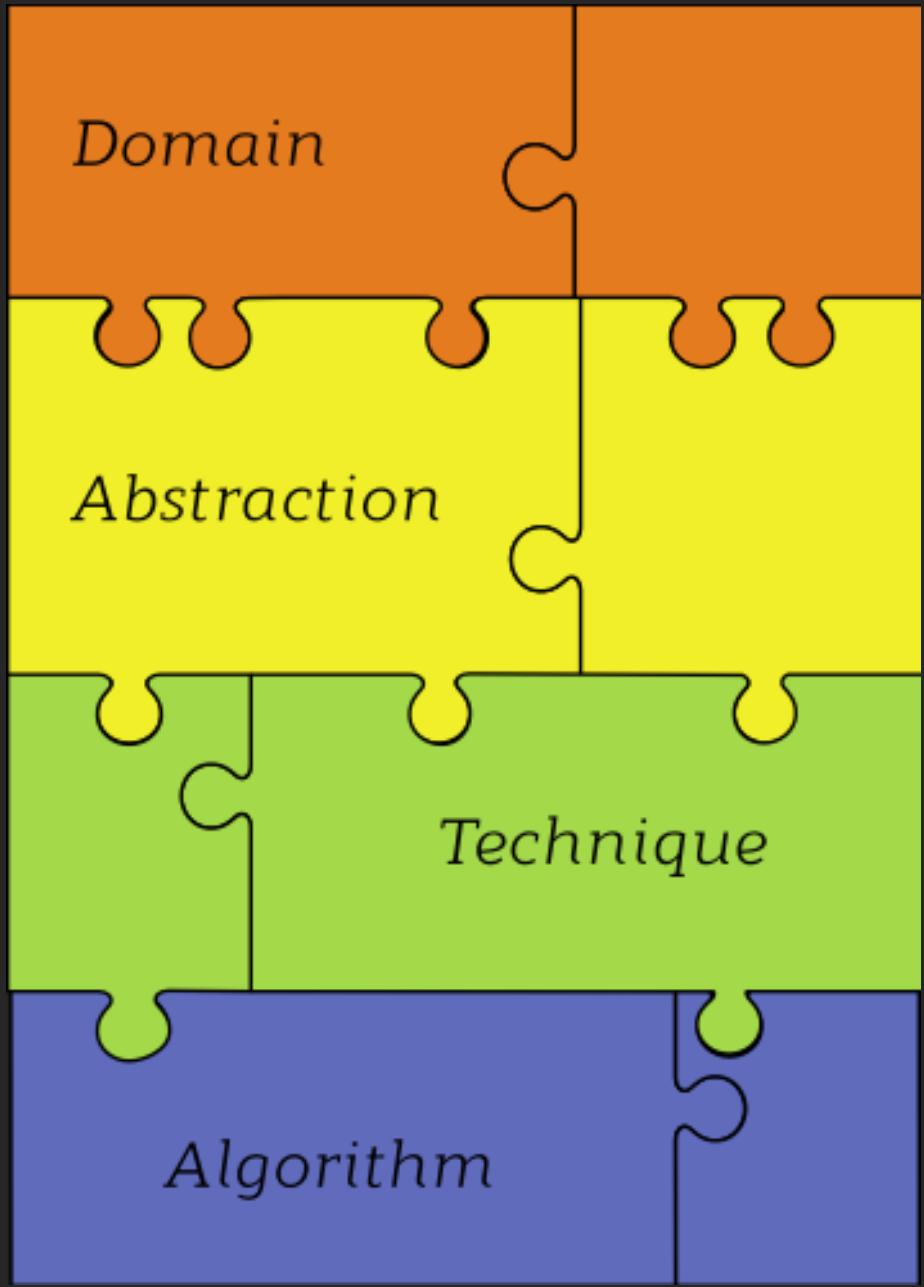


All comparisons can be supported in one display

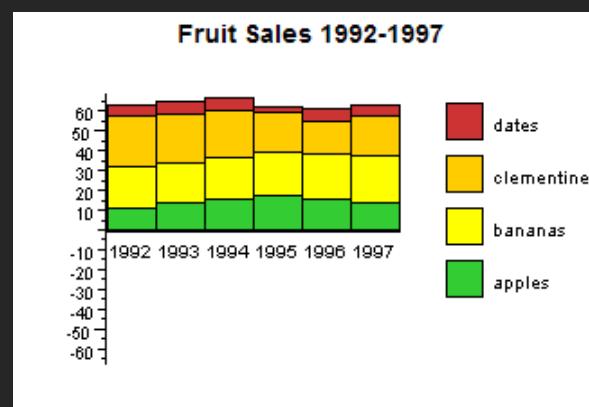
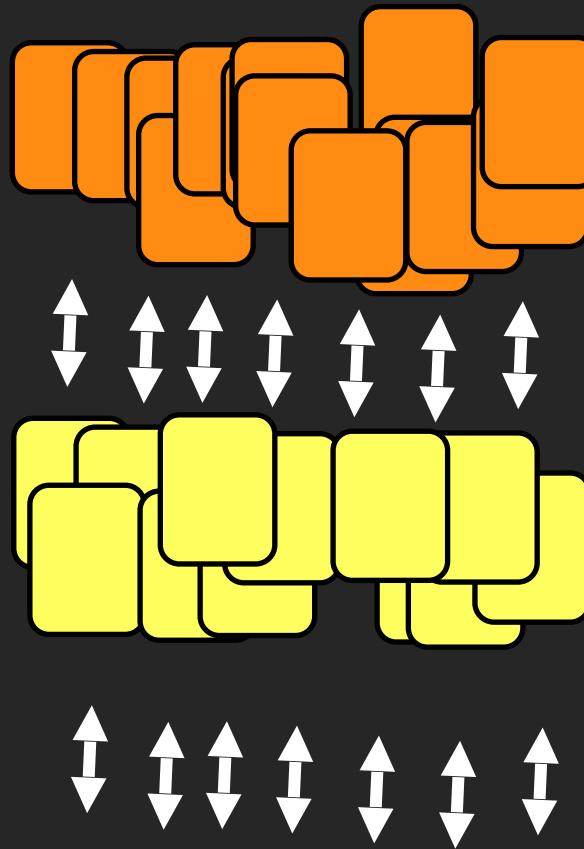
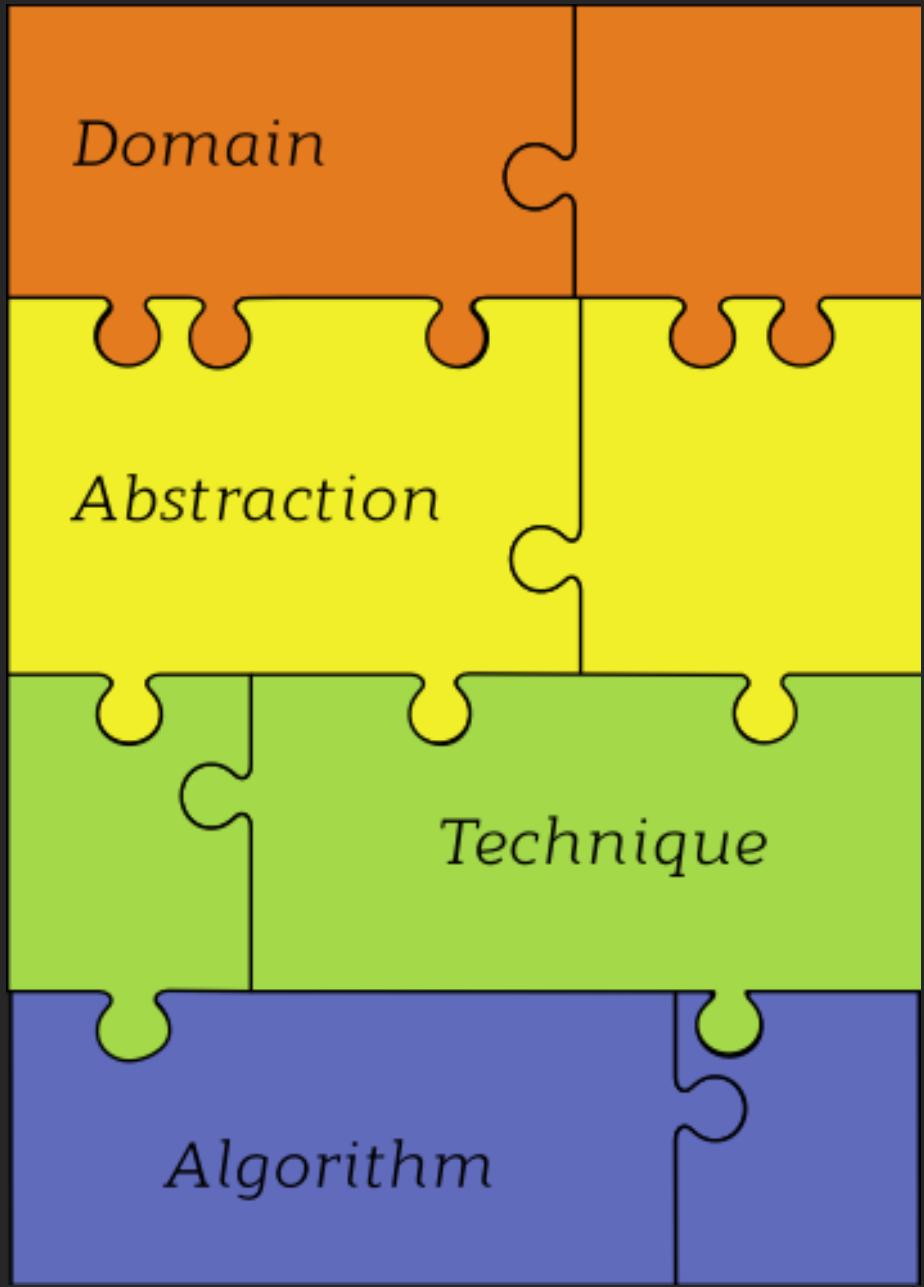
Simplest, cleanest representation possible that still has all the data





