Web Science:
Intro to InfoVis with R and Python
(Part 1 - InfoVis Principles)

CS 432/532
Old Dominion University

Many slides courtesy Tamara Munzner, VAD minicourse, June 2014
Based on Tamara Munzner, *Visualization Analysis and Design*, AK Peters / CRC Press, Oct 2014

Dataset and data types

Data and Dataset Types

Tables	Networks & Trees	Fields	Geometry	Clusters, sets, lists
Items	Items (nodes)	Grids	Items	Items
Attributes	Links	Positions	Positions	
	Attributes	Attributes		

Data Types

→ Items → Attributes → Links → Positions → Grids

Dataset Availability

→ Static → Dynamic

Attribute types

- Attribute Types
  - Categorical

  - Ordered
    - *Ordinal*

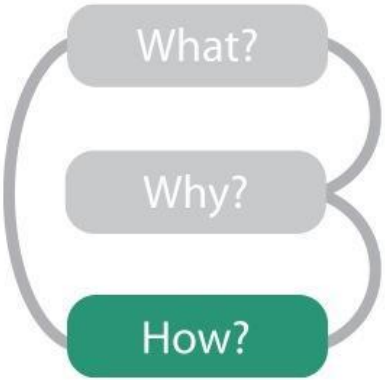
    - *Quantitative*

How?

Encode

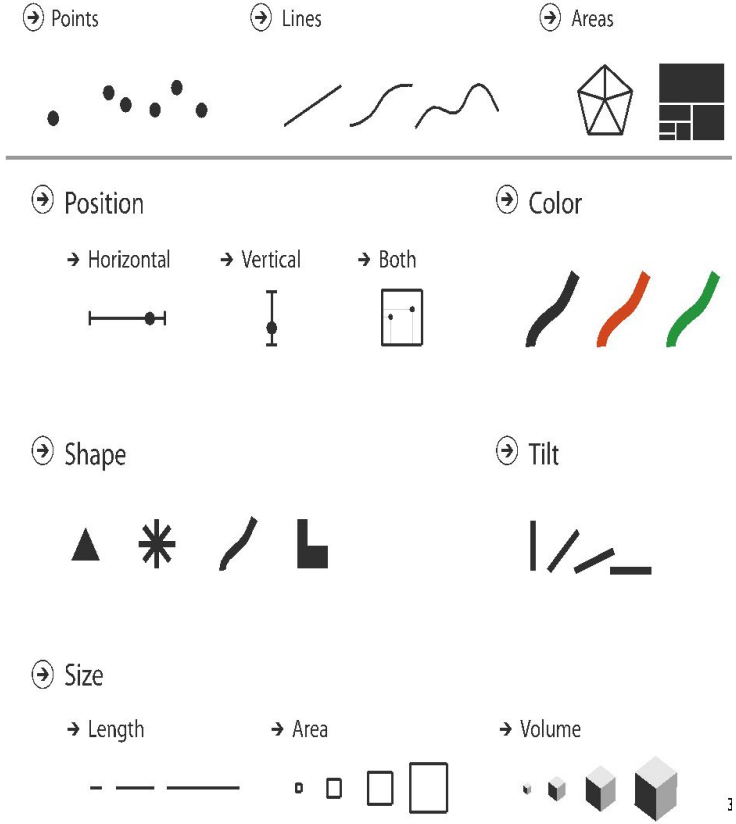
- **Arrange**
  - Express
  - Separate
  - Order
  - Align
  - Use

- **Map**
  from categorical and ordered attributes
  - Color
    - *Hue*
    - *Saturation*
    - *Luminance*
  - Size, Angle, Curvature, ...
  - Shape
  - Motion
    Direction, Rate, Frequency, ...



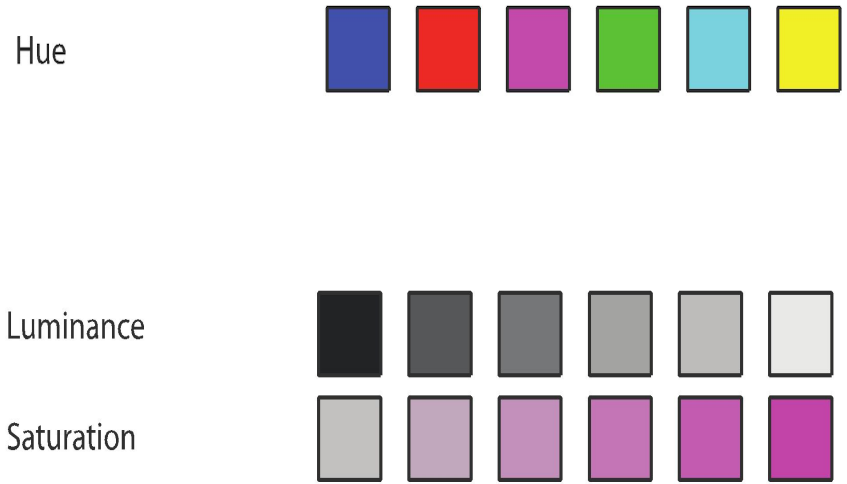
Definitions: Marks and channels

- marks
  - geometric primitives
- channels
  - control appearance of marks
  - can redundantly code with multiple channels
- interactions
  - point marks only convey position; no area constraints
    - can be size and shape coded
  - line marks convey position and length
    - can only be size coded in 1D (width)
  - area marks fully constrained
    - cannot be size or shape coded

