Exploratory Data Analysis

Maneesh Agrawala

CS 448B: Visualization
Fall 2021

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The Rise of Statistics (1900-1950s)

Rise of **formal methods** in statistics and social science – Fisher, Pearson, …

Little innovation in graphical methods

A period of **application** and **popularization**

Graphical methods enter textbooks, curricula, and **mainstream use**

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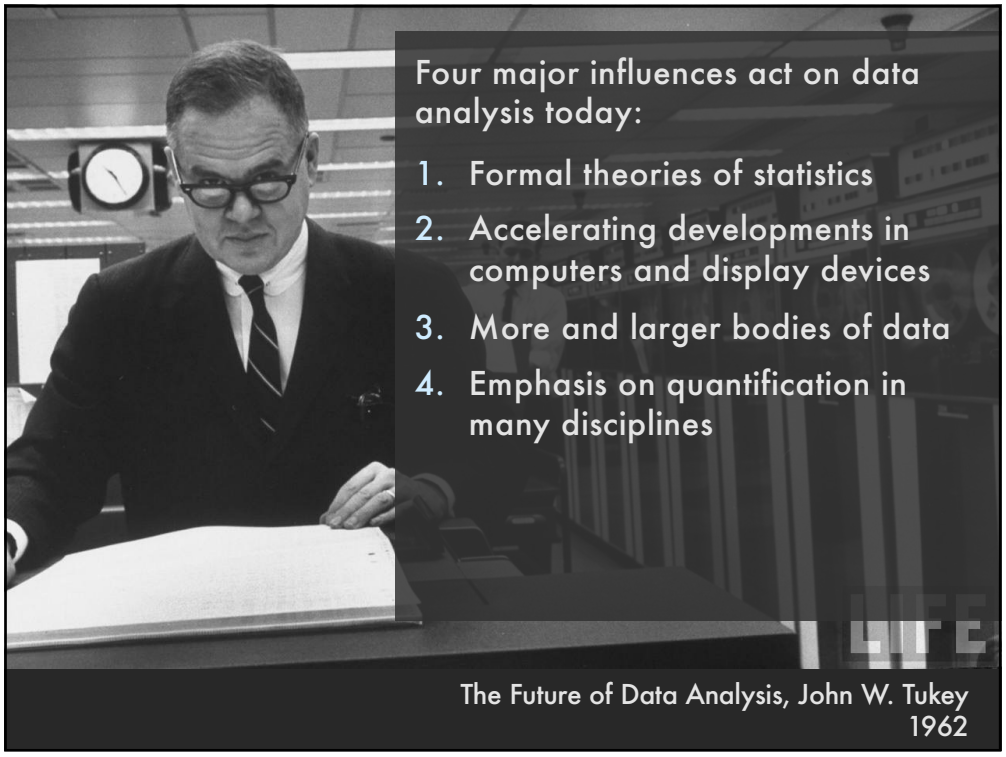
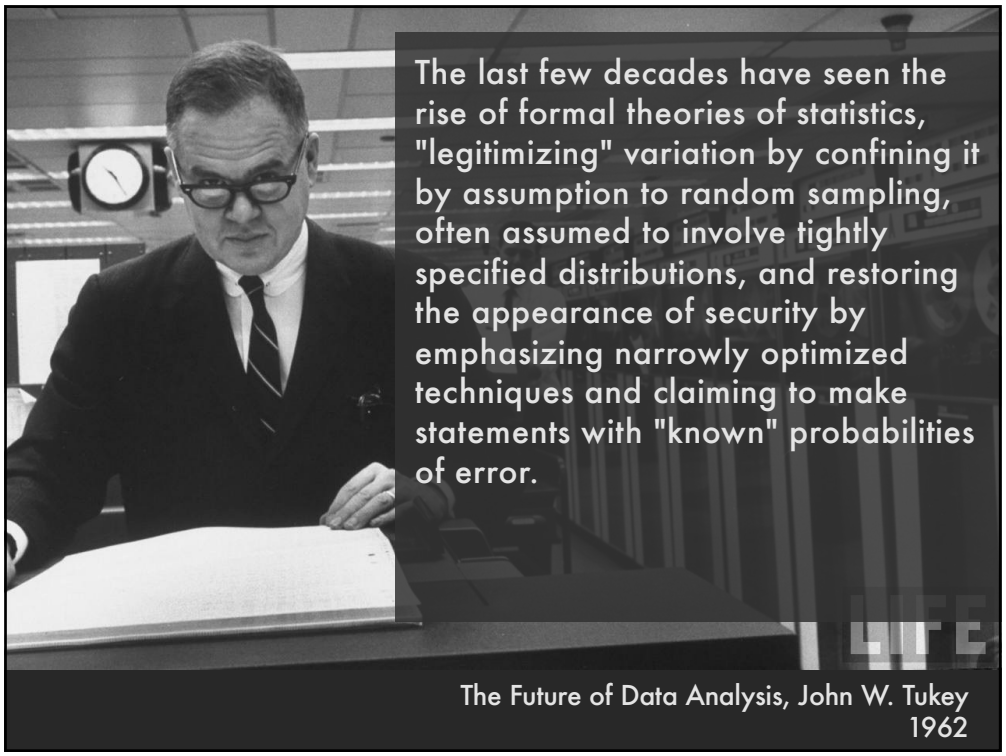
LIFE