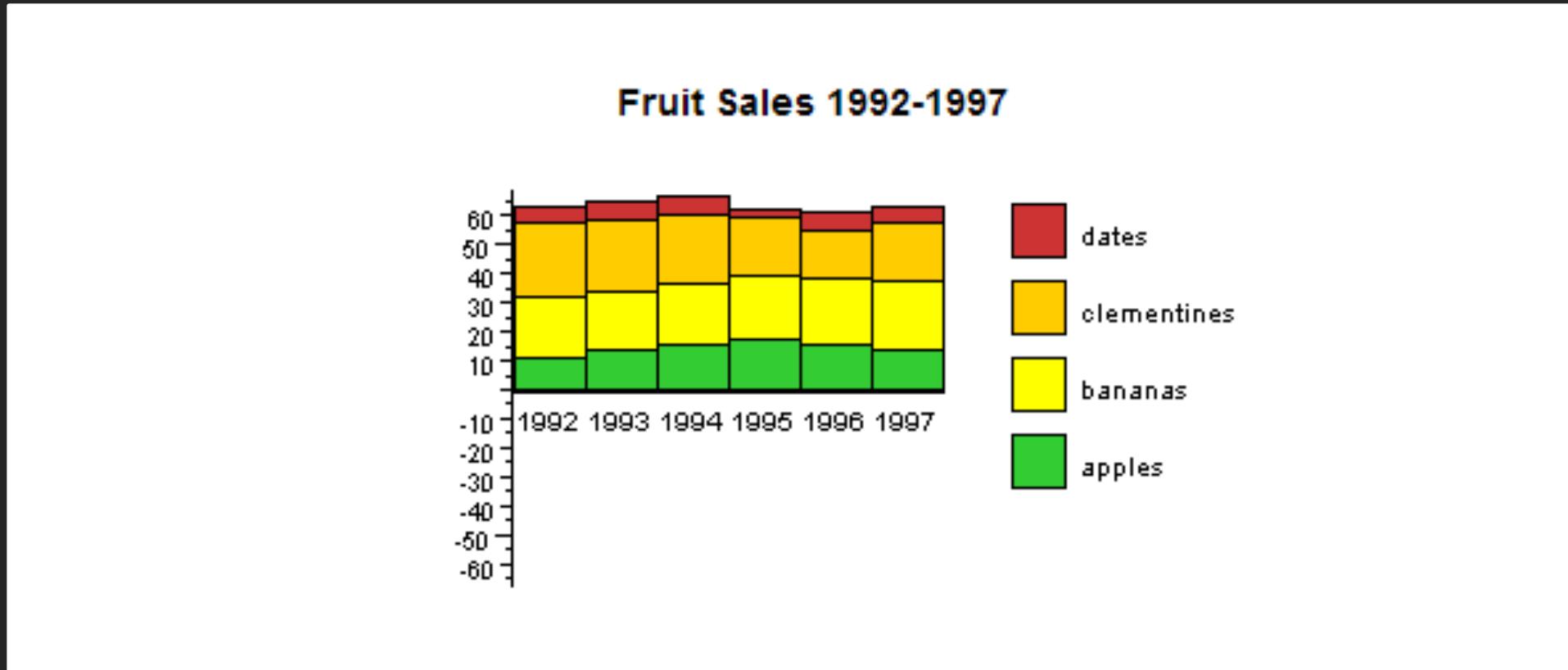


Make this more
effective/expressive



Make this more effective/expressive

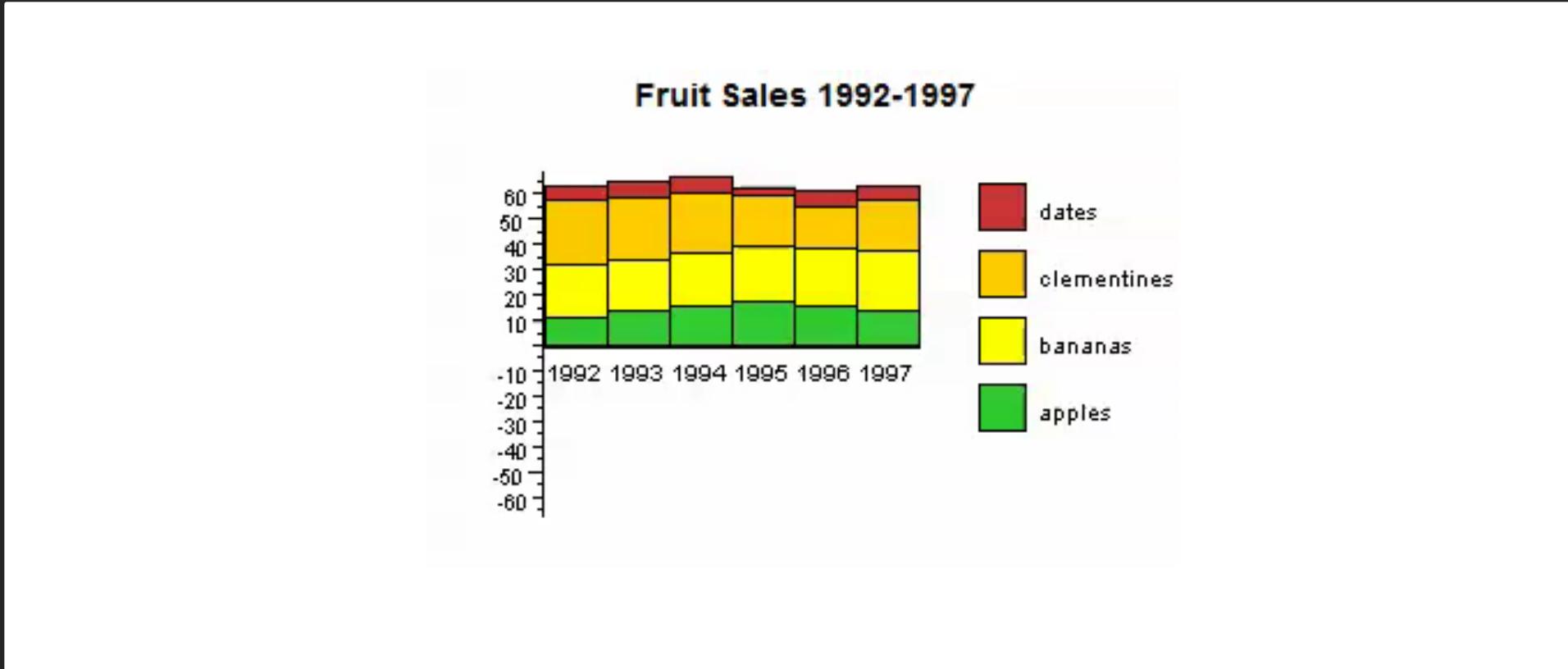
Small changes, big improvements



Stacked/Dancing Histograms

<http://www.meandeviation.com/dancing-histograms/hist.html>

Small changes, big improvements



Stacked/Dancing Histograms

<http://www.meandeviation.com/dancing-histograms/hist.html>

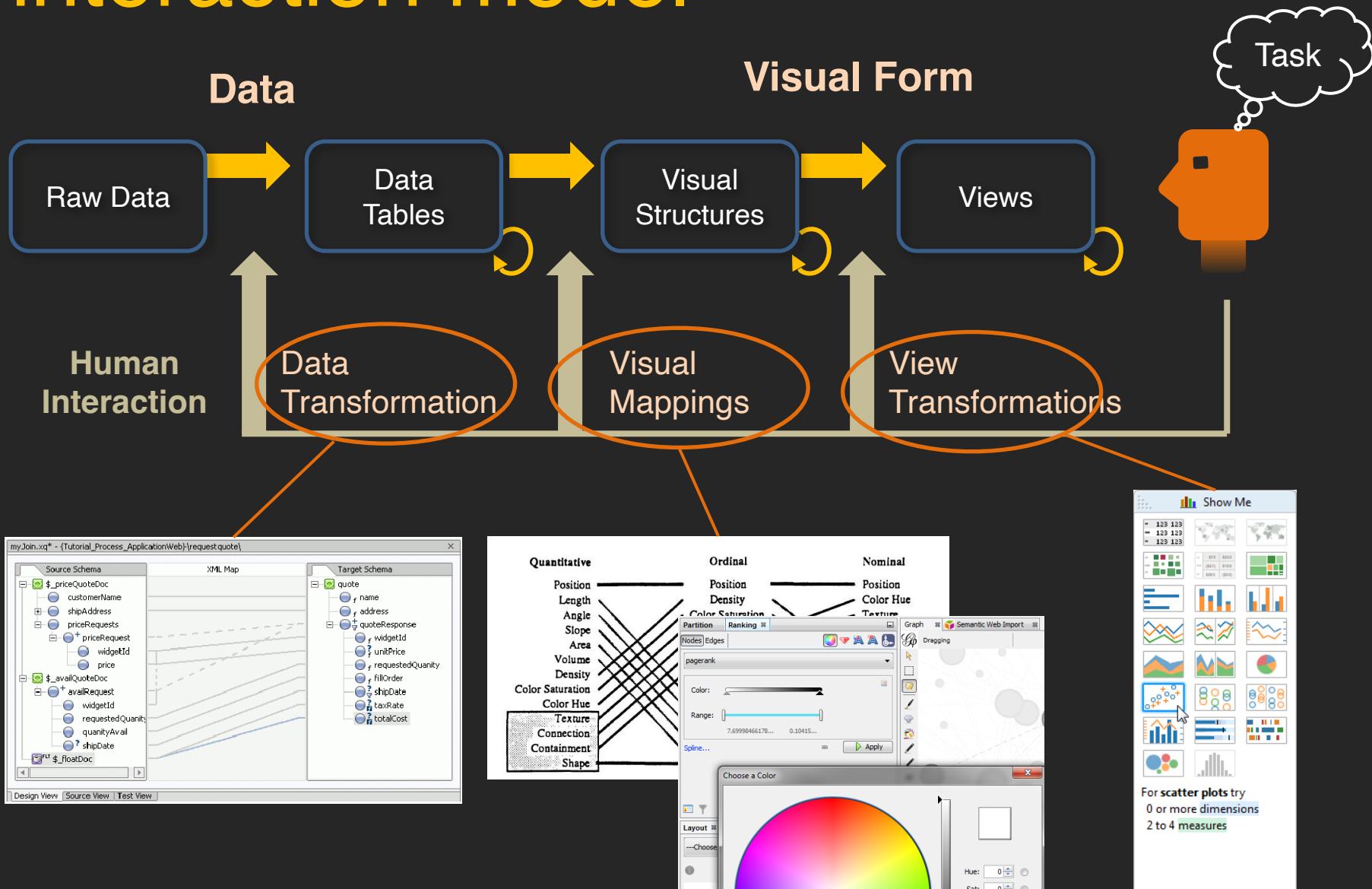


Interaction is a power booster!



Let's us make more comparisons and
make them better

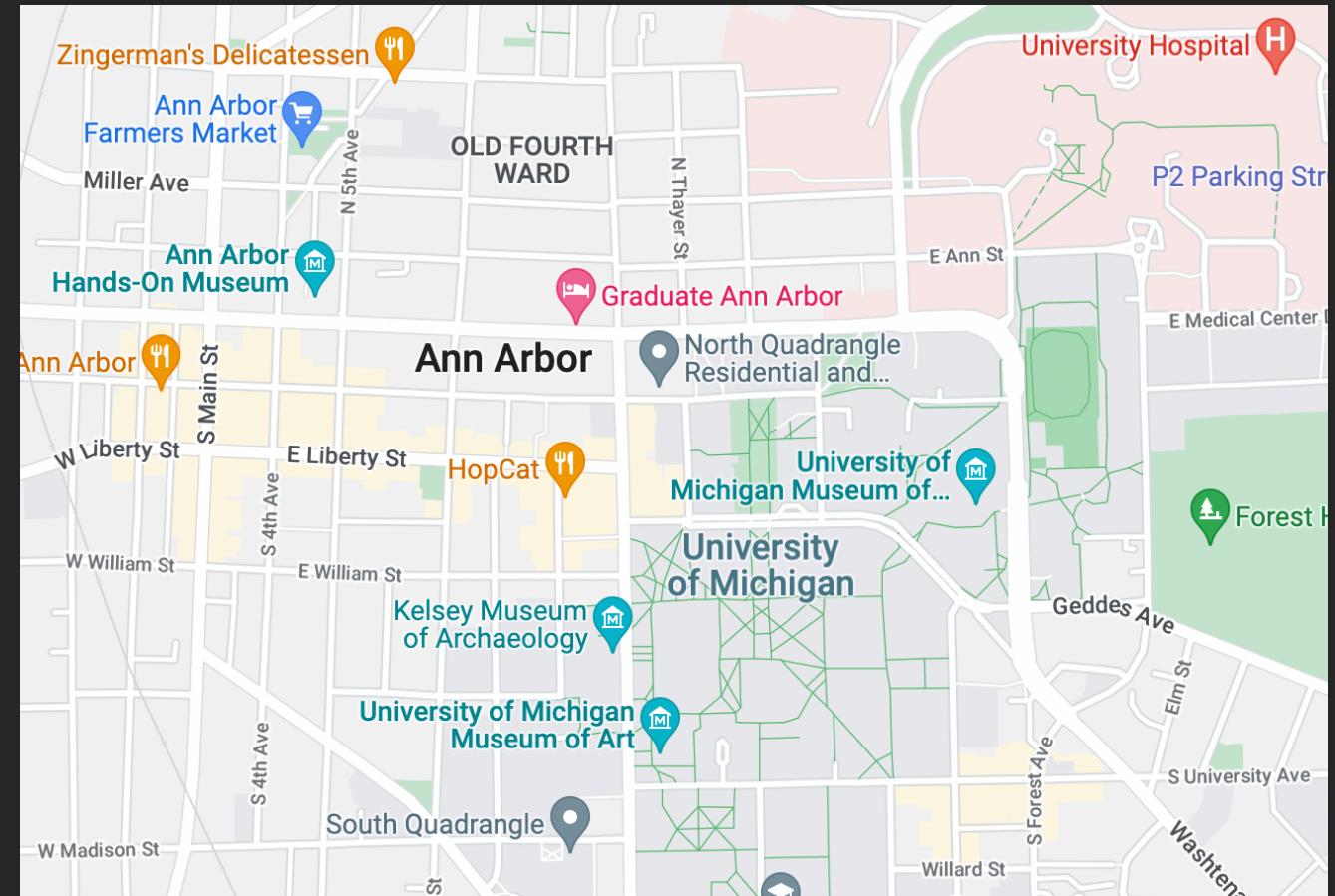
The interaction model

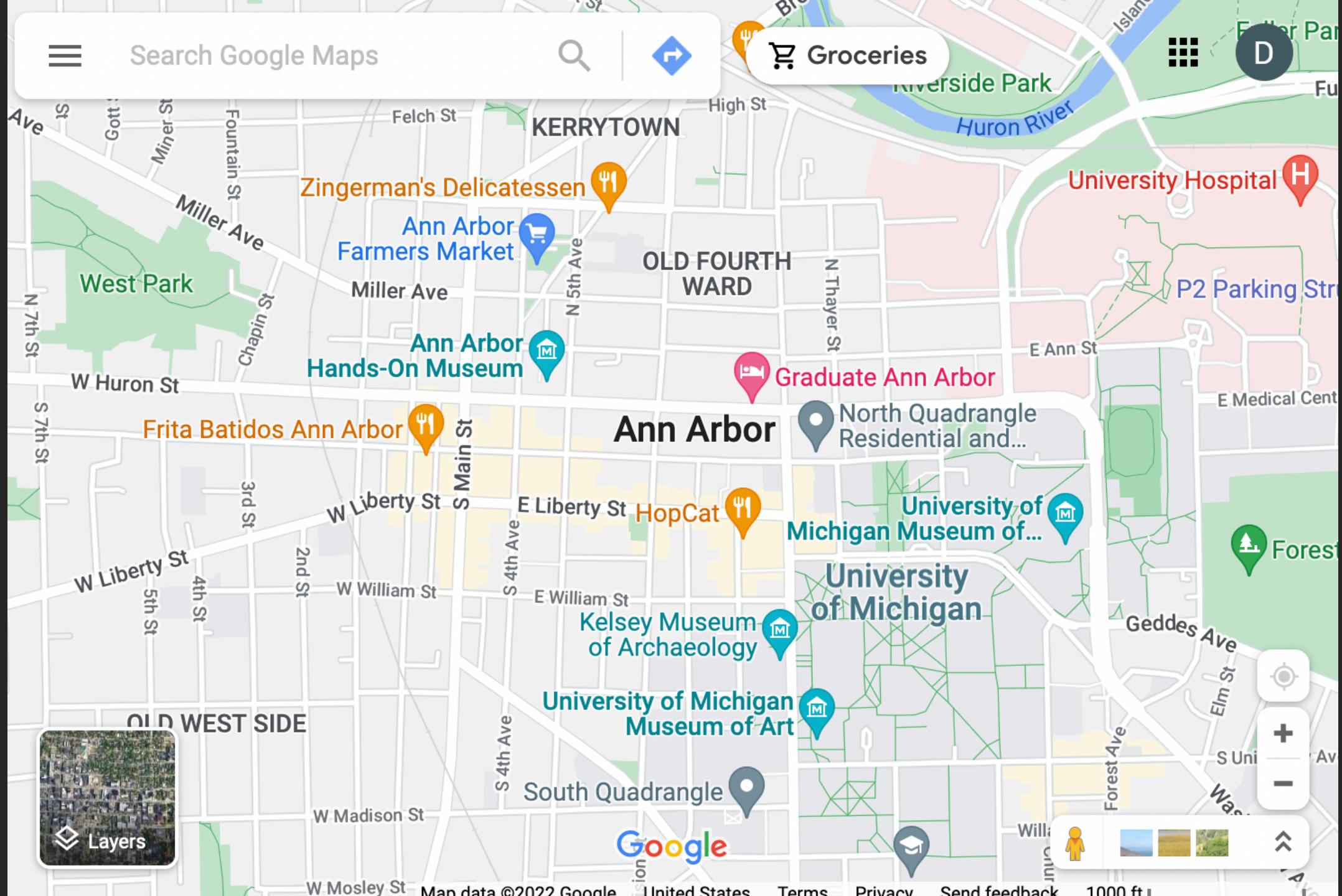


Conventional Vis Interaction

- Communication between user and computer
- Direct manipulation
- Immediate response
- Expanded space of possibilities (but still constrained)

Brainstorming: What kinds of interactivity does Google Maps support?