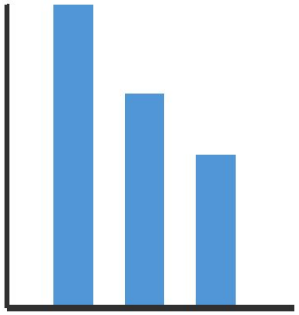


Color: Luminance, saturation, hue

- 3 channels
  - identity channel for categorical
    - hue
  - magnitude channels for ordered
    - luminance
    - saturation

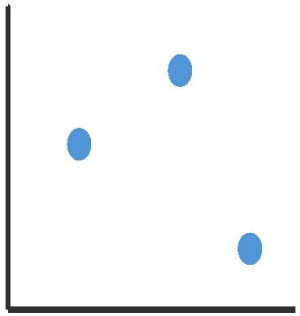


Visual encoding



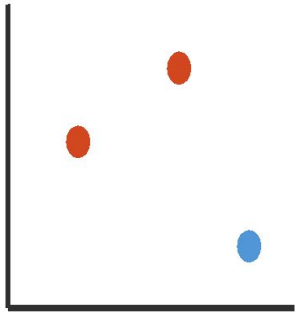
1:
vertical position

mark: line



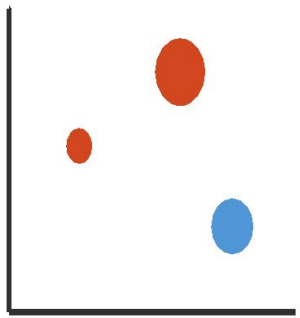
2:
vertical position
horizontal position

mark: point



3:
vertical position
horizontal position
color hue

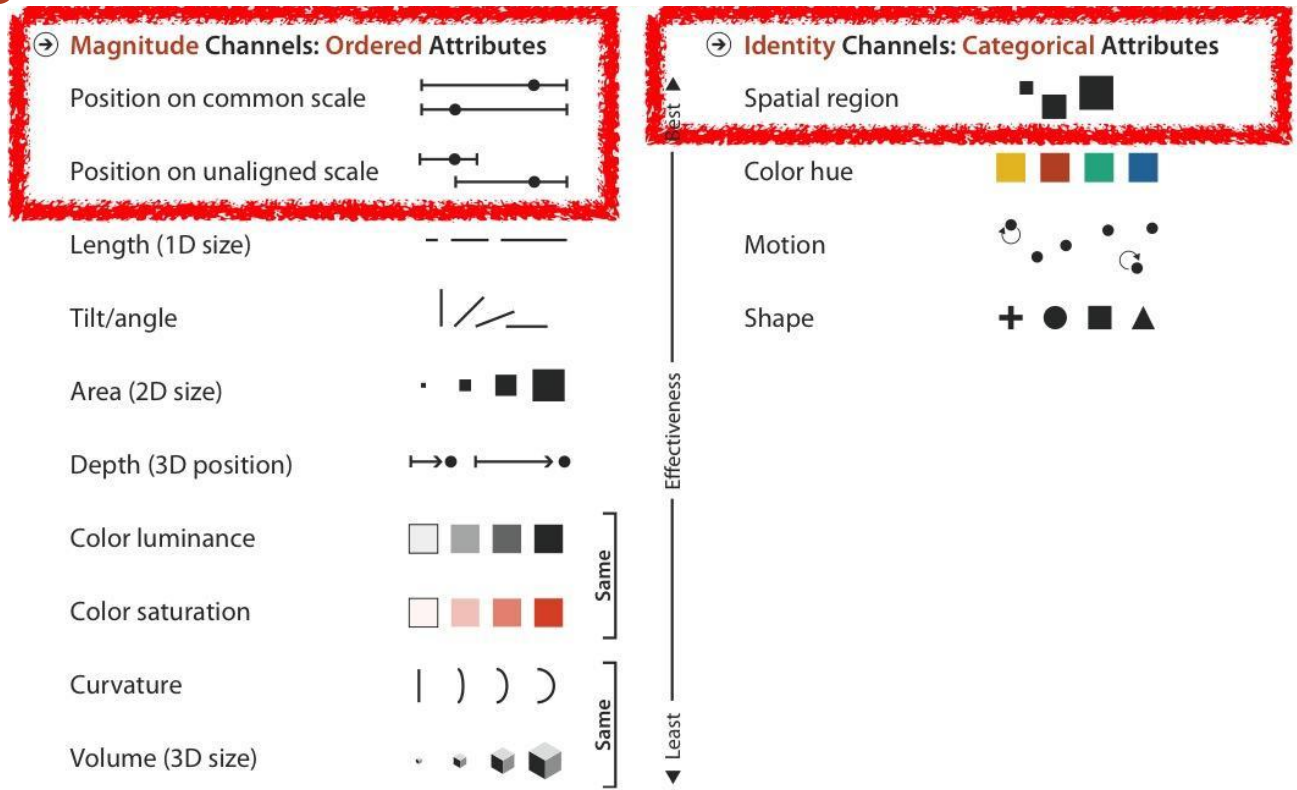
mark: point



4:
vertical position
horizontal position
color hue
size (area)