3


Four major influences act on data analysis today:
1. Formal theories of statistics
2. Accelerating developments in computers and display devices
3. More and larger bodies of data
4. Emphasis on quantification in many disciplines
LIFE
The Future of Data Analysis, John W. Tukey
1962

4


The last few decades have seen the rise of formal theories of statistics, "legitimizing" variation by confining it by assumption to random sampling, often assumed to involve tightly specified distributions, and restoring the appearance of security by emphasizing narrowly optimized techniques and claiming to make statements with "known" probabilities of error.
The Future of Data Analysis, John W. Tukey
1962

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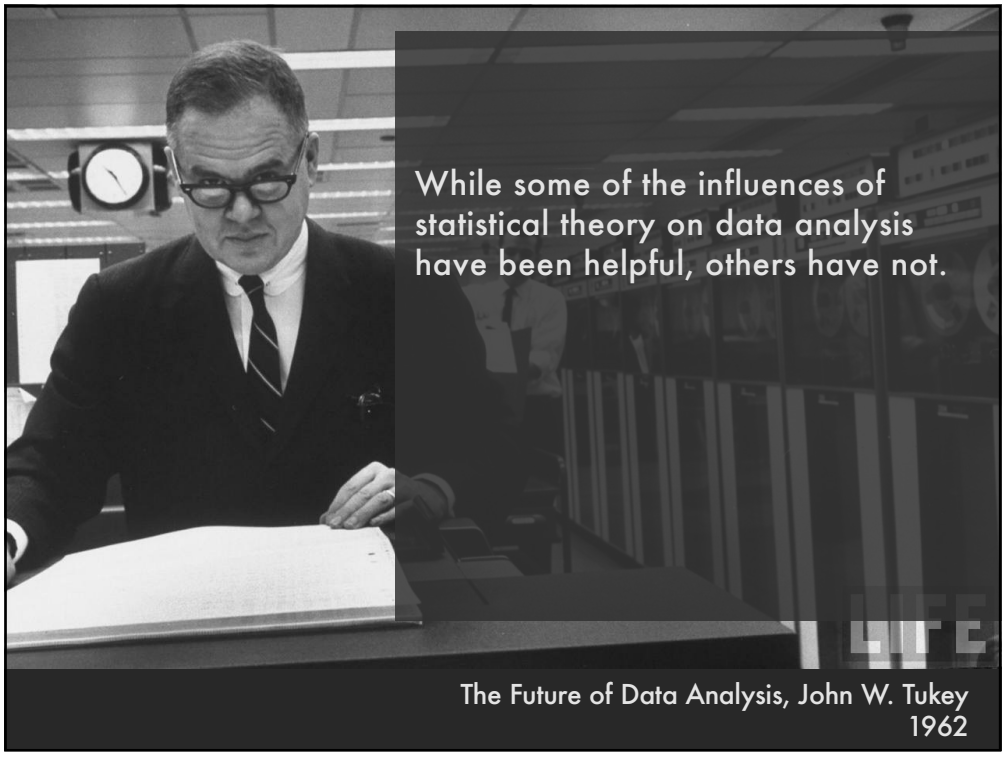
While some of the influences of statistical theory on data analysis have been helpful, others have not.
The Future of Data Analysis, John W. Tukey
1962