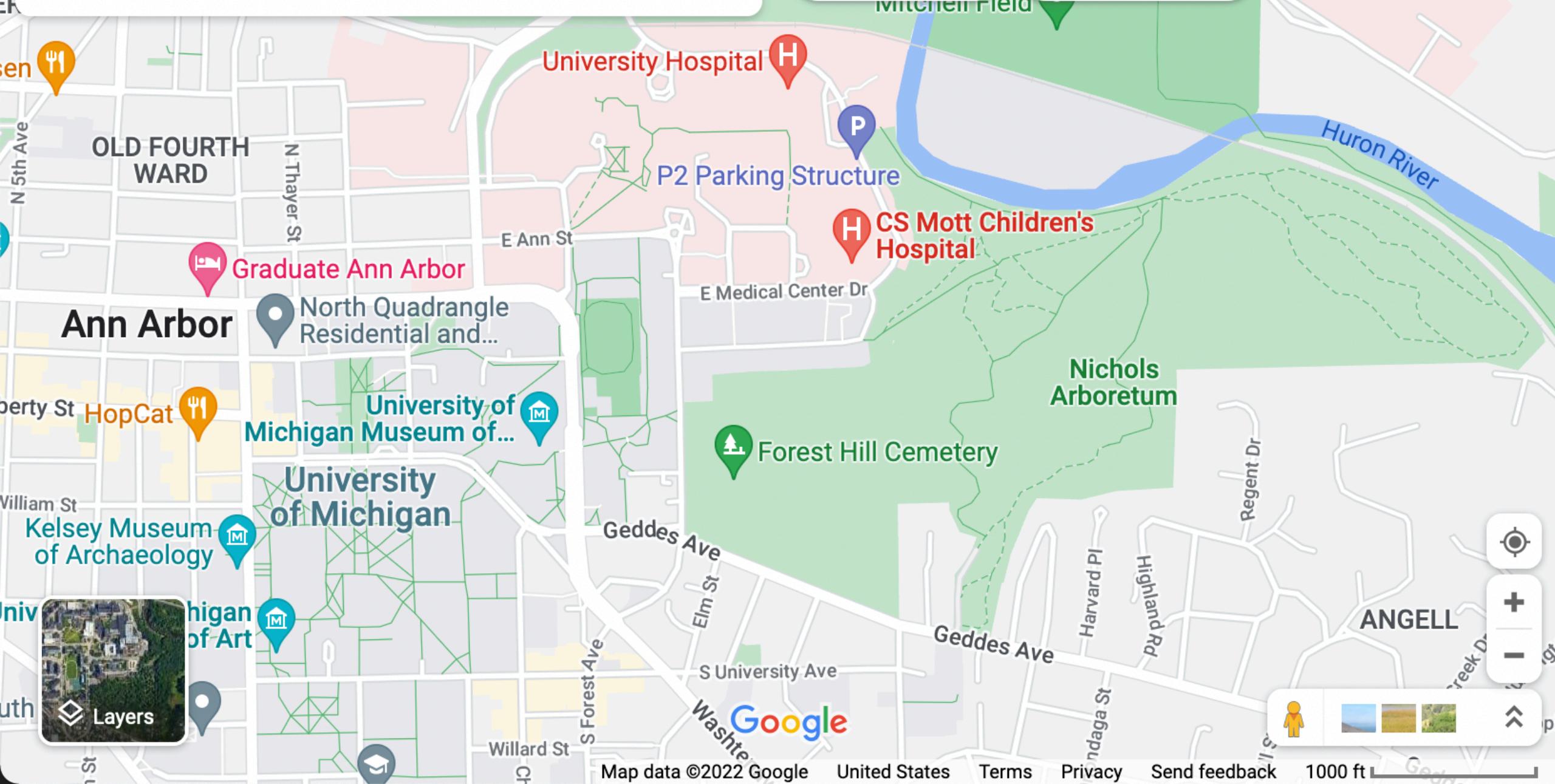


Search Google Maps



Groceries

Restaurants

VA Ann Arbor
Healthcare System

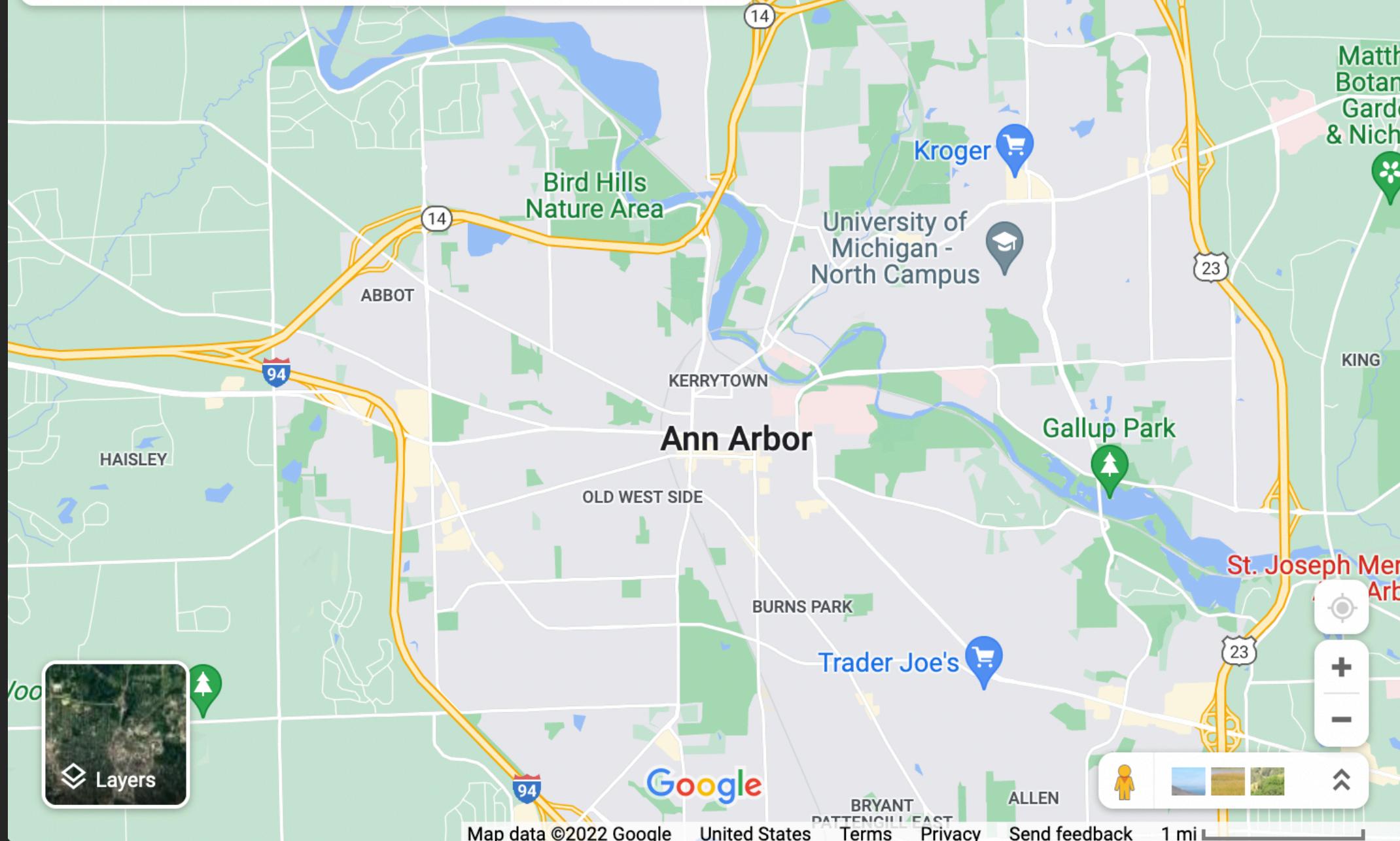


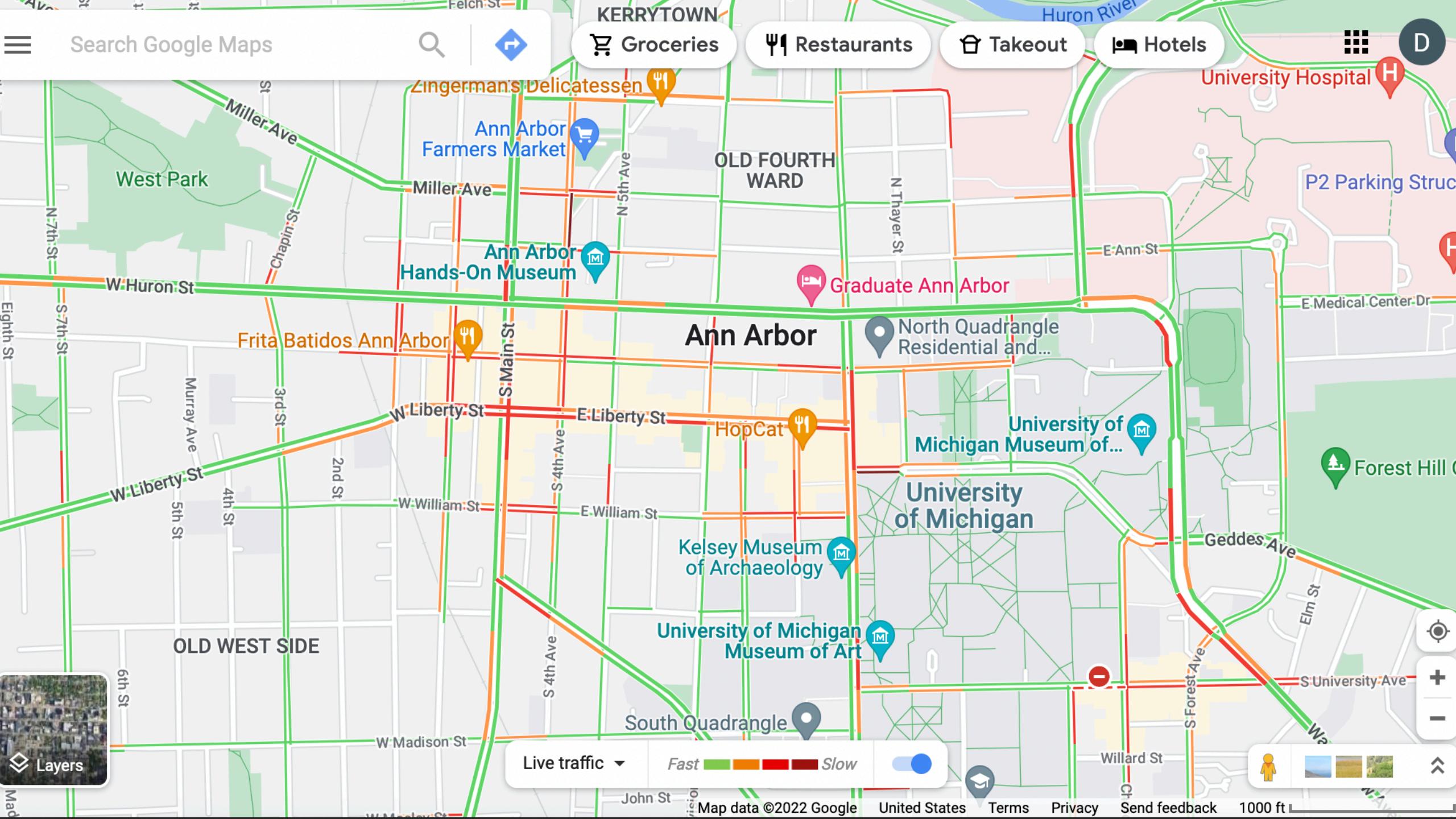
Search Google Maps

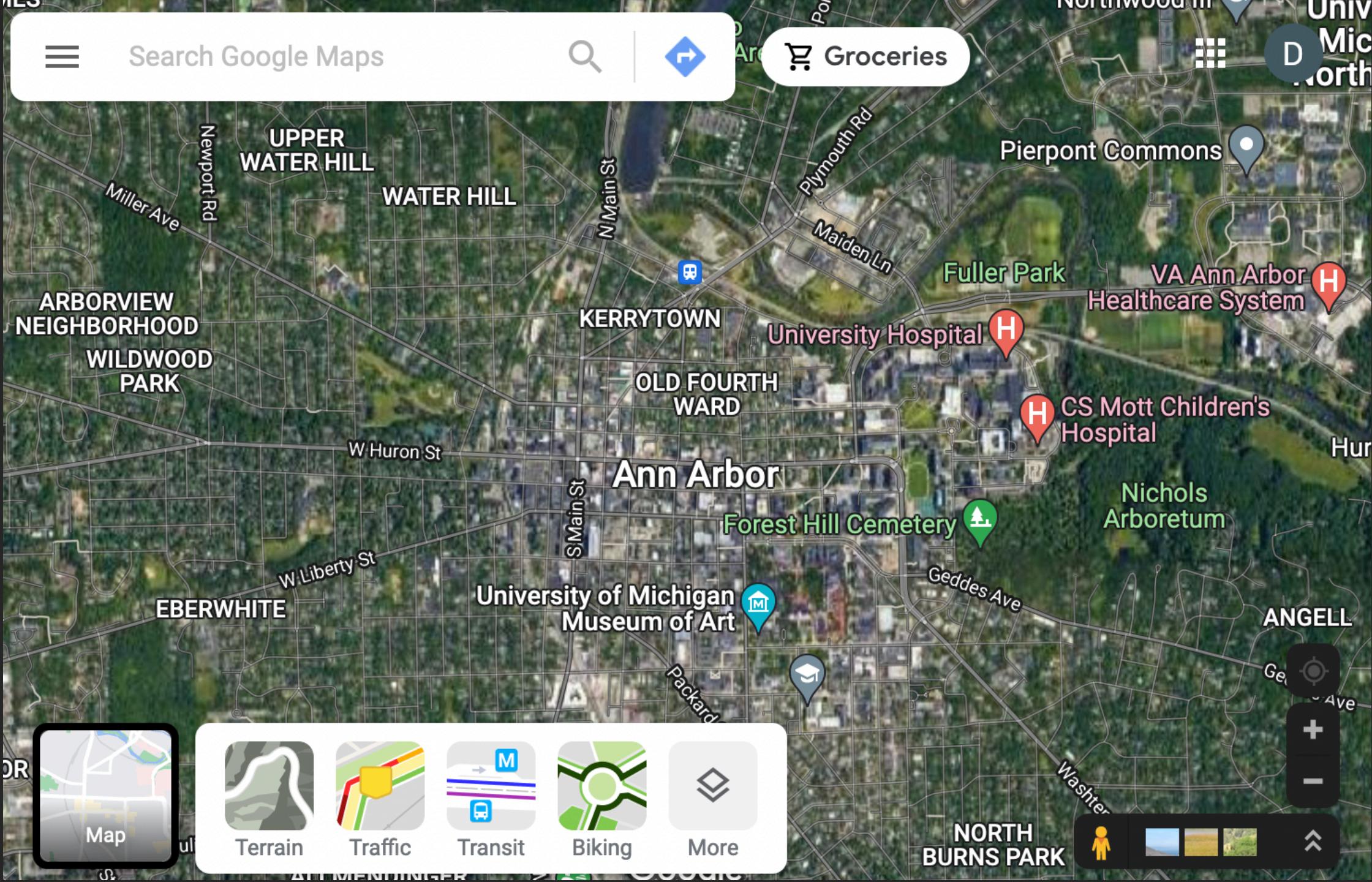


Groceries

D





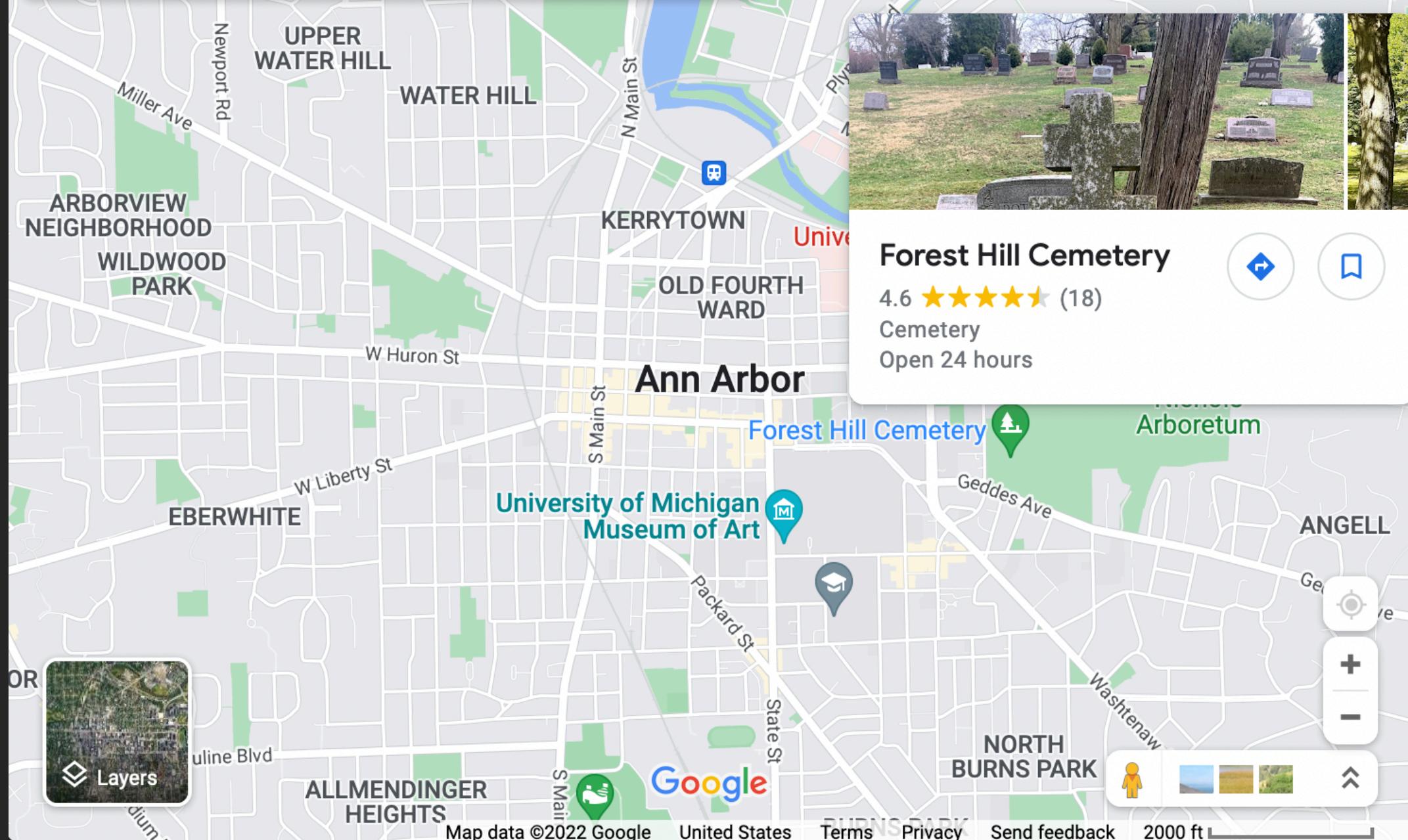




Search Google Maps



Groceries

D
Mic
North



Groceries



Rating ▾

Hours ▾

All filters

People's Food Co-op

4.6 ★★★★★ (614)

Grocery store · 216 N 4th Ave

Open until 8:00 PM · (734) 994-9174



In-store shopping · Curbside pickup · Delivery

Knight's Market

4.7 ★★★★★ (44)

Grocery store · 420 Miller Ave

Closed · Opens at 8:00 AM · (734) 665-6494



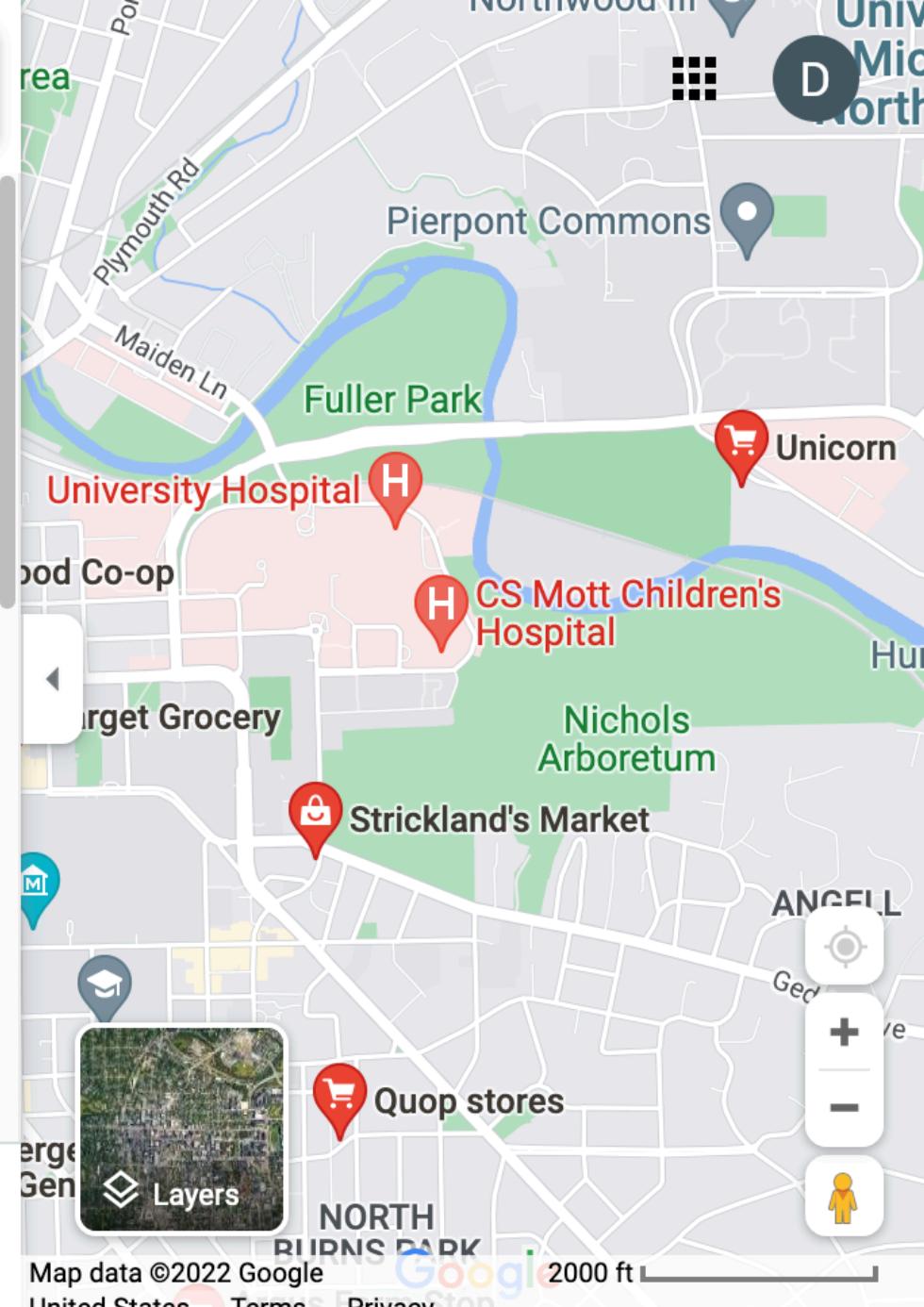
In-store shopping · Curbside pickup

Showing results 1 - 20



Update results when map moves

<https://www.google.com/maps/place/People's+Food+Co-op/data=...9c03!8m2!3d42.2828447!4d-83.7468052?authuser=0&hl=en&rclk=1>