mark: point

Channels: Expressiveness types and effectiveness rankings



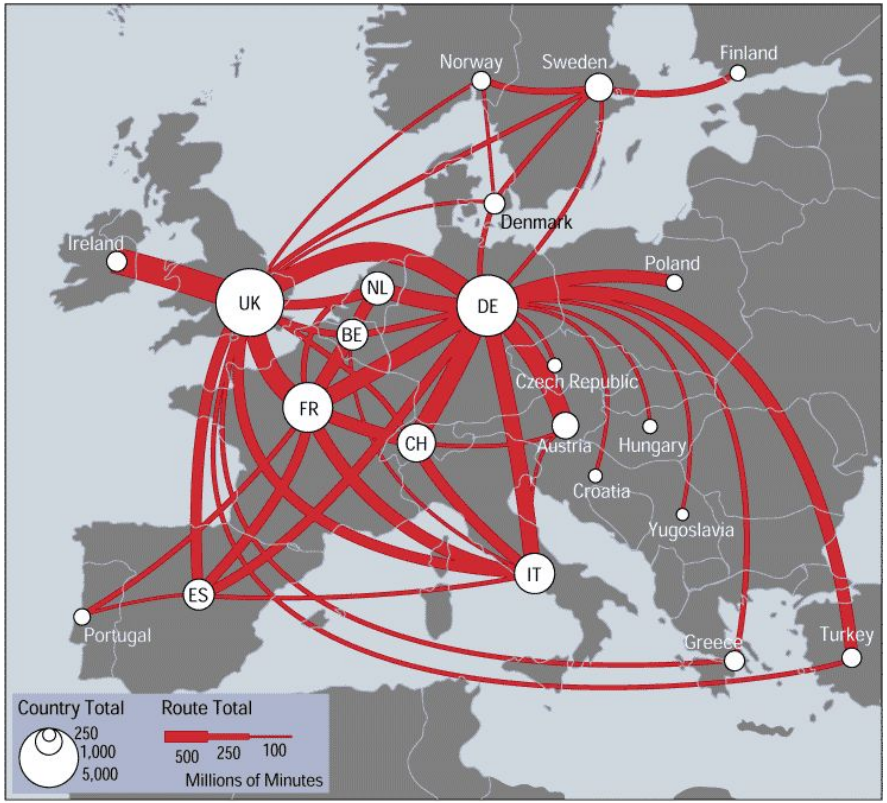
Effectiveness and expressiveness principles

- effectiveness principle
  - encode most important attributes with highest ranked channels

- expressiveness principle
  - match channel and data characteristics

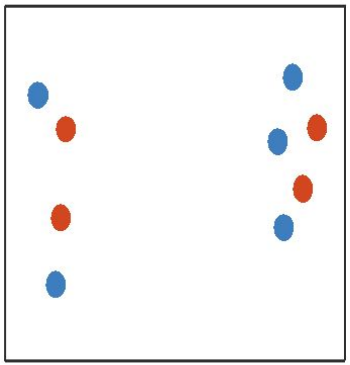
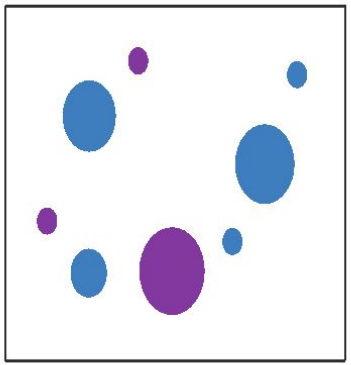
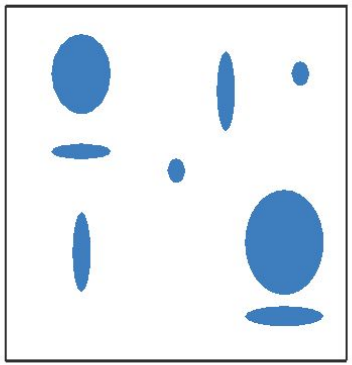
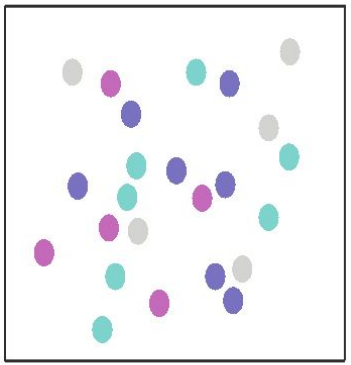
Discriminability: How many usable steps?

- linewidth: only a few



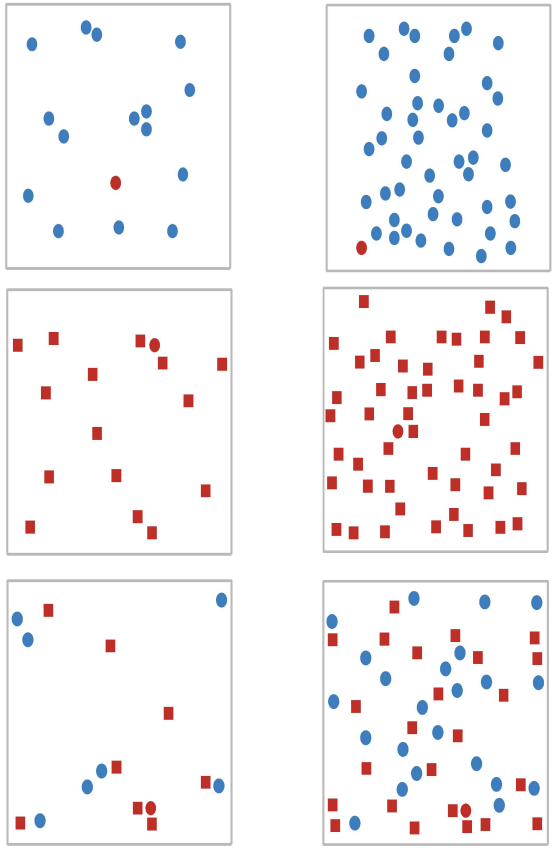
source: *Telecommunications Traffic Flow Map*

Separability vs. Integrality

Position + Hue (Color)	Size + Hue (Color)	Width + Height	Red + Green
			
Fully separable	Some interference	Some/significant interference	Major interference
2 groups each	2 groups each	3 groups total: integral area	4 groups total: integral hue

Popout

- find the red dot
  - how long does it take?