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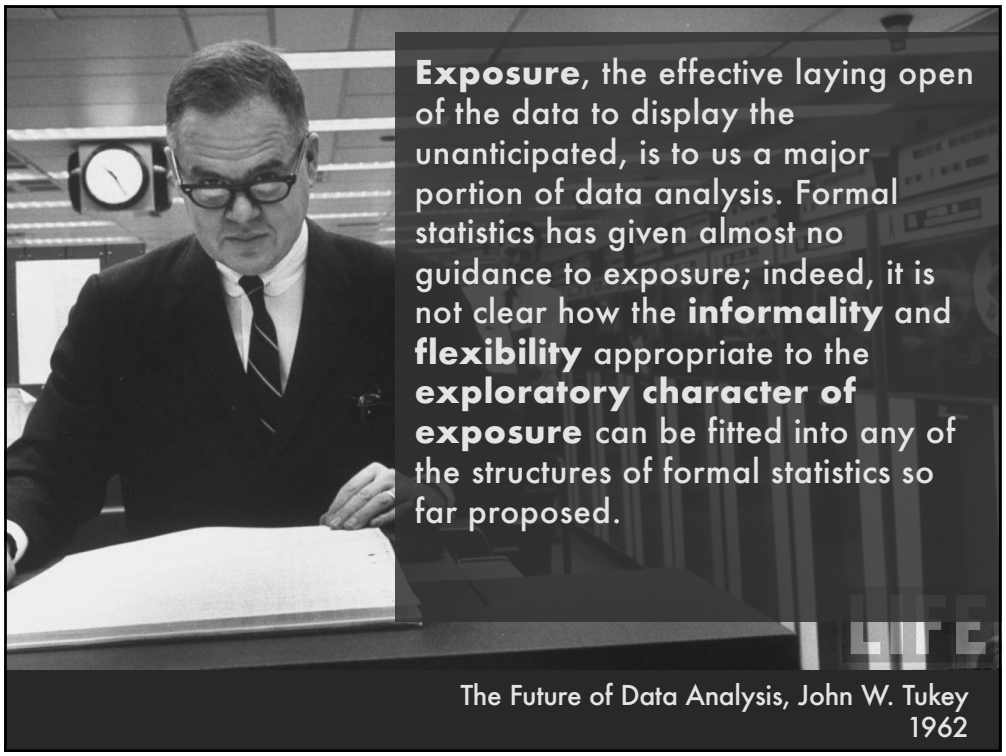
Exposure, the effective laying open of the data to display the unanticipated, is to us a major portion of data analysis. Formal statistics has given almost no guidance to exposure; indeed, it is not clear how the **informality** and **flexibility** appropriate to the **exploratory character of exposure** can be fitted into any of the structures of formal statistics so far proposed.
The Future of Data Analysis, John W. Tukey
1962