Restaurants

Price ▾

Rating ▾

Fleetwood Diner

4.3 ★★★★★ (1,585) · \$

American · 300 S Ashley St

Classic American fare served

Open 24 hours

Dine-in · Takeout · No-con

ORDER

Krazy Jim's Blimpy Bu

4.4 ★★★★★ (1,413) · \$

Hamburger · 304 S Ashley St

Local standby for burgers and sandwiches

Showing results 1 - 20

Update results when map moves

Barbecue
Chinese
French
Hamburger

Indian

Italian

Japanese

Mexican

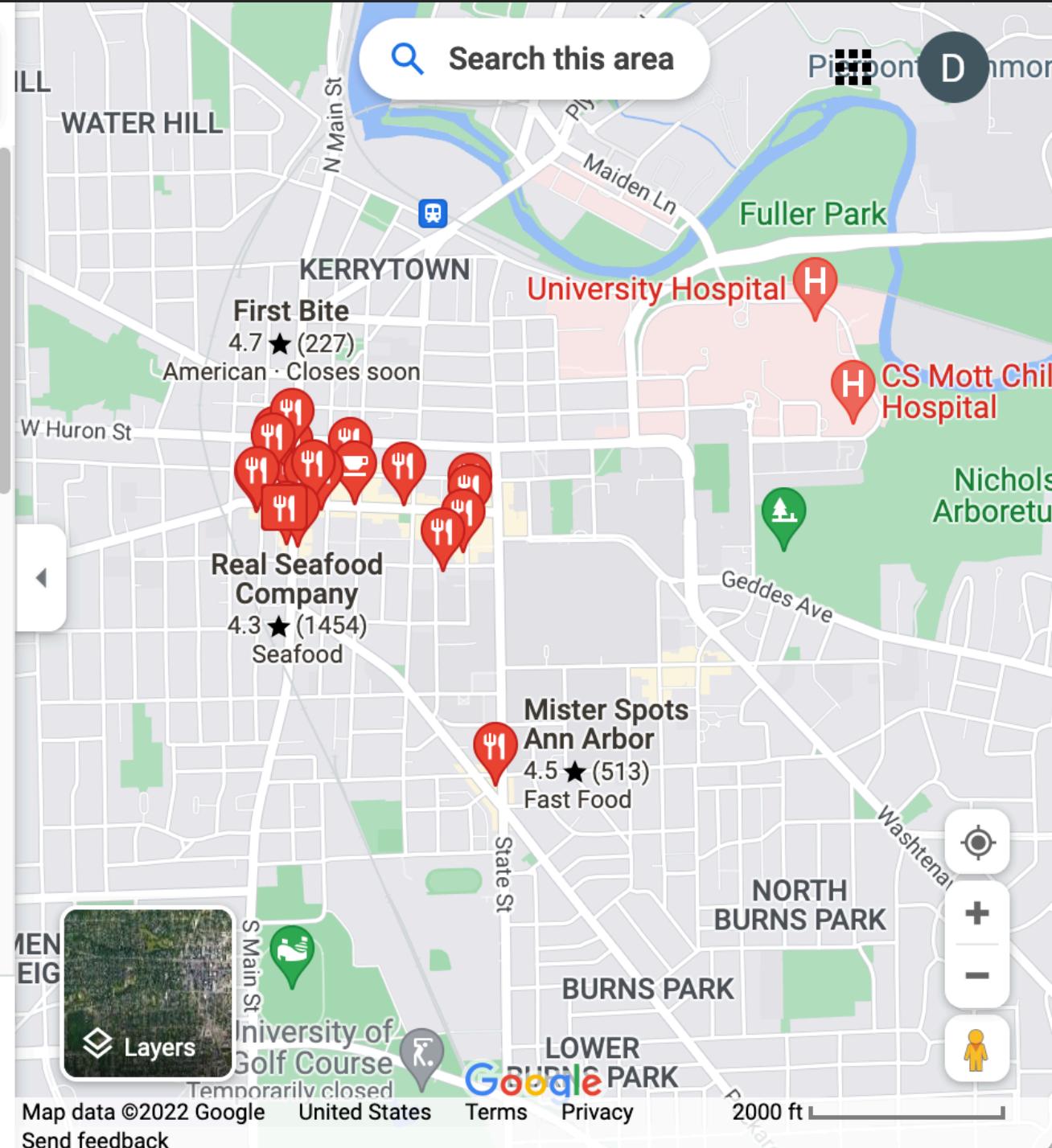
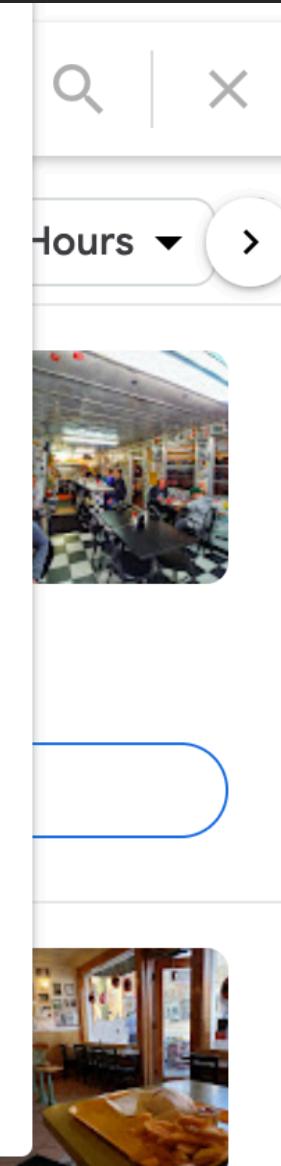
Pizza

Seafood

Steak

Sushi

Thai





DTW, Detroit Metro Airport, Detroit, MI 48



Ann Arbor, Michigan



Add destination

Leave now ▾

Options



Send directions to your phone



via M-14 W

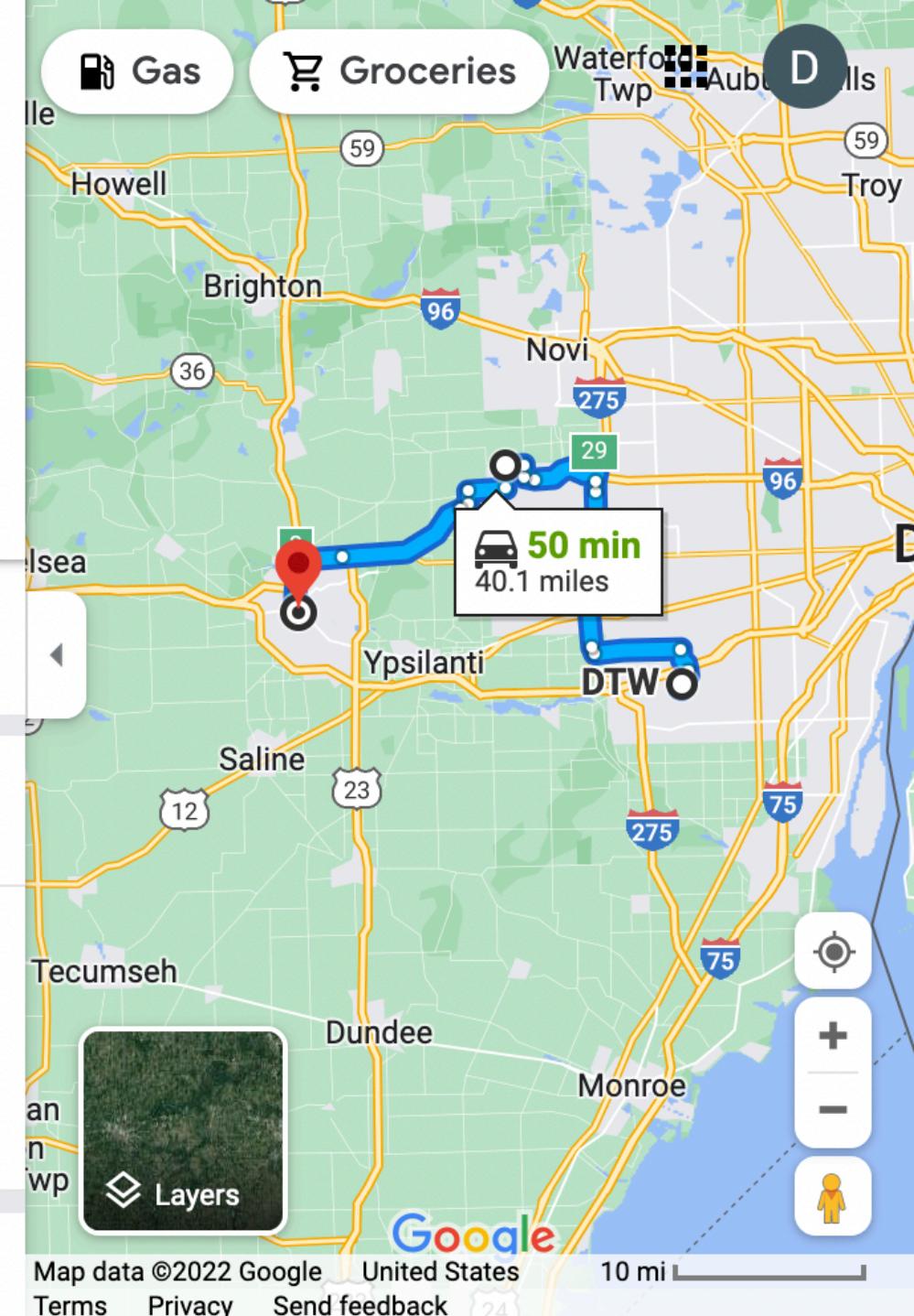
49 min without traffic

Details

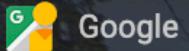
50 min

40.1 miles

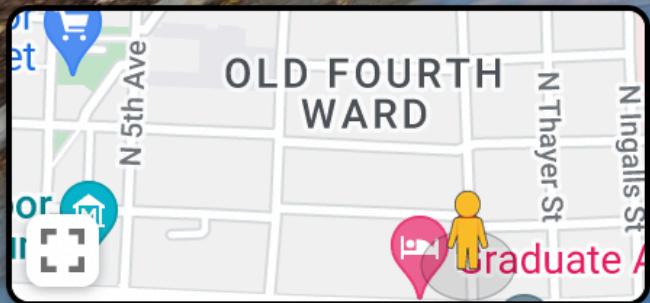
Explore Ann Arbor



116 N State St
Ann Arbor, Michigan



Street View - Nov 2020



Google



116 N State St

Ann Arbor, Michigan



Google



Street View - Nov 2020



Google

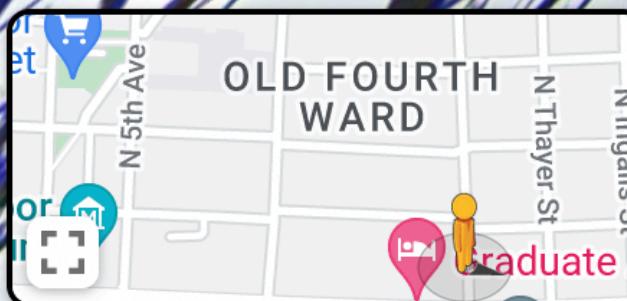


Image capture: Nov 2020

© 2022 Google

United States

Terms

Privacy

Report a problem

Landscape of Interaction

- Many different types of interaction
- User-driven ways to interact with underlying data
- Serves both exploration/analysis and communication
- Fine line between interactive visualization and user interfaces

Interaction Types

- Yi, Kang, Stasko (TVCG'07)
 - Meta study
 - 59 papers
 - 51 systems
 - 311 interaction techniques
- Final classification based on
 - *User intent*

User intent

- Interaction is done by a person for a purpose
 - Seeking more information
 - “Fundamental aspect of exploratory, analytic, discourse”
(Stasko)

7 Categories

- Select
- Explore
- Reconfigure
- Encode
- Abstract/Elaborate
- Connect
- Filter

7 Categories

- Select
- Explore
- Reconfigure
- Encode
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- Connect
- Filter

Selection and Labeling

Select

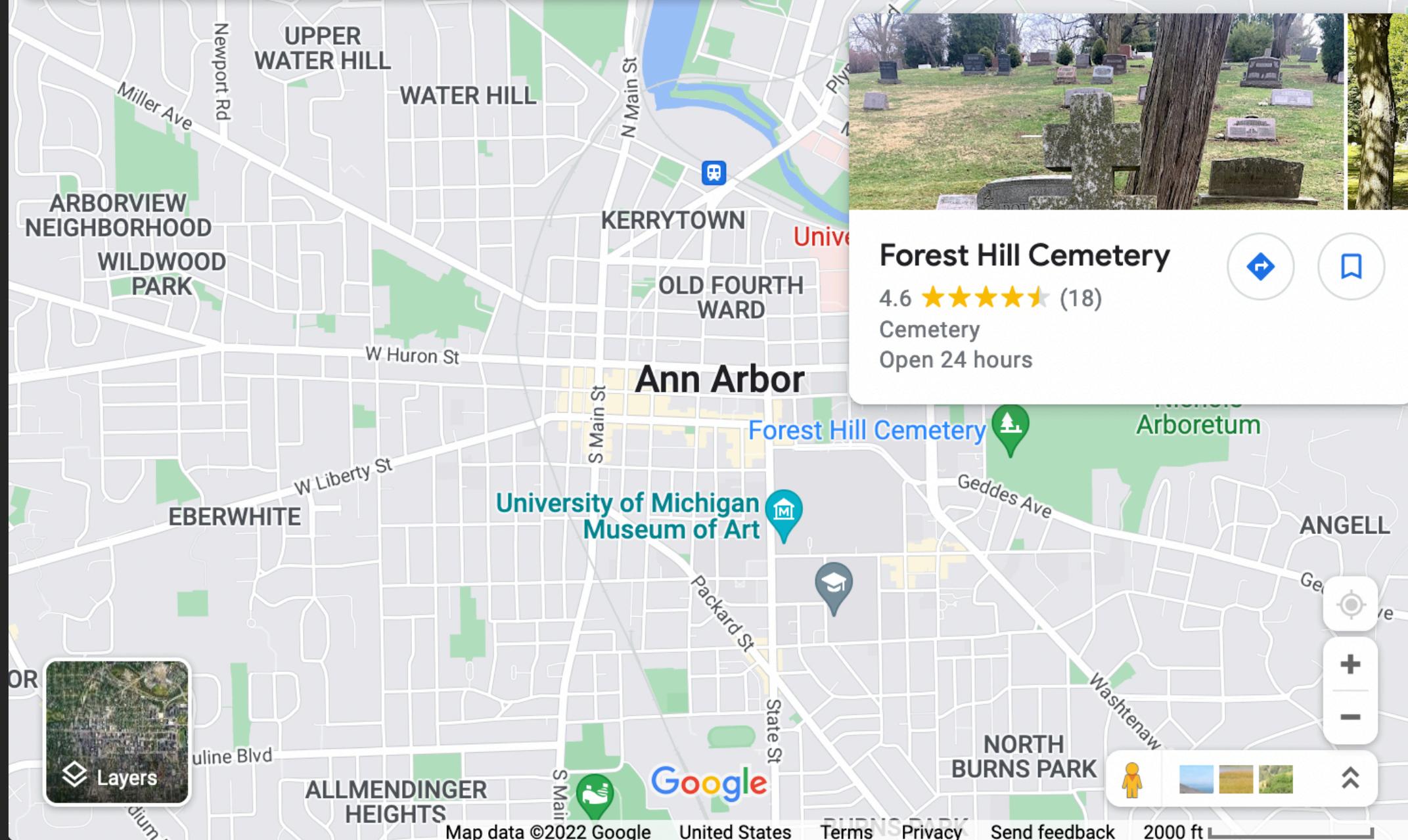
- Mark something as interesting
 - Mark items to keep track of them
 - Often precedes other operations
- Example:
 - Selecting a placemark in Google Maps