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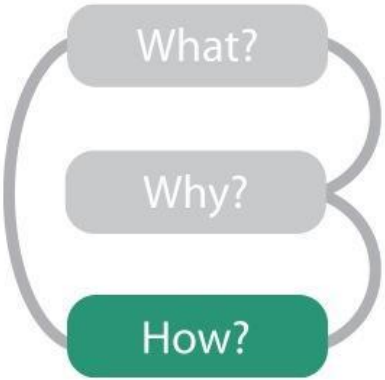

Arrange tables

- Express Values

- Separate, Order, Align Regions
  - Separate

  - Order

  - Align

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(Part 2 - Visualization Idioms)

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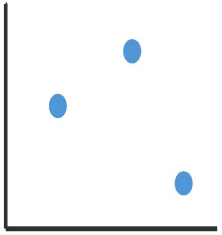
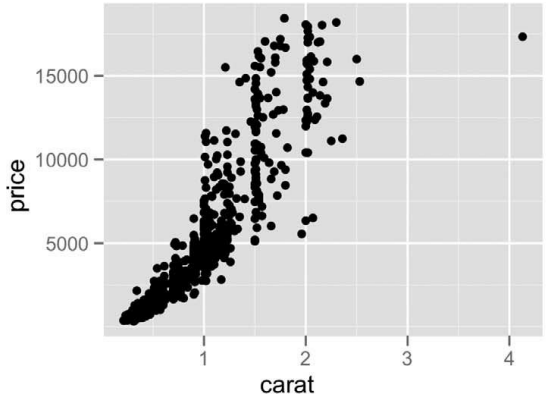
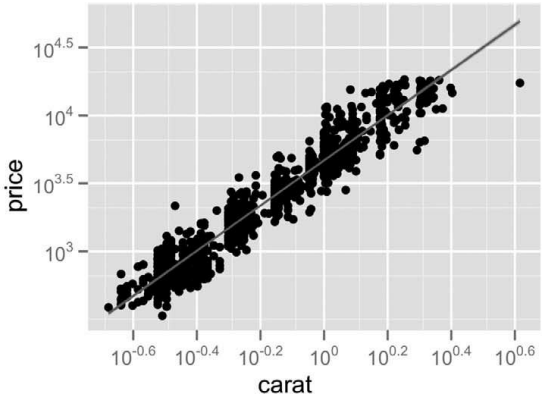
Based on Tamara Munzner, *Visualization Analysis and Design*, AK Peters / CRC Press, Oct 2014

Idiom: **scatterplot**



- ***express*** values
  - quantitative attributes
- no keys, only values
  - data
    - 2 quant attribs
  - mark: points
  - channels
    - horiz + vert position
  - tasks
    - find trends, outliers, distribution, correlation, clusters
  - scalability
    - hundreds of items

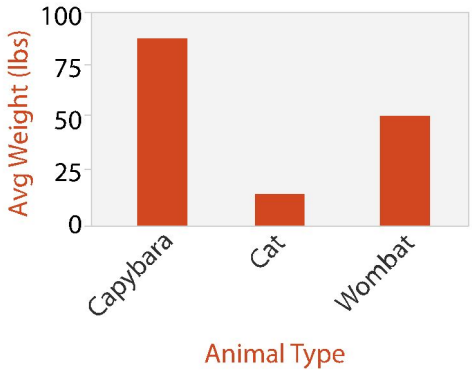


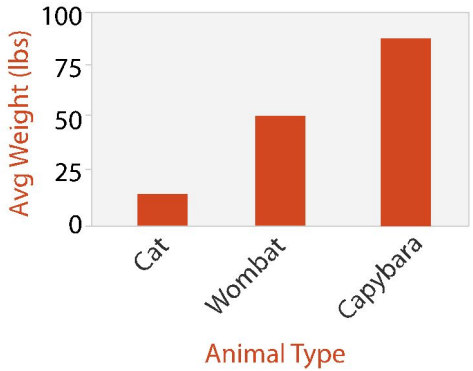


source: [A layered grammar of graphics. Wickham. Journ. Computational and Graphical Statistics 19:1 (2010), 3–28.]

Idiom: **bar chart**

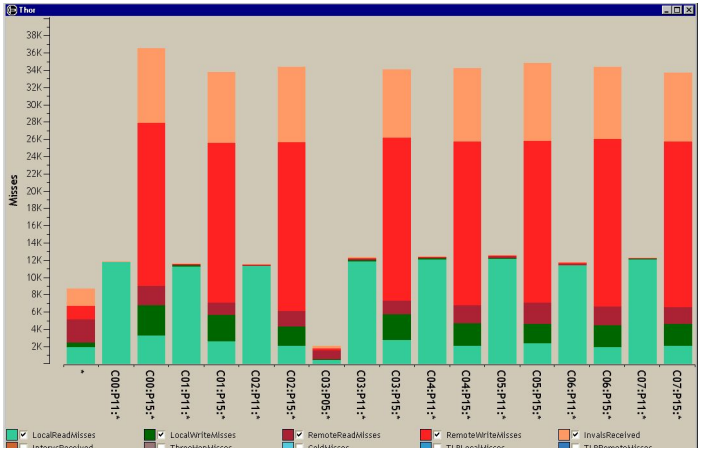
- one key, one value
  - data
    - 1 categ attrib, 1 quant attrib
  - mark: lines
  - channels: length to express quant value
    - spatial regions: one per mark
      - **separate**d horizontally, **align**ed vertically
      - **order**ed by quant attrib
        - » by label (alphabetical), by length attrib (data-driven)
  - task
    - compare, lookup values
  - scalability
    - dozens to hundreds of levels for key attrib