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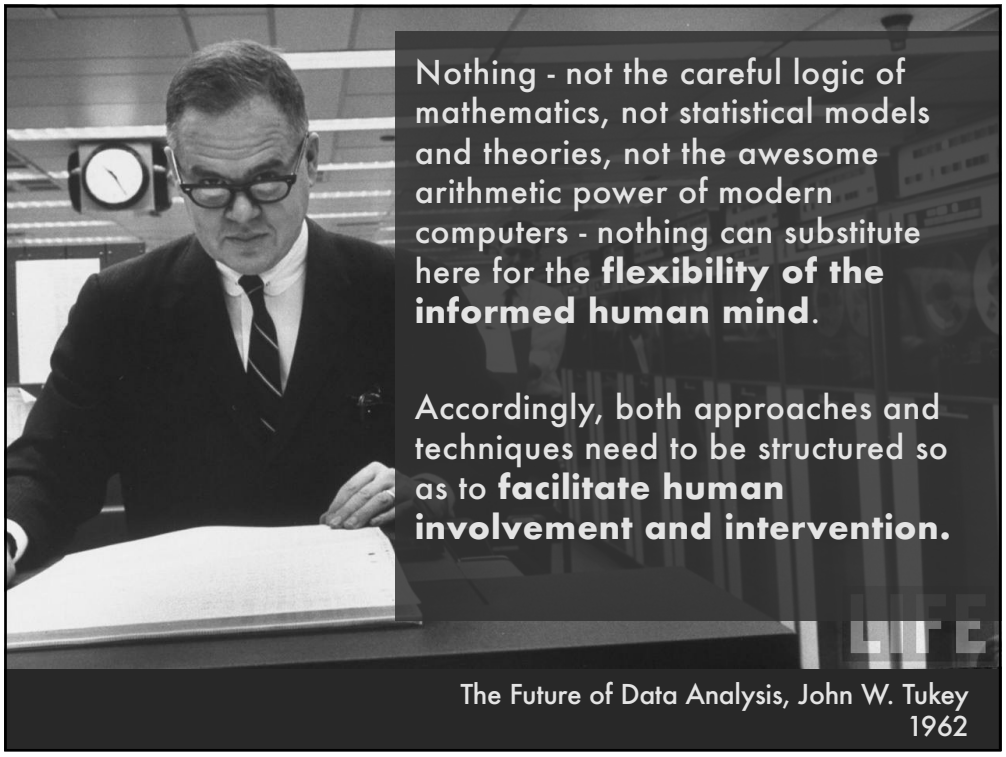
Nothing - not the careful logic of mathematics, not statistical models and theories, not the awesome arithmetic power of modern computers - nothing can substitute here for the **flexibility of the informed human mind**.
Accordingly, both approaches and techniques need to be structured so as to **facilitate human involvement and intervention.**
The Future of Data Analysis, John W. Tukey
1962

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Topics

Data Wrangling
Effectiveness of antibiotics
Intro to Tableau

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Data Wrangling

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Bureau of Justice Statistics - Data Online
http://bjs.ojp.usdoj.gov/

Reported crime in Alabama

Year    Population      Property crime rate     Burglary rate   Larceny-theft rate      Motor vehicle theft rate
2004    4525375 4029.3  987     2732.4  309.9
2005    4548327 3900    955.8   2656    289
2006    4599030 3937    968.9   2645.1  322.9
2007    4627851 3974.9  980.2   2687    307.7
2008    4661900 4081.9  1080.7  2712.6  288.6

Reported crime in Alaska

Year    Population      Property crime rate     Burglary rate   Larceny-theft rate      Motor vehicle theft rate
2004    657755  3370.9  573.6   2456.7  340.6
2005    663253  3615    622.8   2601    391
2006    670053  3582    615.2   2588.5  378.3
2007    683478  3373.9  538.9   2480    355.1
2008    686293  2928.3  470.9   2219.9  237.5

Reported crime in Arizona

Year    Population      Property crime rate     Burglary rate   Larceny-theft rate      Motor vehicle theft rate
2004    5739879 5073.3  991     3118.7  963.5
2005    5953007 4827    946.2   2958    922
2006    6166318 4741.6  953     2874.1  914.4
2007    6338755 4502.6  935.4   2780.5  786.7
2008    6500180 4087.3  894.2   2605.3  587.8