Search Google Maps



Groceries

D
Mic
North

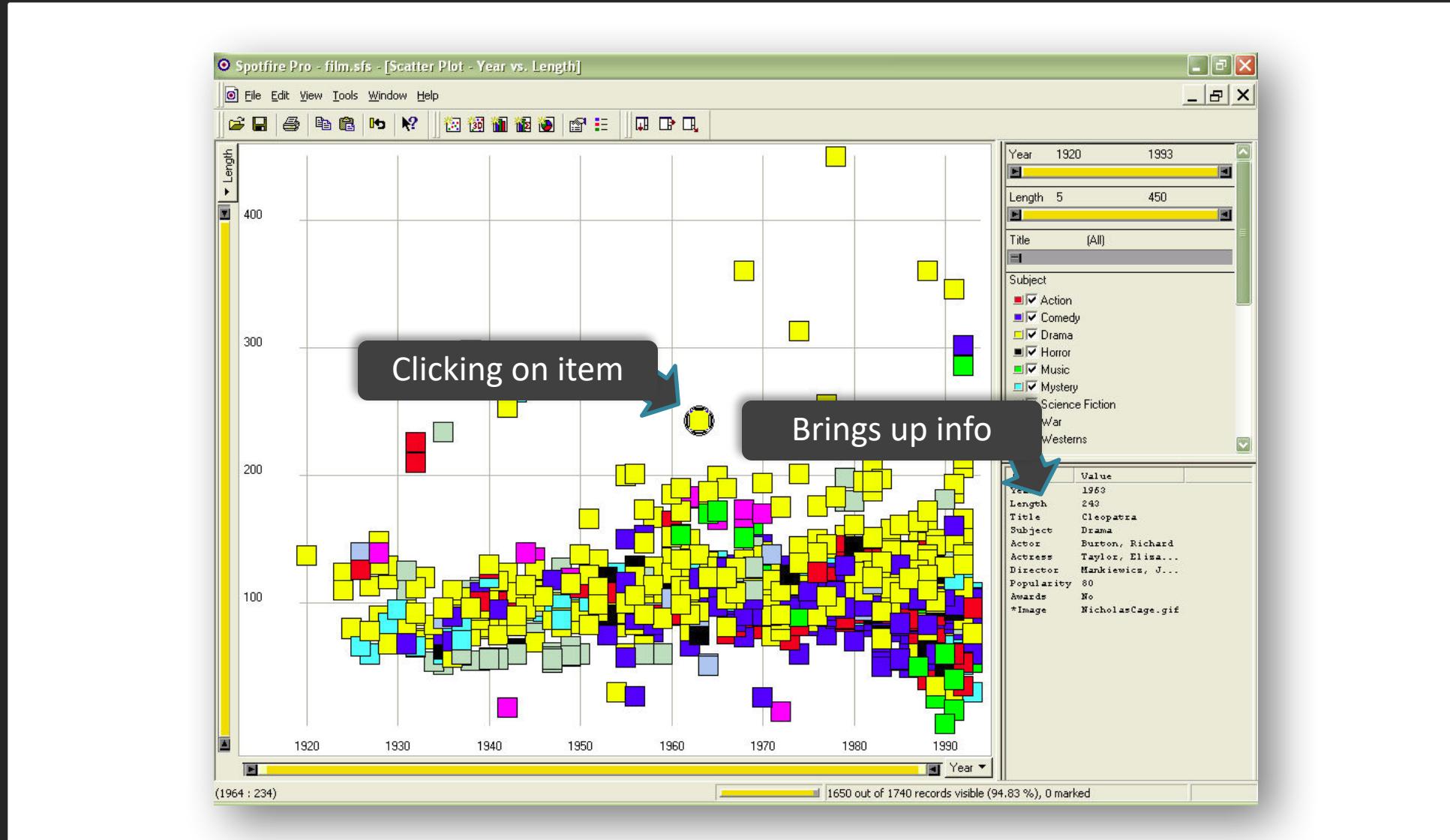
Forest Hill Cemetery

4.6 ★★★★☆ (18)

Cemetery

Open 24 hours

Selection: Pop-up tooltips



Selection: How do we find it?



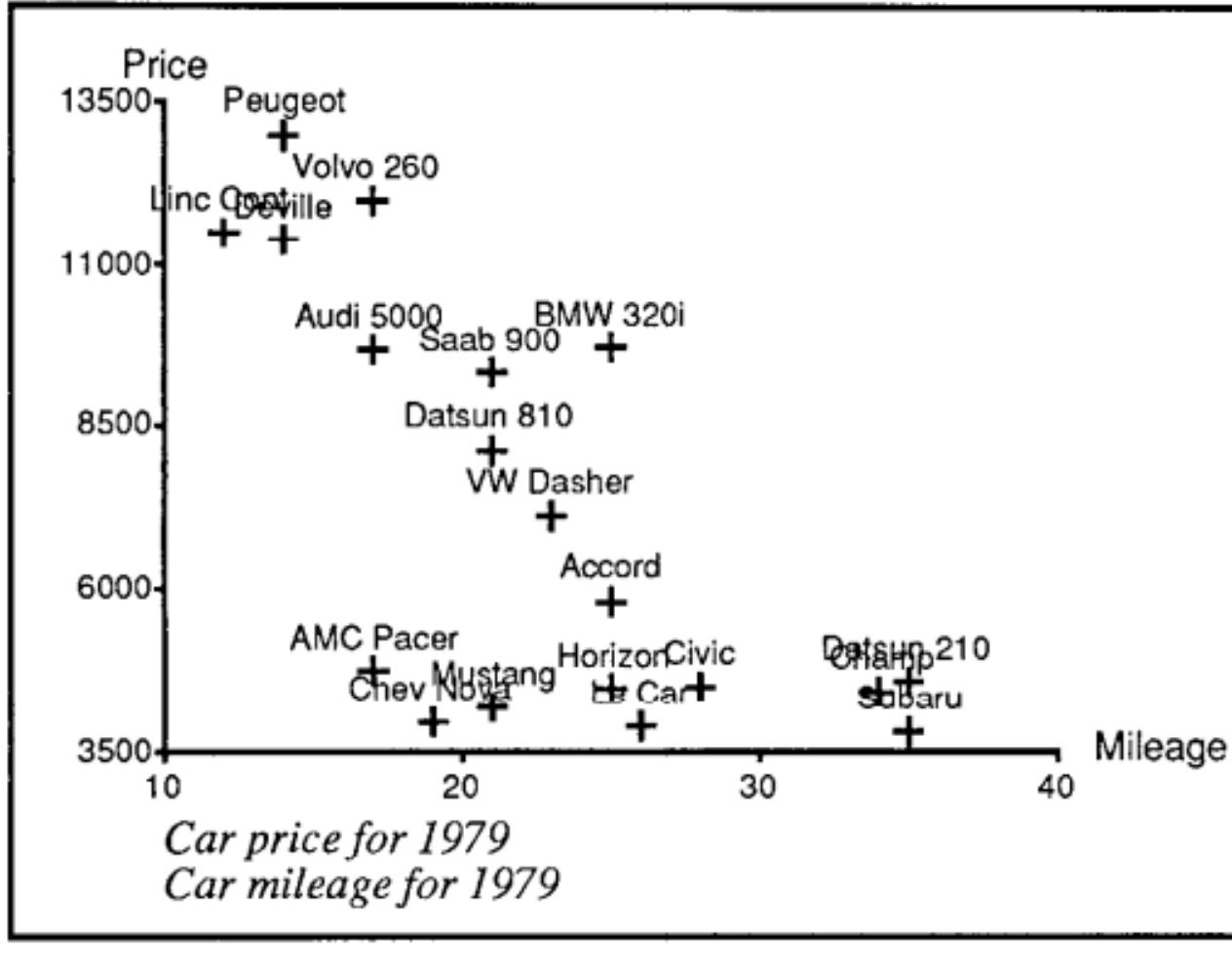
Selection: Labels?

- We need labels to identify what to select
- But... labels take up lots of real estate
 - With lots of data this is a problem



Wicked
Problem

Expressiveness vs Effectiveness

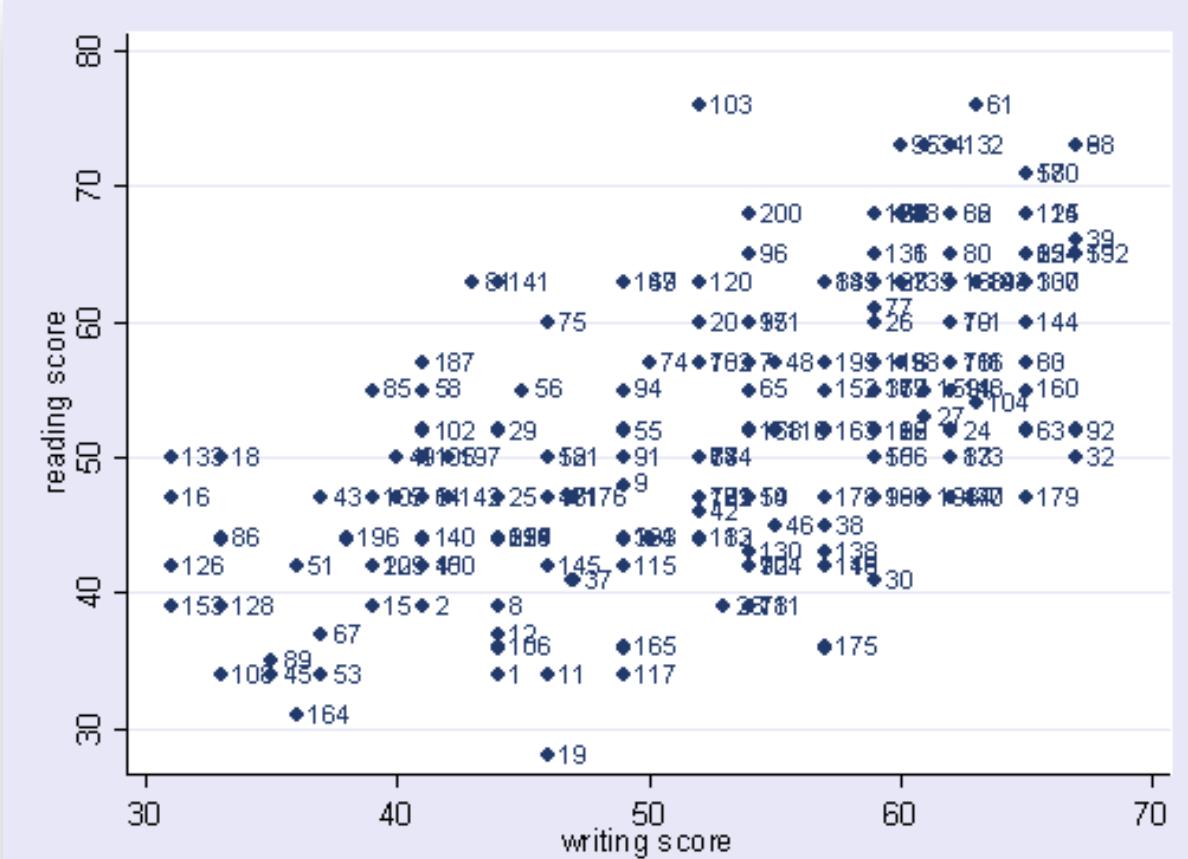


Selection: Labels?

- We need labels to identify what to select
- But... labels take up lots of real estate
 - With lots of data this is a problem
- Each label should:
 - Be readable
 - Non-ambiguous relationship to graphical object
 - Not occlude other pertinent information
- Completeness: label everything (desired, but not always possible)



Certainly don't want this...

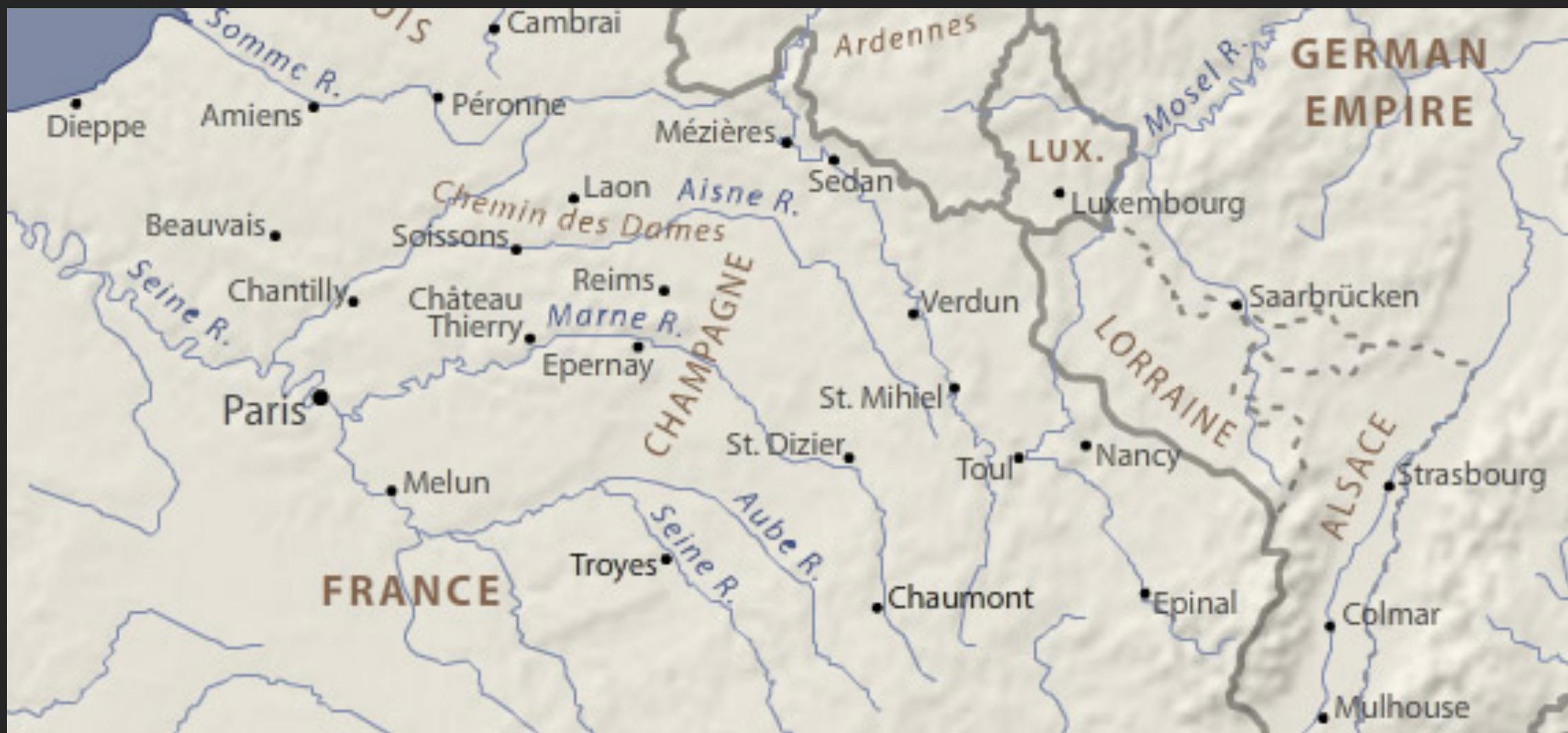


Selection: Labeling techniques

- Static
 - Maps
 - Physical presentations
 - E.g., Cartography
 - Dynamic
 - Interactive data points