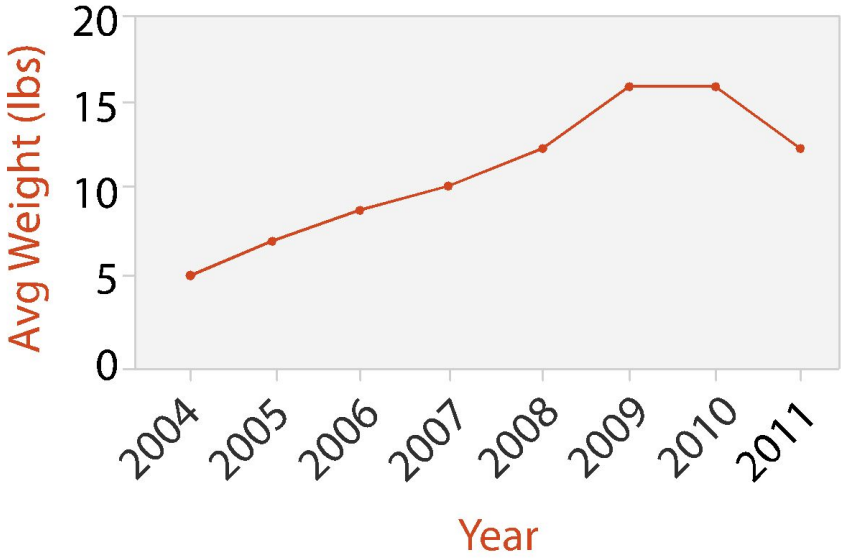
Idiom: **stacked bar chart**

- one more key
  - data
    - 2 categ attrib, 1 quant attrib
  - mark: vertical stack of line marks
    - **glyph**: composite object, internal structure from multiple marks
  - channels
    - length and color hue
    - spatial regions: one per glyph
      - aligned: full glyph, lowest bar component
      - unaligned: other bar components
  - task
    - part-to-whole relationship
  - scalability
    - several to one dozen levels for stacked attrib



source: [Using Visualization to Understand the Behavior of Computer Systems. Bosch. Ph.D. thesis, Stanford Computer Science, 2001.]

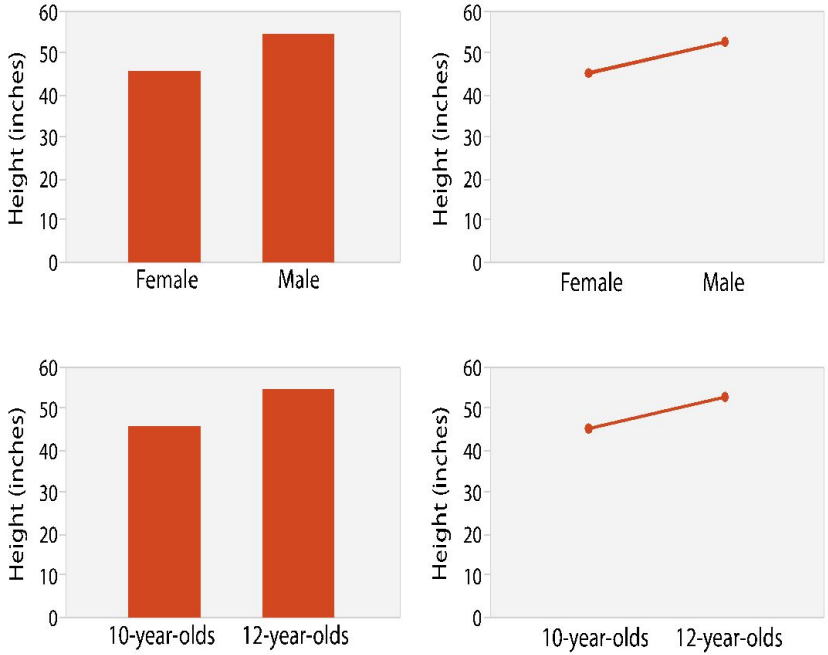
Idiom: **line chart**



- one key, one value
  - data
    - 1 quant attrib, 1 ordered attrib
  - mark: points
    - line connection marks between them
  - channels
    - aligned vertical position
    - separated and ordered by key attrib into horizontal regions
  - task
    - find trend
      - connection marks emphasize ordering of items along key axis by explicitly showing relationship between one item and the next

Choosing bar vs line charts

- depends on type of key attrib
  - bar charts if categorical
  - line charts if ordered
- do not use line charts for categorical key attribs
  - violates expressiveness principle
    - implication of trend so strong that it overrides semantics!
      - "The more male a person is, the taller he/she is"