Reported crime in Arkansas

Year    Population      Property crime rate     Burglary rate   Larceny-theft rate      Motor vehicle theft rate
2004    2750000 4033.1  1096.4  2699.7  237
2005    2775708 4068    1085.1  2720    262
2006    2810872 4021.6  1154.4  2596.7  270.4
2007    2834797 3945.5  1124.4  2574.6  246.5
2008    2855390 3843.7  1182.7  2433.4  227.6

Reported crime in California

Year    Population      Property crime rate     Burglary rate   Larceny-theft rate      Motor vehicle theft rate
2004    35842038        3423.9  686.1   2033.1  704.8
2005    36154147        3321    692.9   1915    712
2006    36457549        3175.2  676.9   1831.5  666.8
2007    36553215        3032.6  648.4   1784.1  600.2
2008    36756666        2940.3  646.8   1769.8  523.8

Reported crime in Colorado

Year    Population      Property crime rate     Burglary rate   Larceny-theft rate      Motor vehicle theft rate
2004    4601821 3918.5  717.3   2679.5  521.6
```

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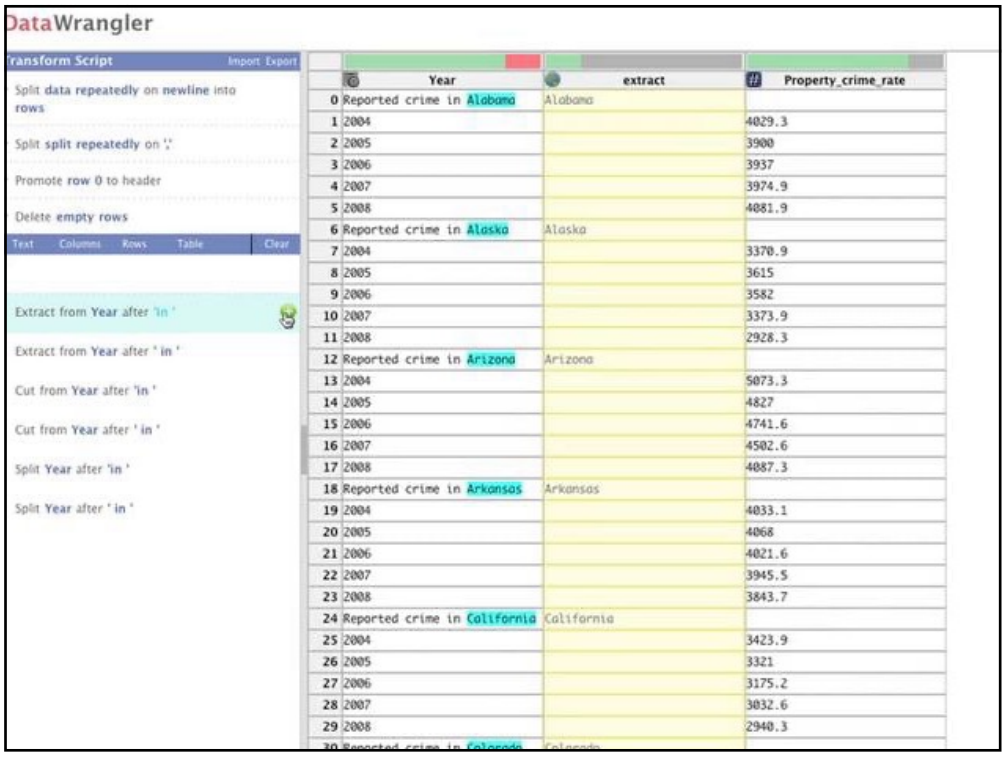

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Data "Wrangling"

One often needs to manipulate data prior to analysis. Tasks include reformatting, cleaning, quality assessment, and integration

Some approaches:

- Writing custom scripts
- Manual manipulation in spreadsheets
- Trifacta Wrangler: http://trifacta.com/products/wrangler/
- Open Refine: http://openrefine.org
- Arquero.js: https://observablehq.com/@uwdata/introducing-arquero

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How to gauge the quality of a visualization?

"The first sign that a visualization is good is that it shows you a problem in your data…