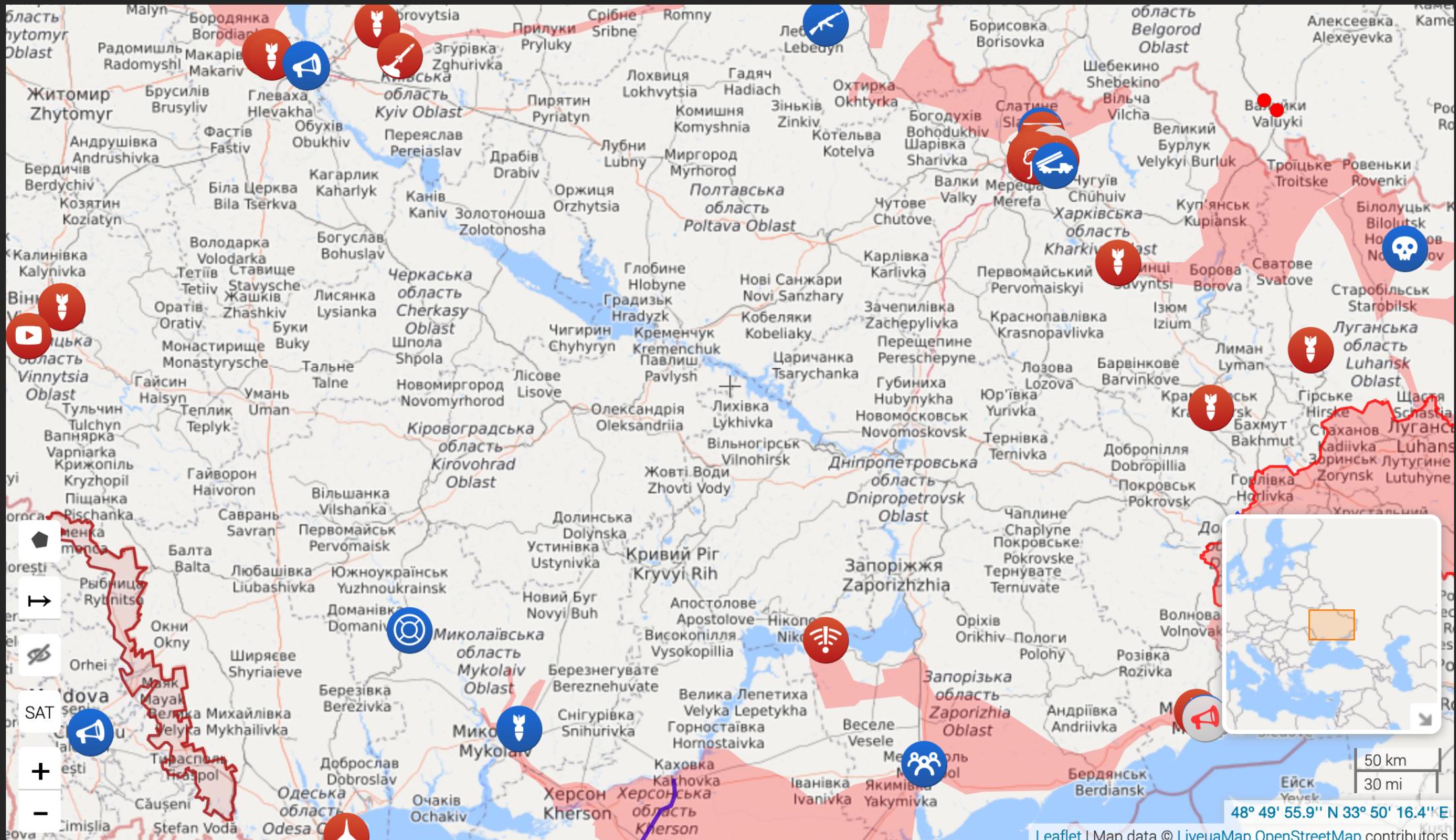


Grammar of labels



Nuclear plant Coal plant Areas occupied by Russia





Leaflet | Map data © Liveuamap OpenStreetMap contributors

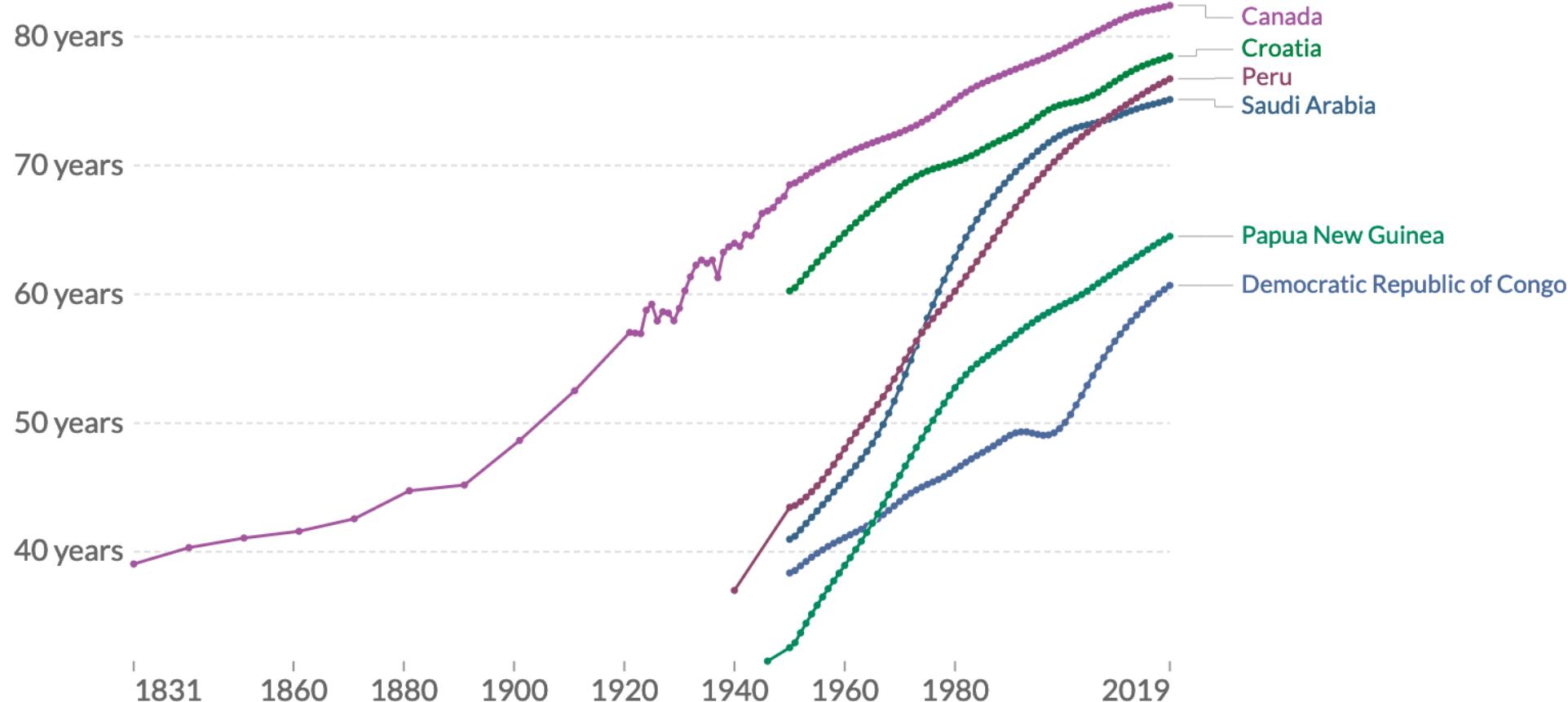
<https://liveuamap.com/en>

Life expectancy, 1831 to 2019

LINEAR

LOG

+ Add country



Source: Riley (2005), Clio Infra (2015), and UN Population Division (2019)

Note: Shown is period life expectancy at birth, the average number of years a newborn would live if the pattern of mortality in the given year were to stay the same throughout its life.

OurWorldInData.org/life-expectancy • CC BY

► 1831

2019

CHART

MAP

TABLE

SOURCES

DOWNLOAD

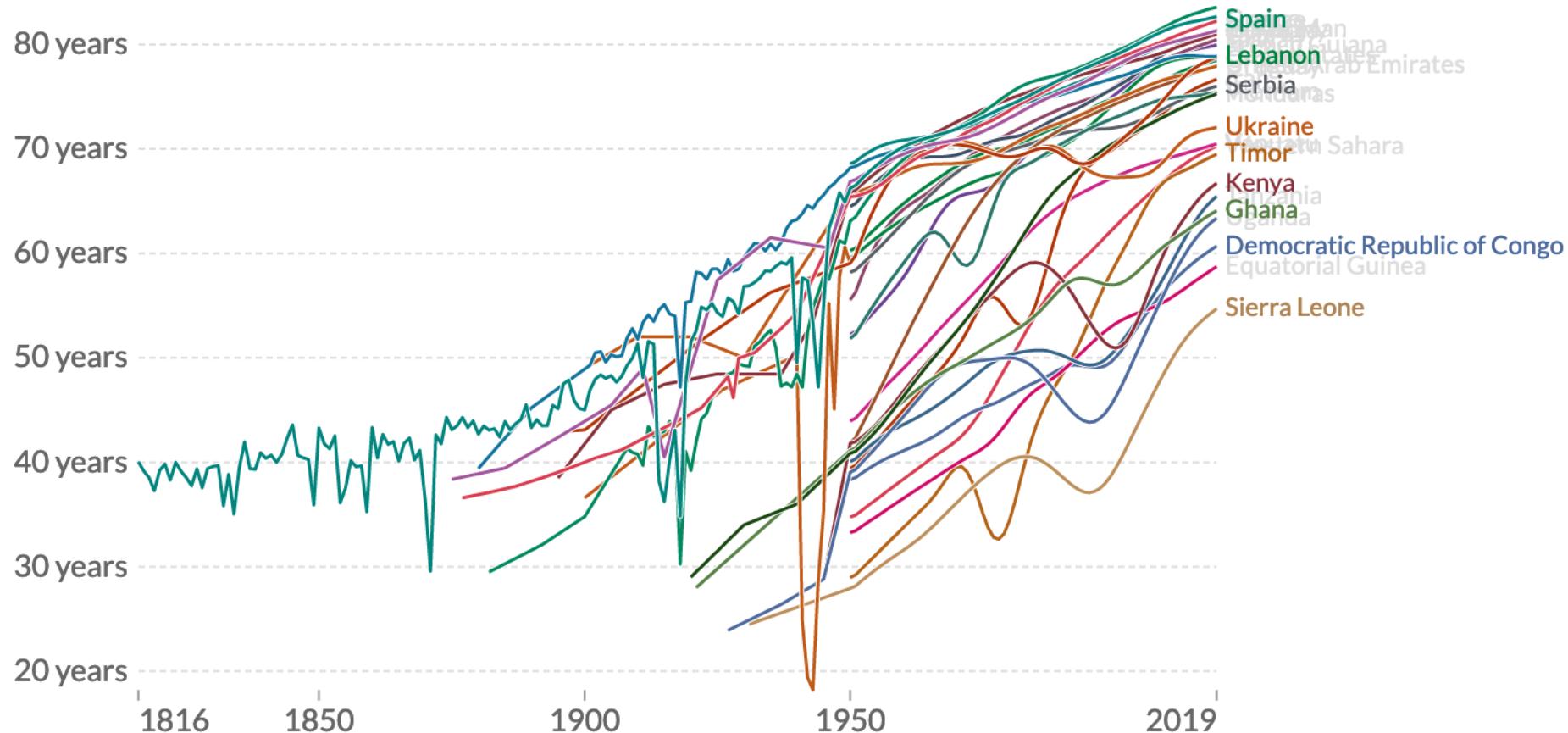


Life expectancy, 1816 to 2019

LINEAR

LOG

+ Add country



Source: Riley (2005), Clio Infra (2015), and UN Population Division (2019)

Note: Shown is period life expectancy at birth, the average number of years a newborn would live if the pattern of mortality in the given year were to stay the same throughout its life.

OurWorldInData.org/life-expectancy • CC BY

► 1816

2019

CHART

MAP

TABLE

SOURCES

DOWNLOAD



Life expectancy, 1816 to 2019

Our World
in Data

LINEAR LOG

+ Add country

80 years

70 years

60 years

50 years

40 years

30 years

20 years

1816

1850

1900

1950

2019

Djibouti
Iran
Suriname
Guiana
Qatar
Arab Emirates
Togo
Moldova
Ukraine
Western Sahara
Mali
Kenya
Tanzania
Uganda
Democratic Republic of Congo
Equatorial Guinea
Sierra Leone

Source: Riley (2005), Clio Infra (2015), and UN Population Division (2019)

Note: Shown is period life expectancy at birth, the average number of years a newborn would live if the pattern of mortality in the given year were to stay the same throughout its life.

OurWorldInData.org/life-expectancy • CC BY

► 1816

2019

CHART

MAP

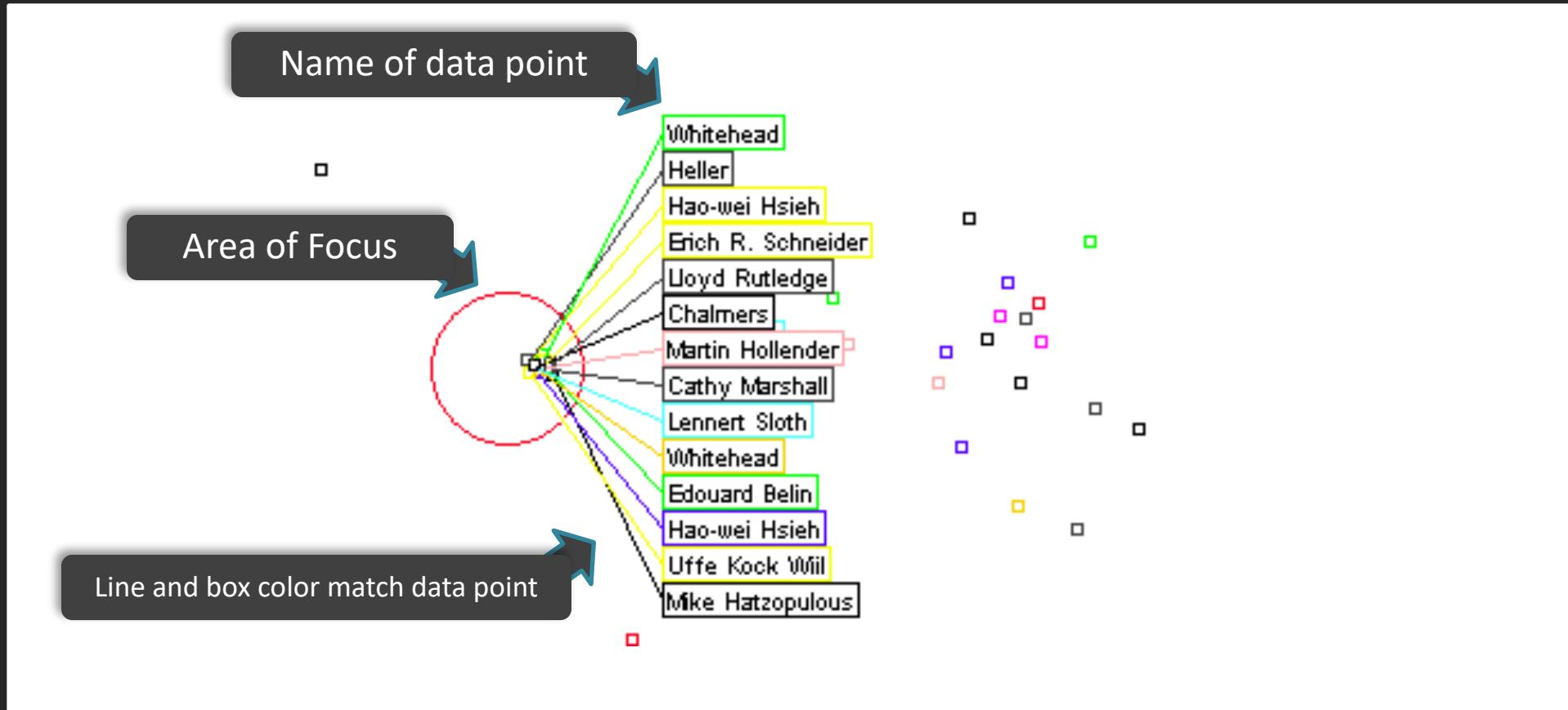
TABLE

SOURCES

DOWNLOAD



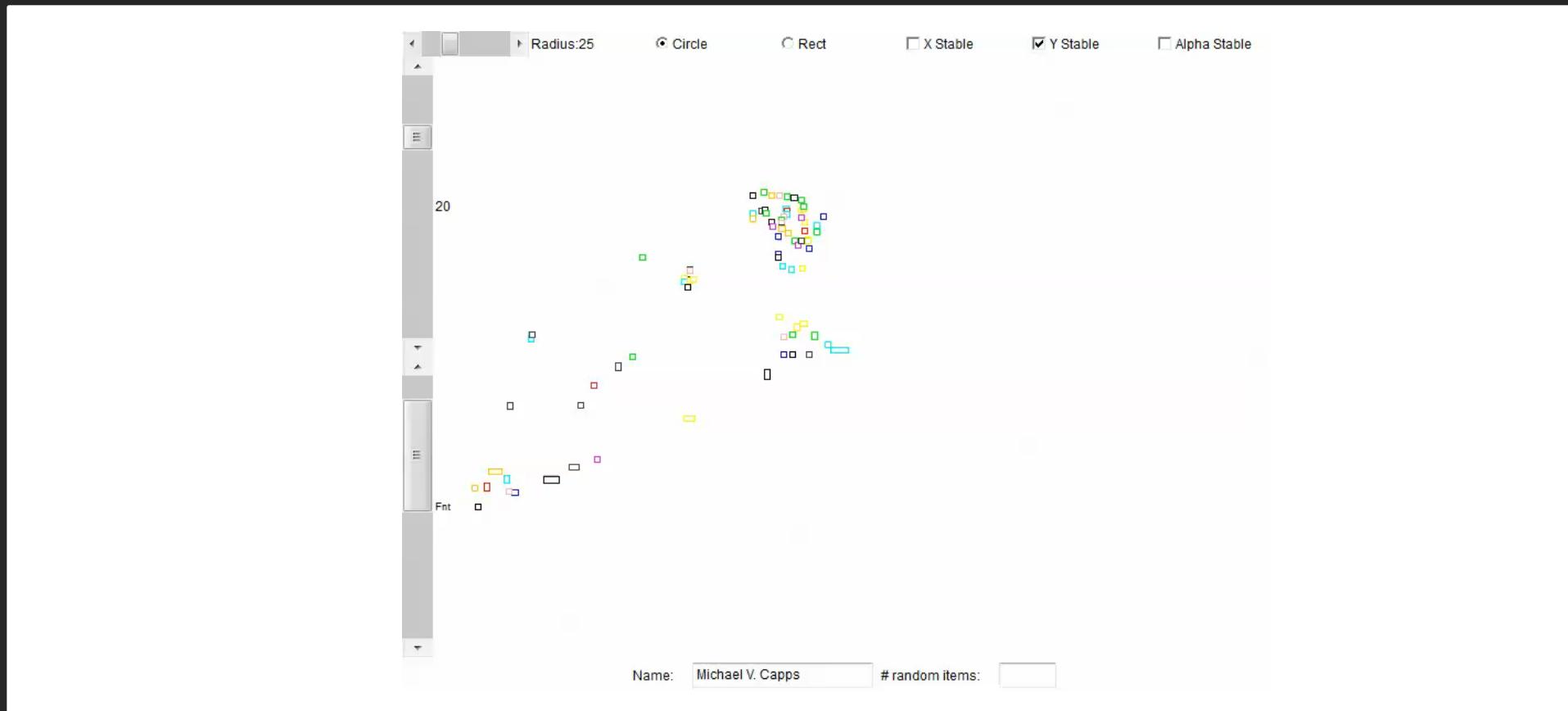
Selection: Excentric Labeling (example)



Fekete and Plaisant, CHI '99

<http://www.cs.umd.edu/hcil/excentric/dist/bin/test7.html>

Selection: Excentric Labeling (example)