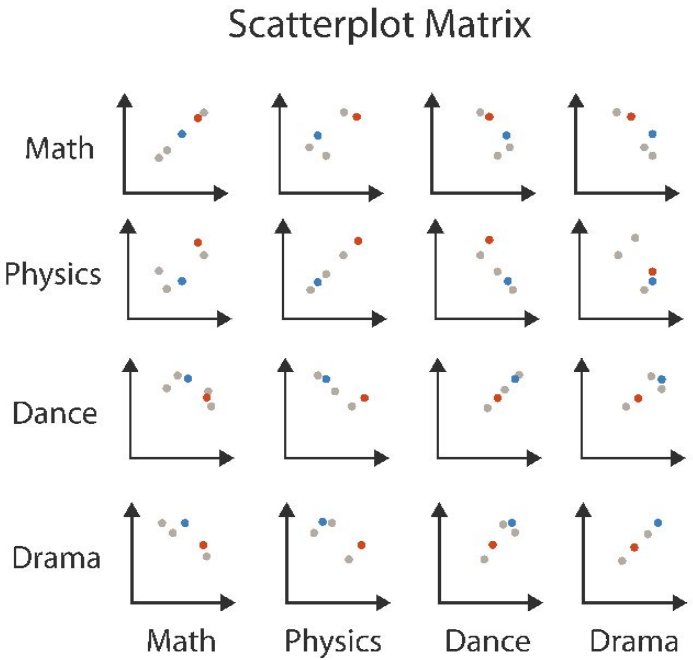
source: [Bars and Lines: A Study of Graphic Communication. Zacks and Tversky. Memory and Cognition 27:6 (1999), 1073–1079.]

Idiom: **scatterplot matrix**

- scatterplot matrix (SPLOM)
  - rectilinear axes, point mark
  - all possible pairs of axes
  - scalability
    - one dozen attribs
    - dozens to hundreds of items
  - task: correlation
    - positive correlation: diagonal low-to-high
    - negative correlation: diagonal high-to-low
    - uncorrelated

Table

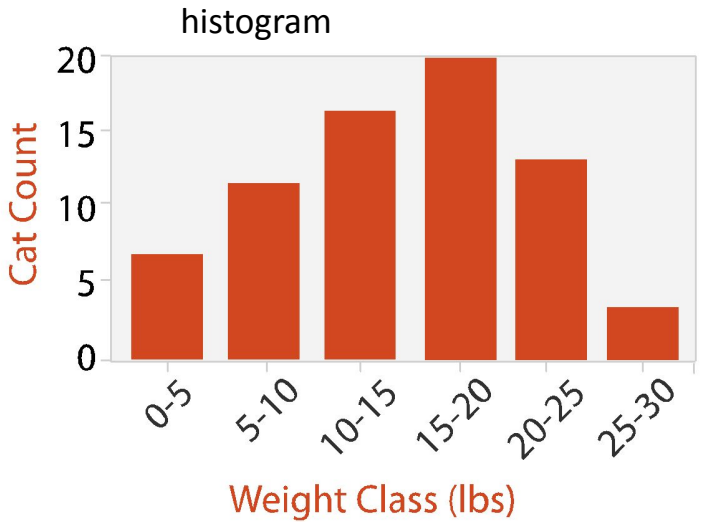
Math	Physics	Dance	Drama
85	95	70	65
90	80	60	50
65	50	90	90
50	40	95	80
40	60	80	90

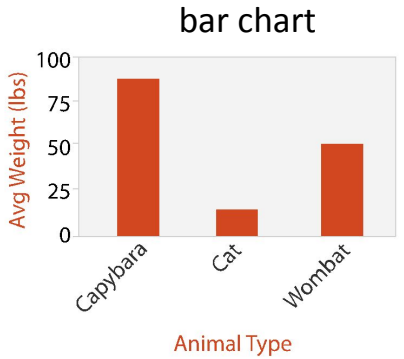


source: [Visualization Course Figures. McGuffin, 2014]

Idiom: **histogram**

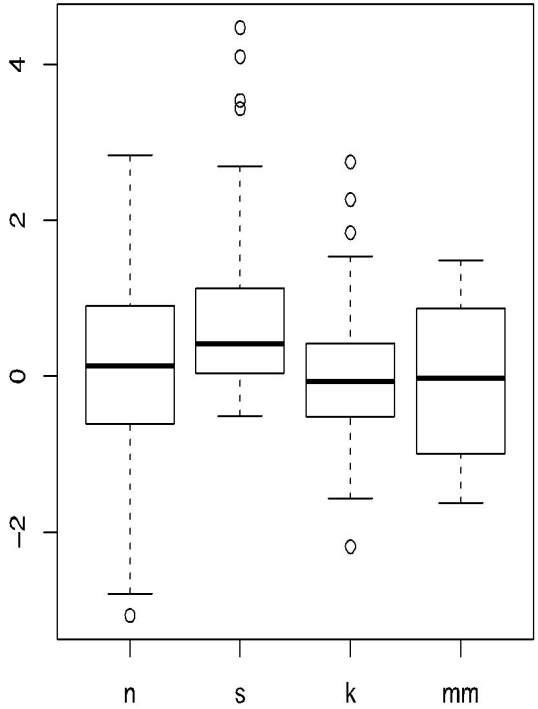
- static item aggregation
- task: find distribution
- data: table
- derived data
  - new table: keys are bins, values are counts
- bin size crucial
  - pattern can change dramatically depending on discretization (bin size)





Idiom: **boxplot**

- static item aggregation
- task: find distribution
- data: table
- derived data
  - 5 quant attribs
    - median: central line
    - lower and upper quartile: boxes
    - lower upper fences: whiskers
      - values beyond which items are outliers
  - outliers beyond fence cutoffs explicitly shown