…every successful visualization that I've been involved with has had this stage where you realize, "Oh my God, this data is not what I thought it would be!" So already, you've discovered something."

- Martin Wattenberg

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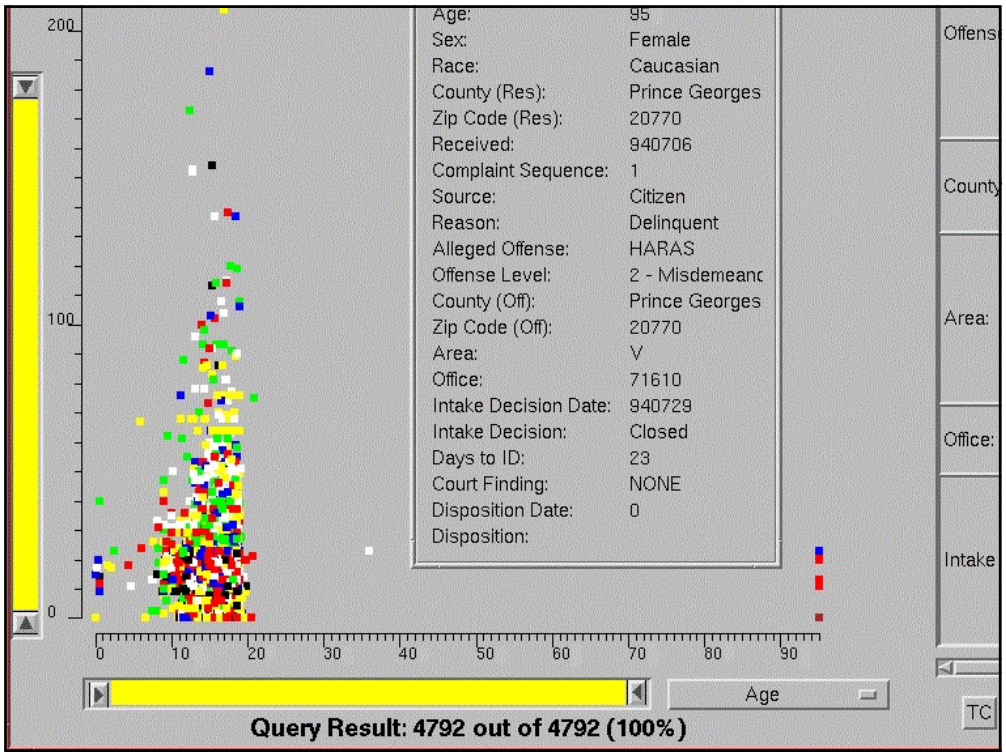
Age: 95
Sex: Female
Race: Caucasian
County (Res): Prince Georges
Zip Code (Res): 20770
Received: 940706
Complaint Sequence: 1
Source: Citizen
Reason: Delinquent
Alleged Offense: HARAS
Offense Level: 2 - Misdemeanc
County (Off): Prince Georges
Zip Code (Off): 20770
Area: V
Office: 71610
Intake Decision Date: 940729
Intake Decision: Closed
Days to ID: 23
Court Finding: NONE
Disposition Date: 0
Disposition:
Offens
County
Area:
Office:
Intake
Age
TC
Query Result: 4792 out of 4792 (100%)

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facebook
Profile edit Friends Networks Inbox
home account privacy logout
Search
Applications edit
Photos
Groups
Events
Marketplace
The New York Times News Quiz
more
Send Bill a Gift
Send Bill a Message
Poke Bill!
Friends
See All
Bill Gates
is glad he finally joined facebook and hopes you will too!!! :)
Updated 6 minutes ago
Mini-Feed
Displaying 15 stories
See All
Update: Bill has posted a note:
Friends, I have finally caved and joined facebook, America's fastest-growing social-networking web site! At first I didn't join because you needed a college alumni address, and I never quite got one... Then when the place started opening up to high schools and corporations, with everyone and his grandmother joining, I wanted in. But by then I was mad I didn't have any shares in this $15 billion baby. ... So just now I decided to plunk down $240 million to buy 1.6% of the company from cool kid CEO Mark Zuckerberg. Sure I saw the potential for ad revenue right away -- but this is wild. I've never had my own Facebook page before!