Fekete and Plaisant, CHI '99

<http://www.cs.umd.edu/hcil/excentric/dist/bin/test7.html>

7 Categories

- Select
- Explore
- Reconfigure
- Encode
- Abstract/Elaborate
- Connect
- Filter

Explore

- Show something different
 - Enable users to examine different subset
 - Overcome limitations of display size
- Examples:
 - Panning in Google Map
 - “Walking” in Visual Thesaurus
 - http://www.youtube.com/watch?v=HGUD45_k5y0

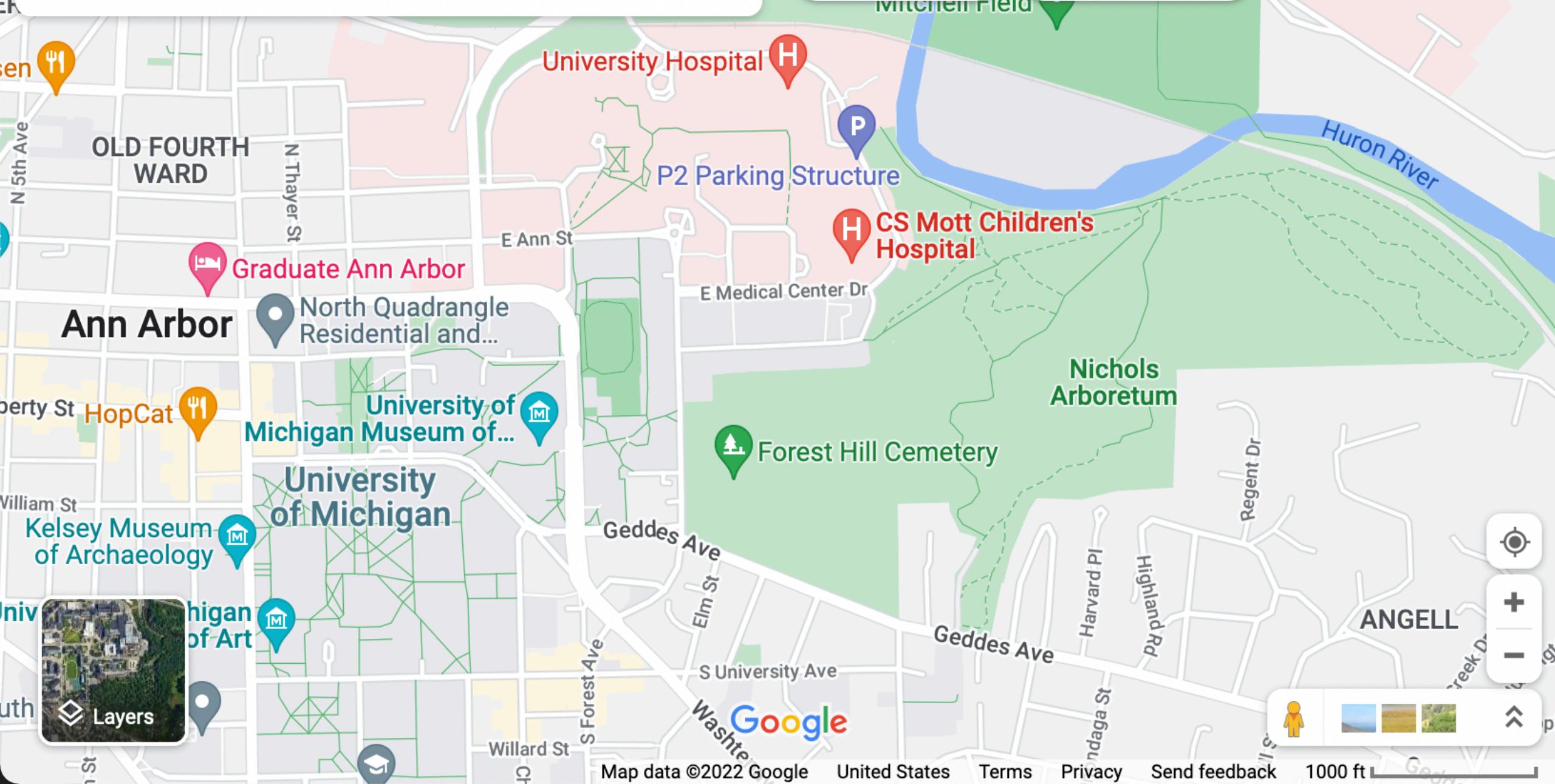


Search Google Maps



Groceries

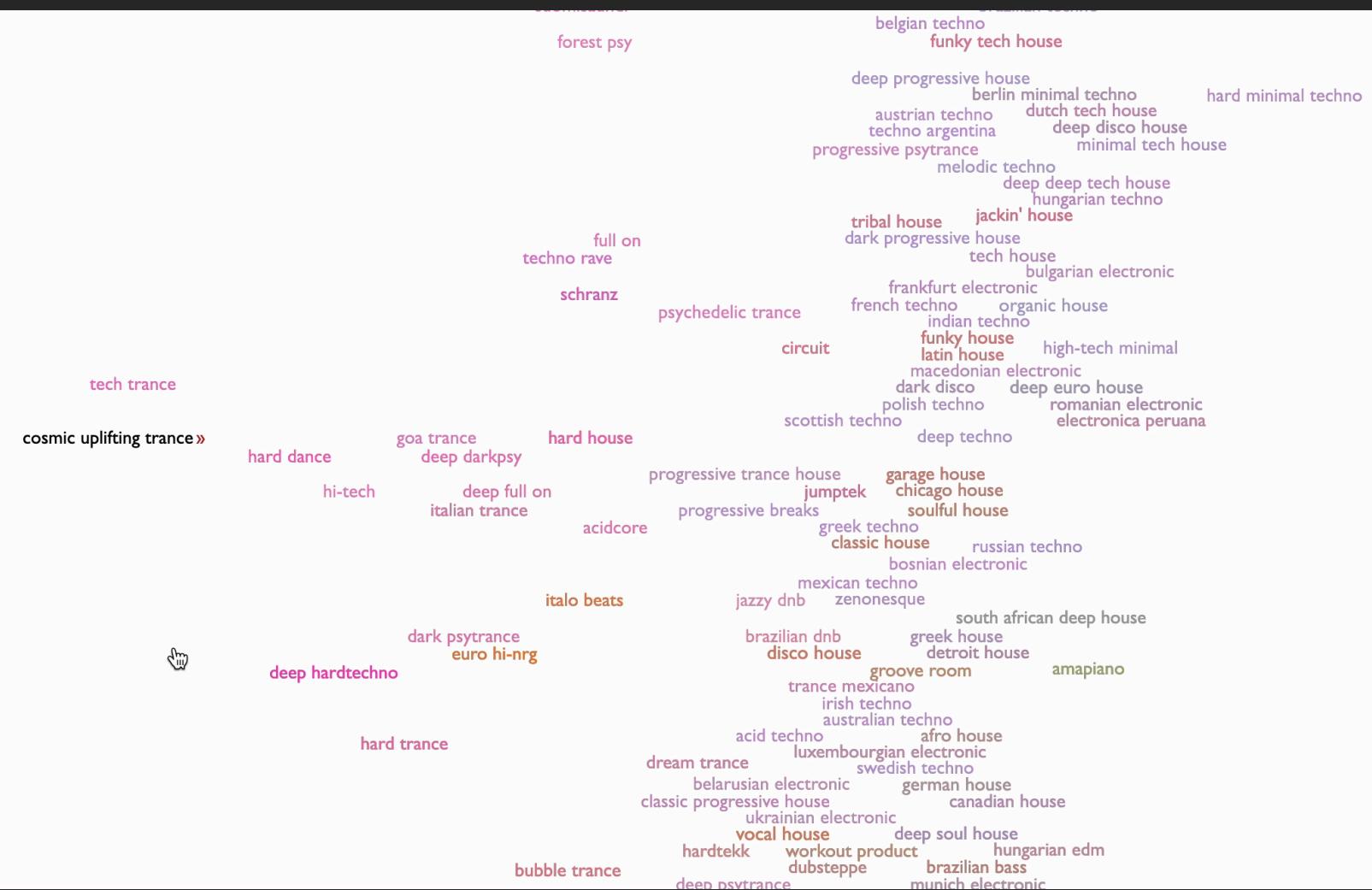
Restaurants

VA Ann Arbor
Healthcare System

Explore



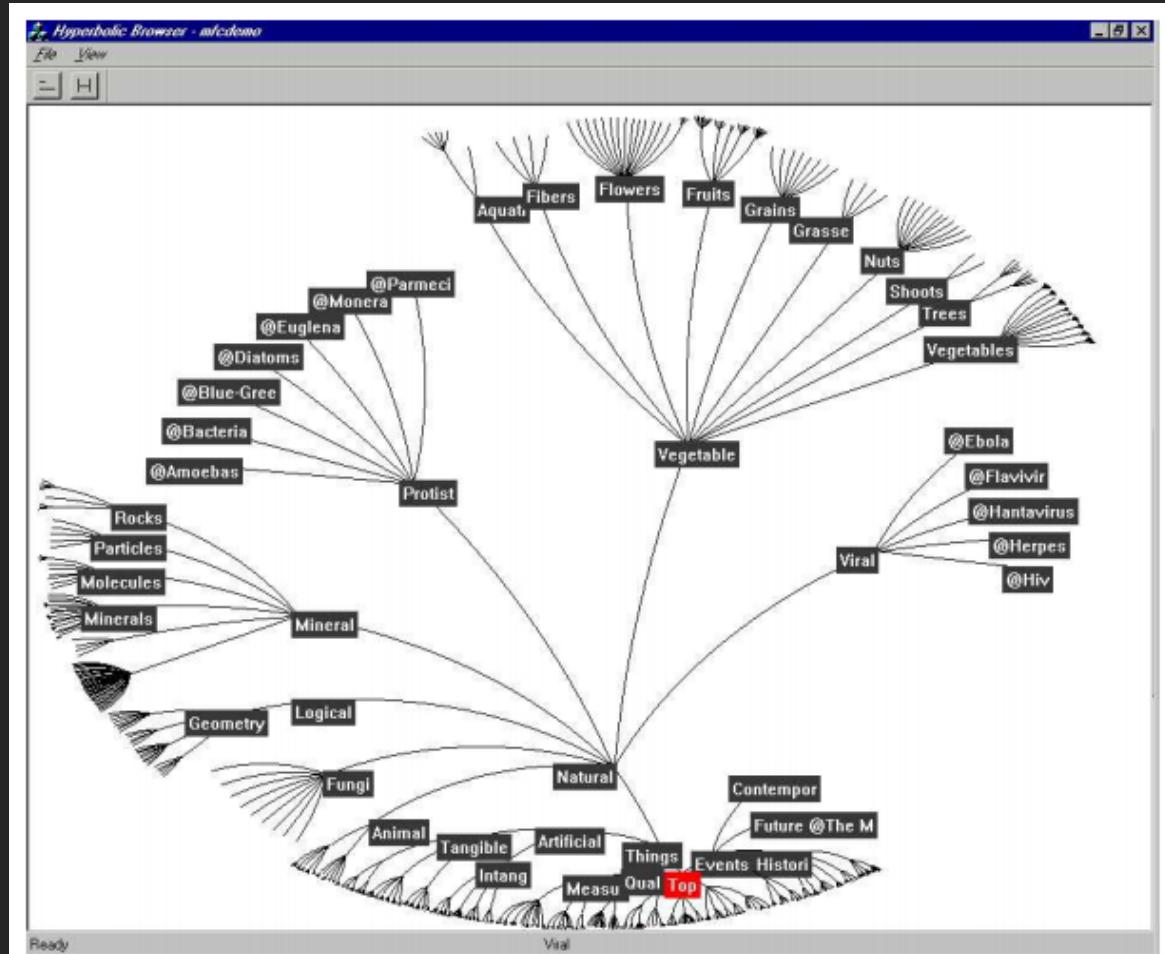
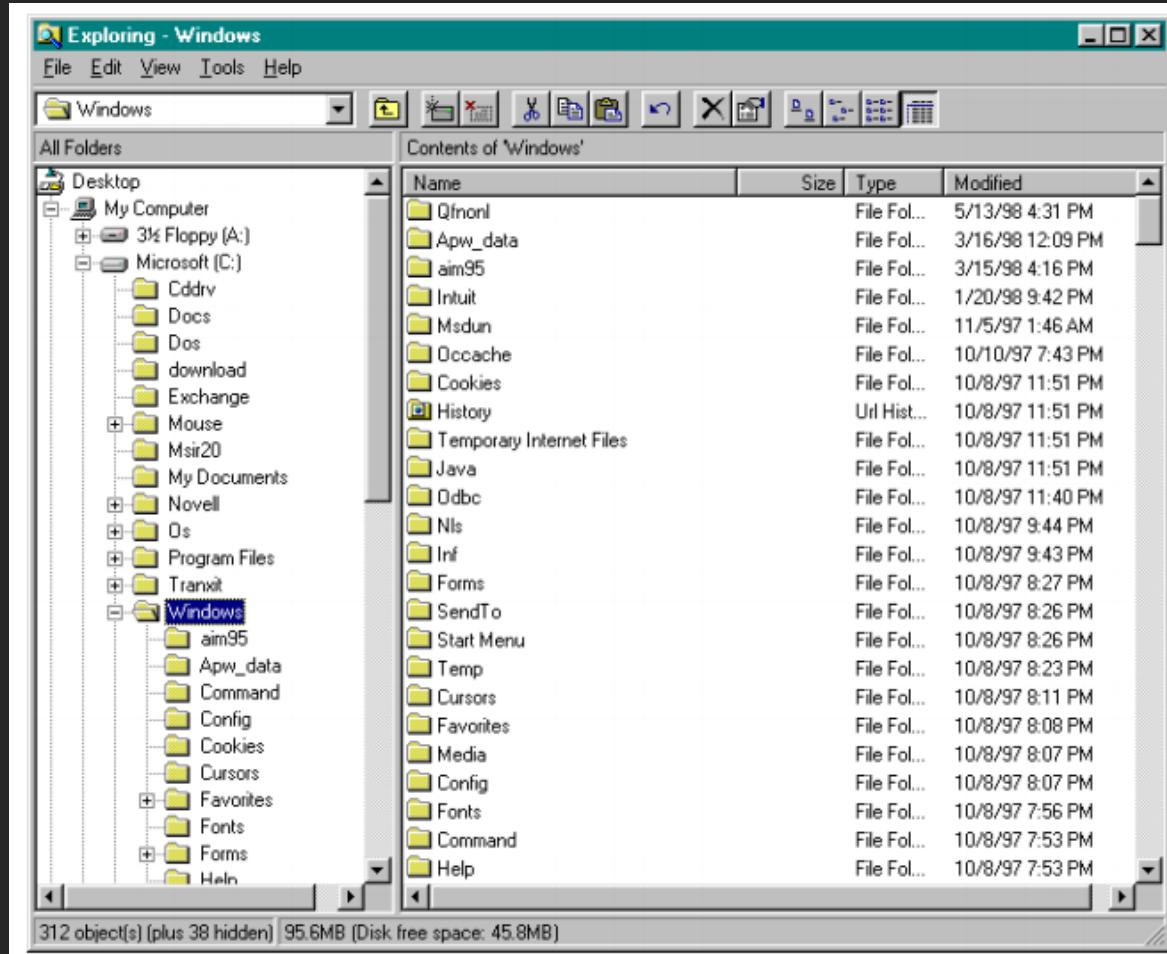
Example: Every Noise At Once