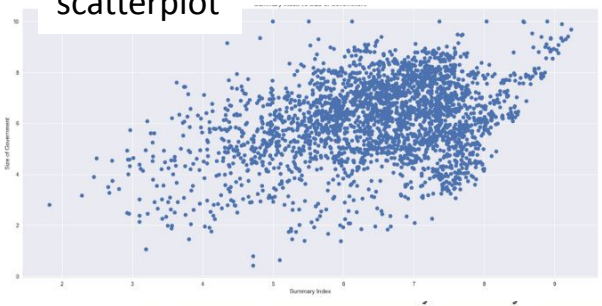


source: [40 years of boxplots. Wickham and Stryjewski. 2012]

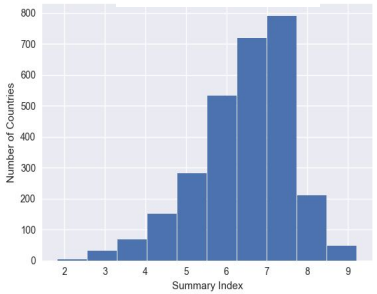
Empirical CDF (ECDF)

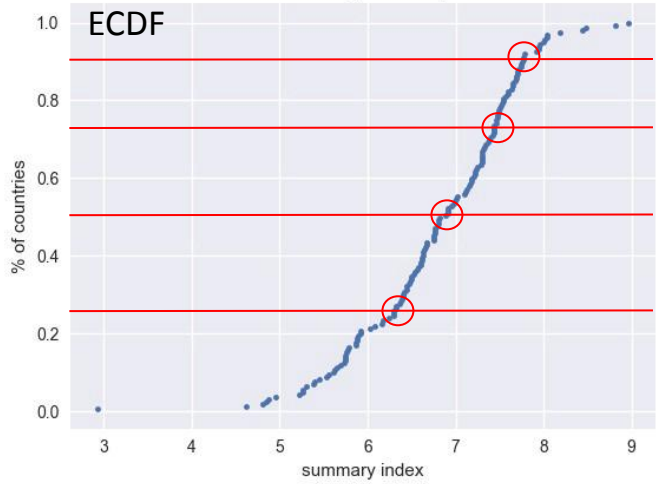
- Expresses percentage of values <= *x*
- Never decreases
- Easy to spot median, quantiles

scatterplot



histogram





source: [What, Why, and How to Read Empirical CDF]

Interested in learning more?

Watch Tamara Munzner's D3 Unconference Keynote, Nov 2015 (55 min)

Still interested?

Take CS 625 - Data Visualization

covers most of Munzner's textbook

Still interested?

Take CS 725/825 - Information Visualization and Visual Analytics

more advanced visualizations, research-based, assumes knowledge of all material from CS 625

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(Part 3 - Charts with R)

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What is R?

- Software for statistical computing and graphics
- Free (GNU General Public Licence) implementation of the S programming language
- Based on a command line interface (various GUIs are available)
- Extensible through loadable libraries
- Available for multiple platforms including Linux, MacOS, Windows
- Well-documented with its own documentation format, similar to UNIX man pages

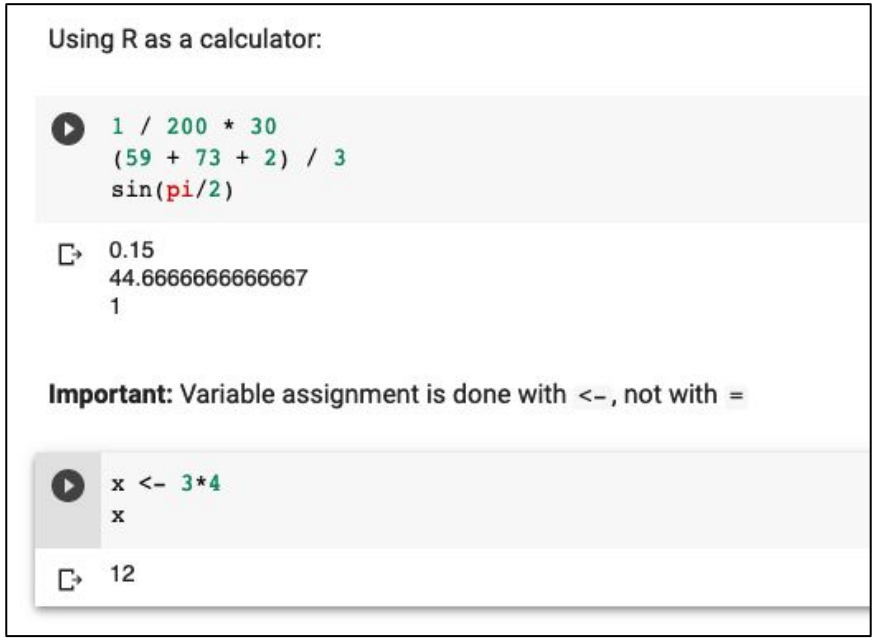
ref: "An Incomplete R Tutorial", Martin Klein

available at The R Project for Statistical Computing
popular GUI: RStudio

R Resources

- The R Project - main R website
  - R Documentation
- RStudio - most popular GUI for R
  - Connect RStudio to Git and GitHub
- RStudio and R for Beginners
- *R for Data Science* - tutorials from O'Reilly book
  - R TidyVerse packages - helper packages for Data Science (used in "R for Data Science")
- "An Incomplete R Tutorial", by Martin Klein