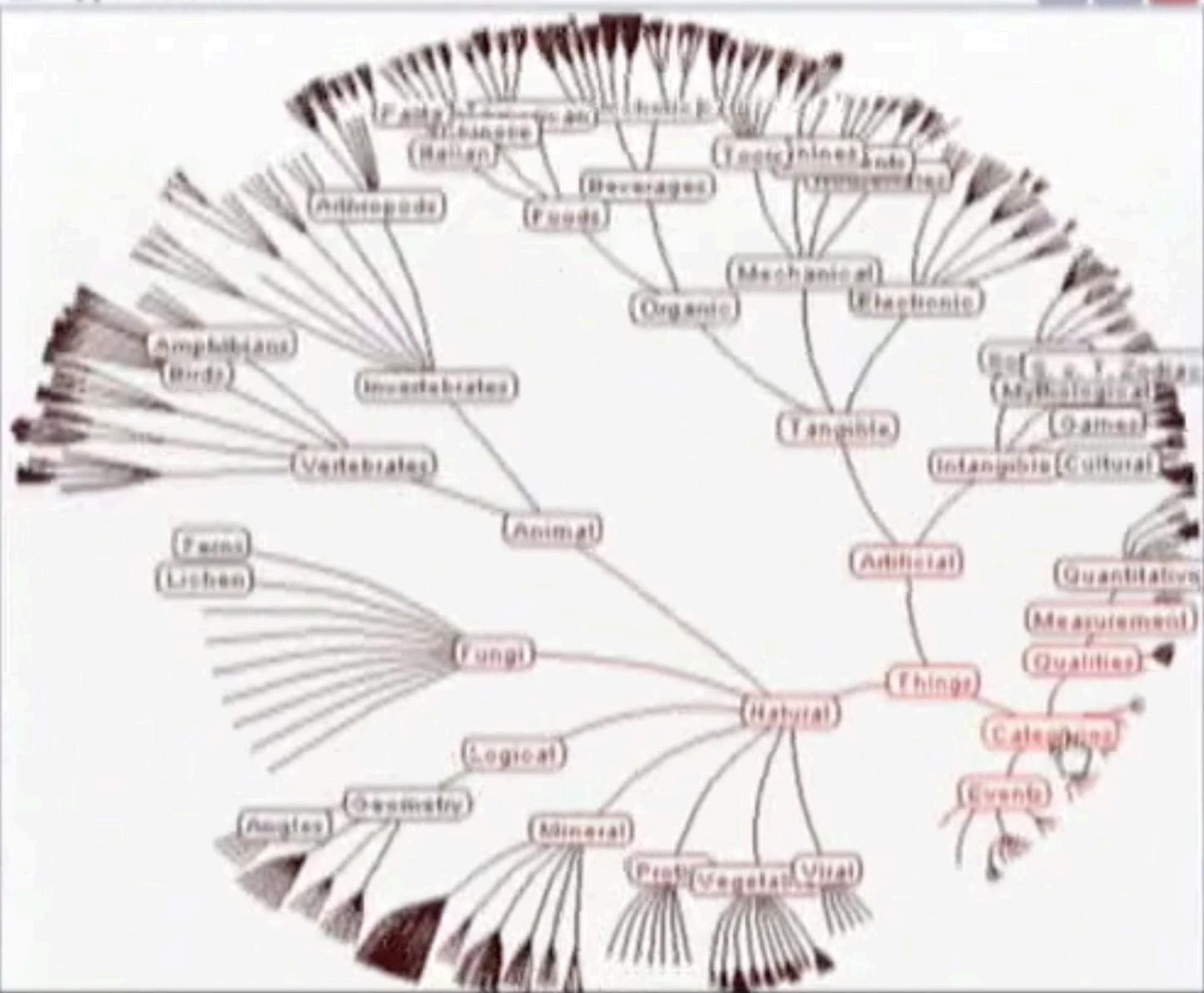
<https://everynoise.com/>

Example: File Browser Bakeoff

CHI'97 Bakeoff



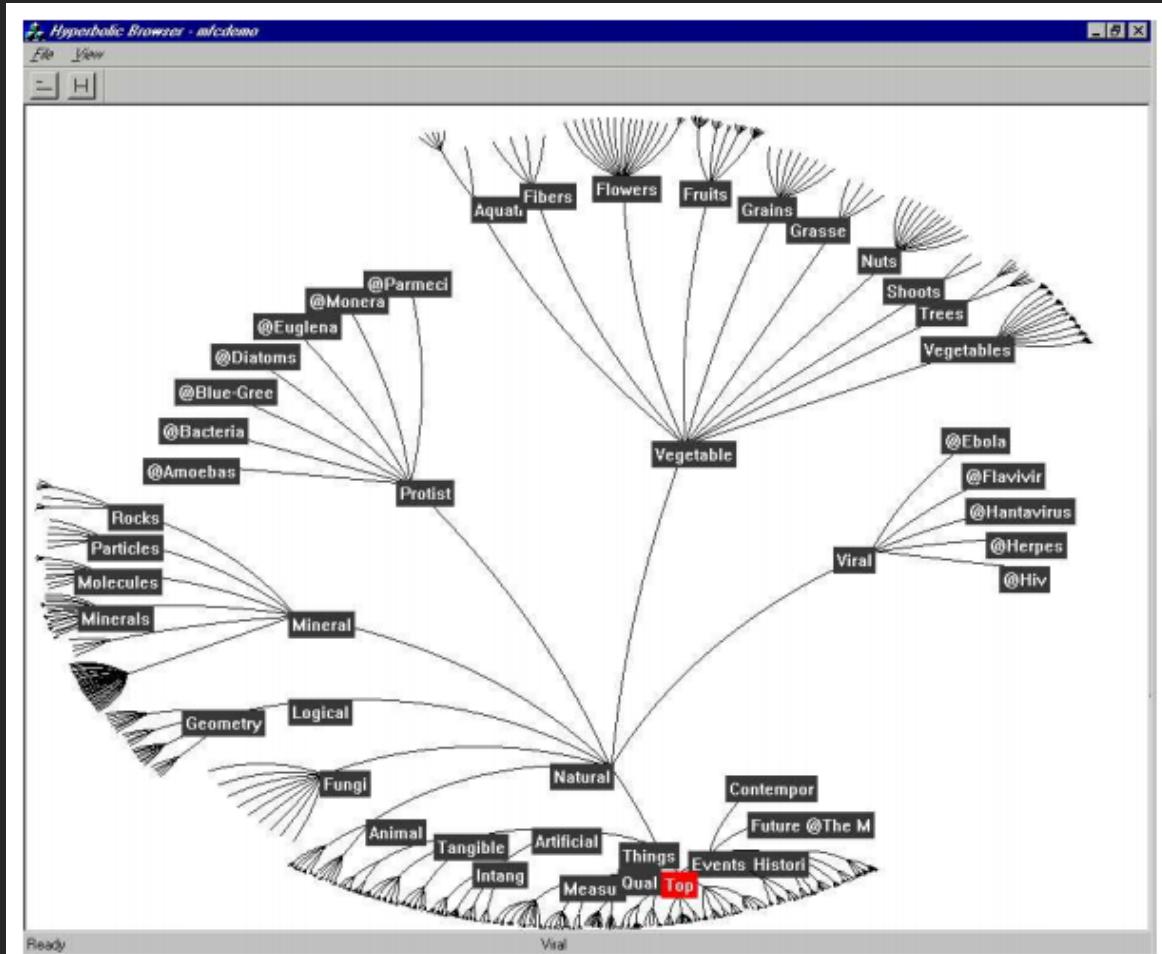
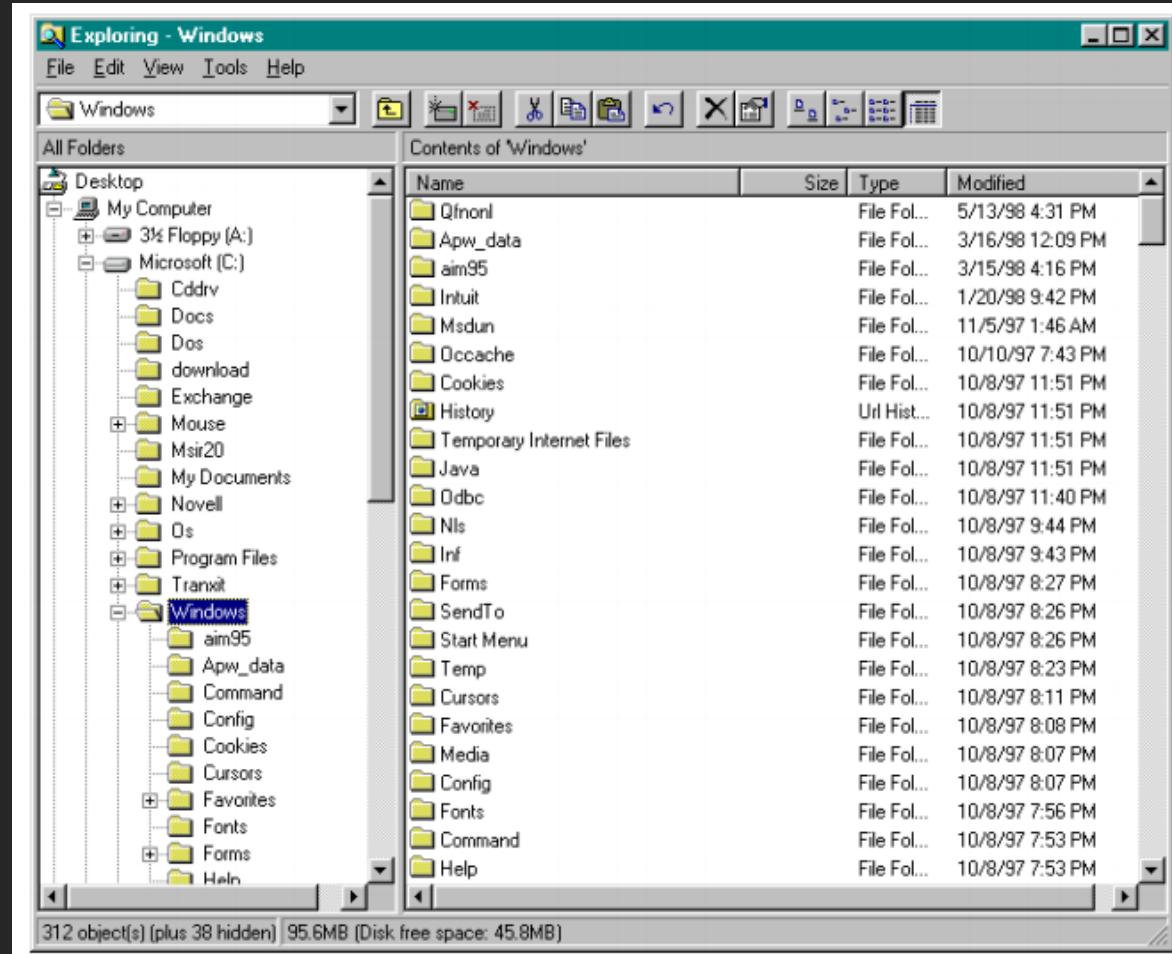
Hyperbolic Tree



Evaluation

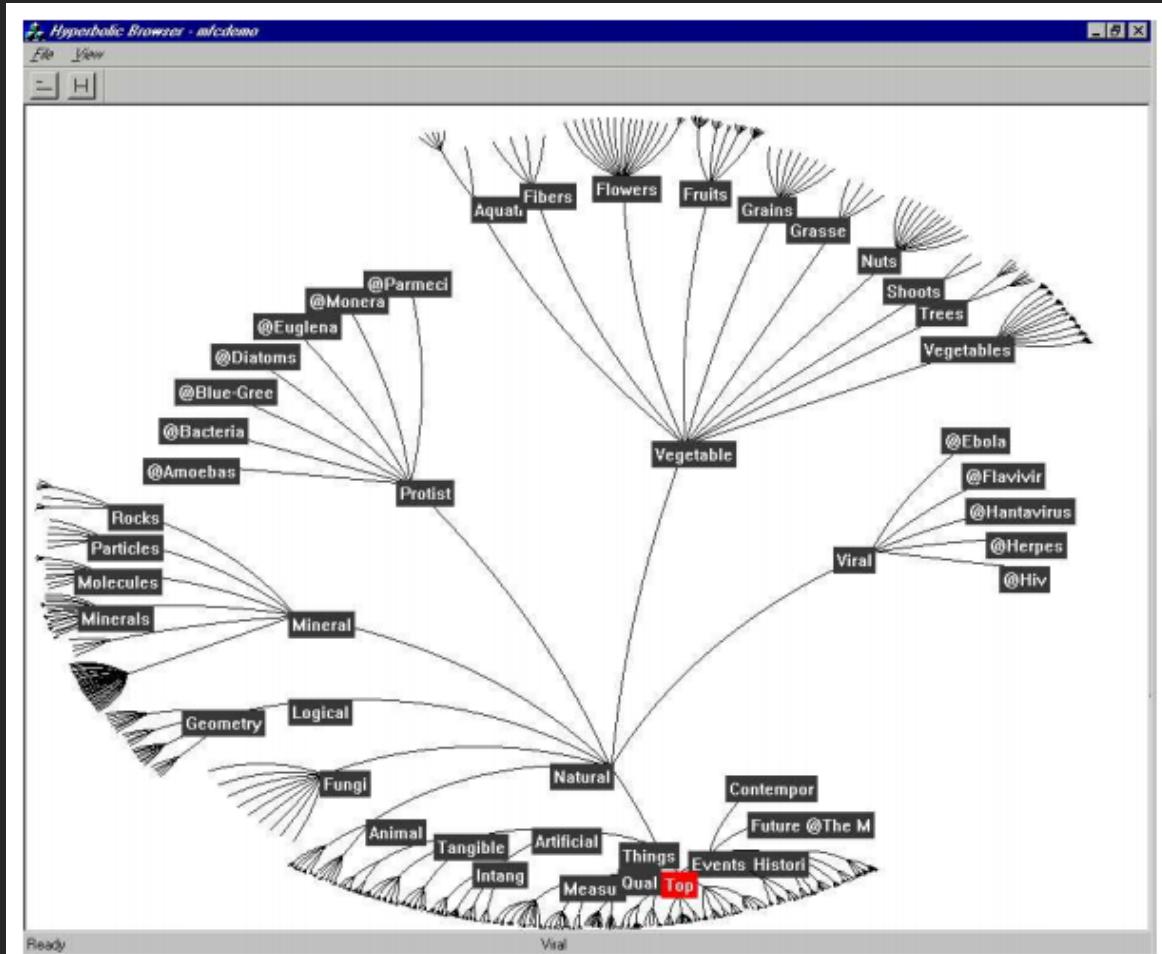
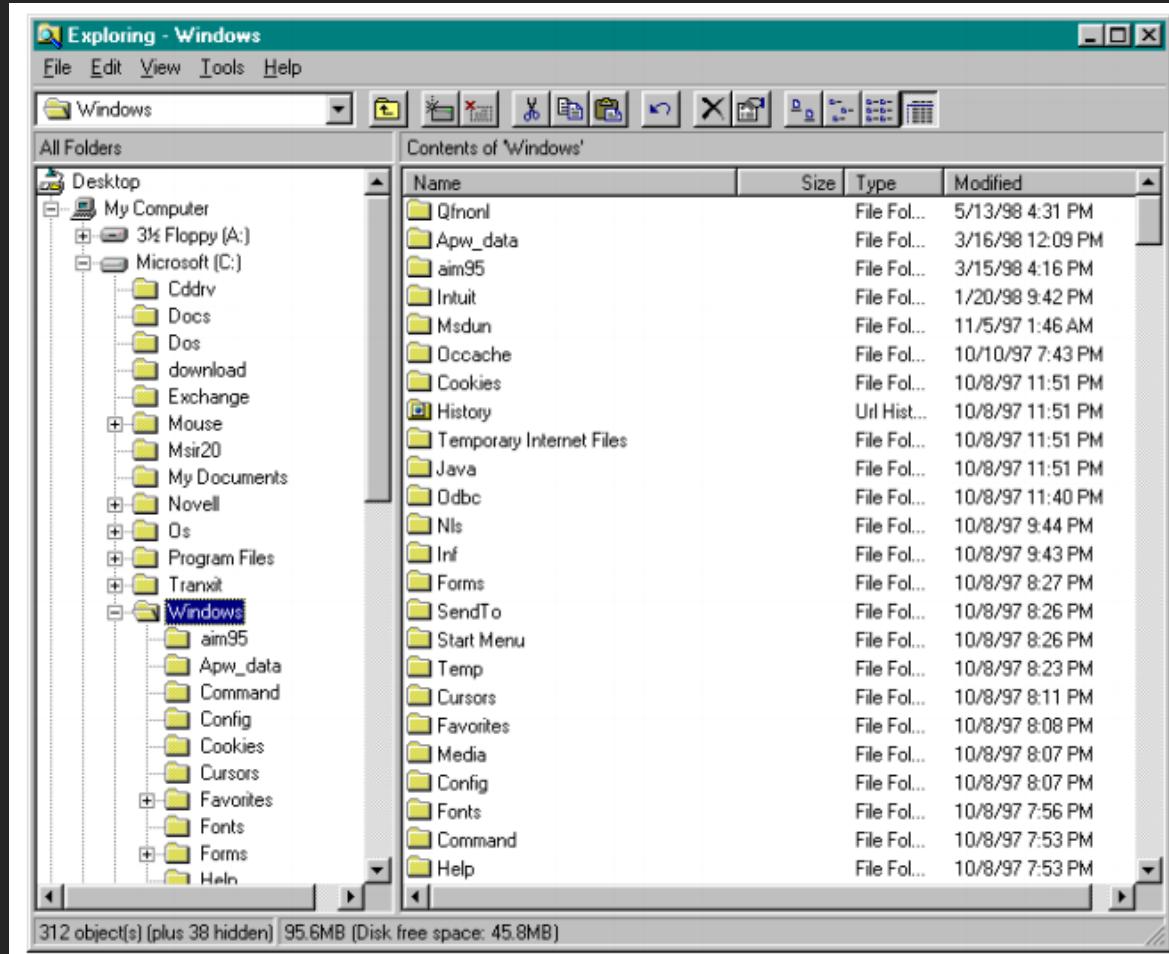
- Expert + Novice
 - “Expert and (for two systems) novice operators used the visualization and browsing tools to complete a set of generic retrieval tasks as quickly and accurately as possible within a large hierarchical data set.”
- Generic retrieval tasks
 - Speed/accuracy test

CHI'97 Bakeoff



CHI'97 Bakeoff

Winner!



Evaluating Exploration

- Expert + Novice
 - “Expert and (for two systems) novice operators used the visualization and browsing tools to complete a set of generic retrieval tasks as quickly and accurately as possible within a large hierarchical data set.”
- Generic retrieval tasks
 - Speed/accuracy test

Some issues

- Different designs more effective for different people
 - “The Hyperbolic Tree proved itself to be extremely responsive, graphically efficient, and *devastatingly effective in the hands of a skilled operator using novel techniques like ‘fanning’ the data in a focus-plus-context display.*”