R and Google Colab



Note: There's no menu option to create an R notebook, so you have to create a notebook with certain options in the URL (see link below)

[Create new Google Colab R notebook](https://colab.research.google.com/notebook#create=true&language=r)
(https://colab.research.google.com/notebook#create=true&language=r)

ggplot2

- How to make any plot in ggplot2? | ggplot2 Tutorial
  - basic getting started guide
- The Complete ggplot2 Tutorial - Part1 | Introduction To ggplot2 (Full R code)
  - simple syntax explanation
  - scatterplot
- Top 50 ggplot2 Visualizations - The Master List (With Full R Code)
  - code for 50 different types of charts
- Data Visualization Cheat Sheet
- A ggplot2 Tutorial for Beautiful Plotting in R and Beautiful plotting in R: A ggplot2 cheatsheet
  - examples on how to change a ton of options for customizing the look

ggplot2 Intro

```
library(ggplot2)
ggplot(diamonds)  # if only the dataset is known.
ggplot(diamonds, aes(x=carat))  # if only X-axis is known. The Y-axis can be specified in r
espective geoms.
ggplot(diamonds, aes(x=carat, y=price))  # if both X and Y axes are fixed for all layers.
ggplot(diamonds, aes(x=carat, color=cut))  # Each category of the 'cut' variable will now h
ave a distinct  color, once a geom is added.
```

ref: [How to make any plot in ggplot2?]

ggplot2 Intro

```
library(ggplot2)
gg <- ggplot(diamonds, aes(x=carat, y=price, color=cut)) + geom_point() + labs(title="Scatterplot", x="Carat", y="Price")  # add axis lables and plot title.
print(gg)
```

ref: [How to make any plot in ggplot2?]

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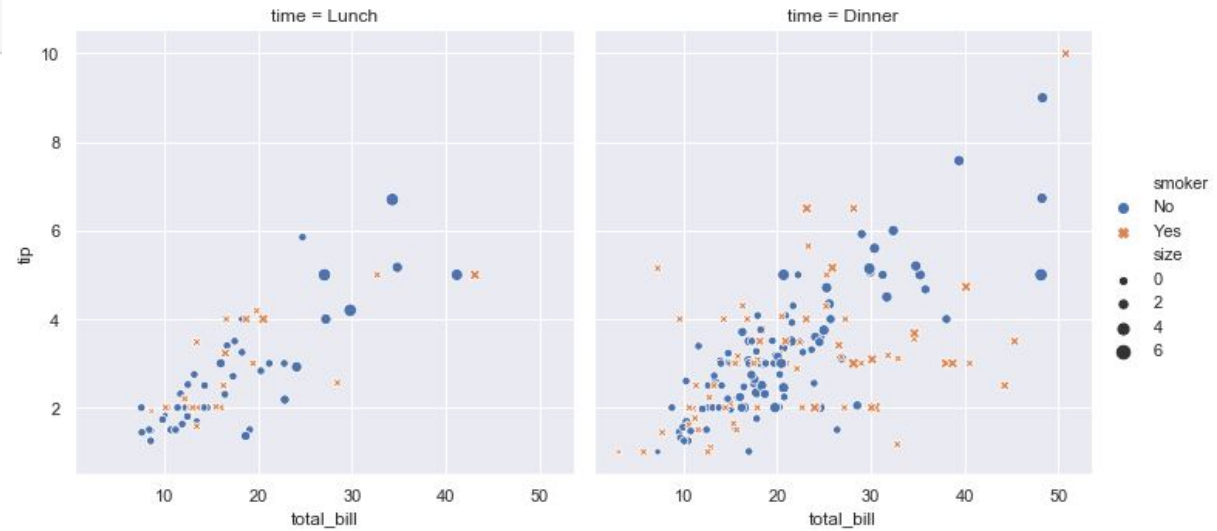
Ways to Plot Data in Python

- Matplotlib
  - most popular Python plotting library, similar to Matplot
- Seaborn
  - high-level interface to Matplotlib
- Plotly
  - interactive, open-source, and browser-based graphing library, built on top of D3
- Bokeh
  - interactive visualization library for modern web browsers, outputs plots as HTML files
- Altair
  - declarative statistical visualization library for Python, based on Vega and Vega-Lite
- Pygal
  - focus on visual appearance, produces SVG plots
- Pandas
  - popular data science library for Python, visualization is wrapper around Matplotlib

ref: The 7 most popular ways to plot data in Python

Seaborn

```
import seaborn as sns
sns.set()
tips = sns.load_dataset("tips")
sns.relplot(x="total_bill", y="tip", col="time",
            hue="smoker", style="smoker", size="size",
            data=tips);
```



Note: A couple updates to the Google Colab notebook have been made since the lecture video was recorded:

- distplot() is deprecated, so that has been replaced with histplot()
- Seaborn has added the ecdfplot() function, so I've added an example using that.

Objectives

- Distinguish between categorical and ordered attributes.
- Explain how marks and channels are related.
- Distinguish between the identity channel type and the magnitude channel type and indicate which channels belong to each type.
- Distinguish between the principles of expressiveness and effectiveness in visual encoding.
- List the channels for ordered attributes in order from most effective to least effective.
- Explain how the concepts of express, separate, order, and align all relate to arranging tabular data.
- Differentiate between line charts and bar charts and explain when each is appropriate.
- Explain how the boxplot idiom can characterize a distribution.
- Use R to create a bar chart, line chart, and scatterplot.
- Use Python charting libraries to create a bar chart, line chart, and scatterplot.