Don't have a lot of friends yet but I've been running into people... Seeing their status updates... Wow, it's a great place to check up on my employees and my kids! They keep saying what their weekend plans are in their status bars. And of course I love how you can add all these little software applications to the page. Or write your very own!
I'm still getting the hang of the whole thing... It seems there are a variety of forums where I can vent to others and display details of my life? O.K.: It wasn't easy being so much smarter than everyone else, pretending to be a grown-up over the telephone so I could get grown-up jobs programming these new things called computers when I was still a child.
At college I led the anti-social group. Never led a social group, or had a social network... Ha, ha, now I've done even better than that: I've bought a piece of the national friend system! Take that cliquesters. Anyone who ever ignored me in the dining hall... Got friends? I own 1.6 % of your friends.
But don't worry about them. Send me a message! Write on my wall!
Bill and Mark Zuckerberg are now friends
Bill and Warren Buffett have joined the group Save the World Now through Creative Capitalism (3 Members)
Steve Ballmer
Mark Zuckerberg
William Randolph
Bono

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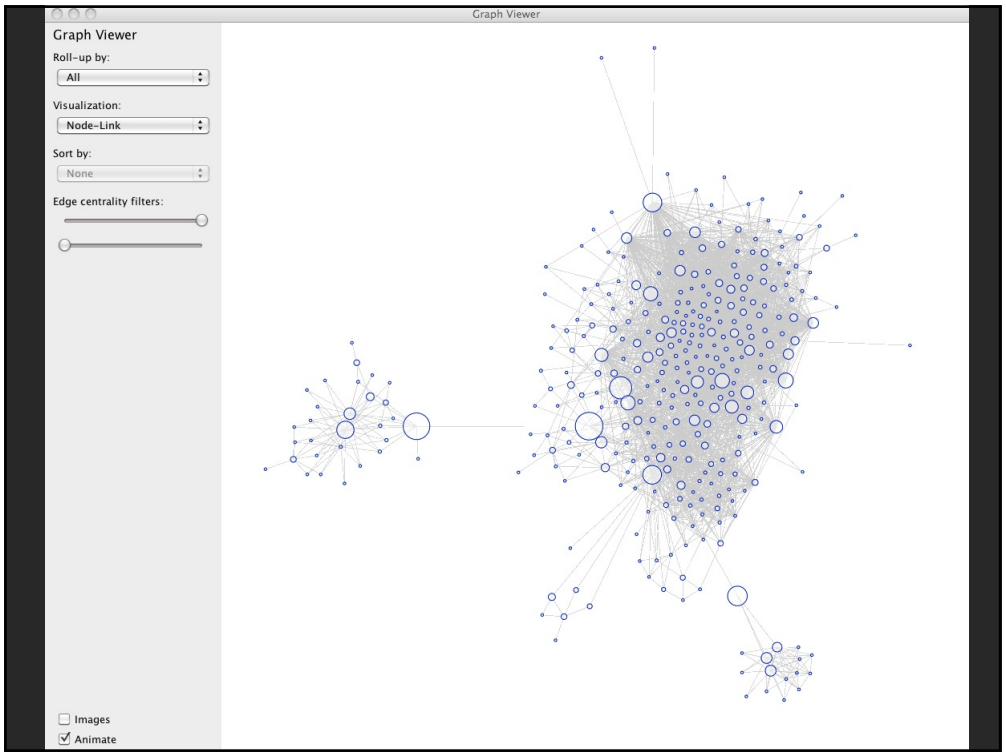
Graph Viewer
Graph Viewer
Roll-up by:
All
Visualization:
Node-Link
Sort by:
None
Edge centrality filters:
Images
Animate

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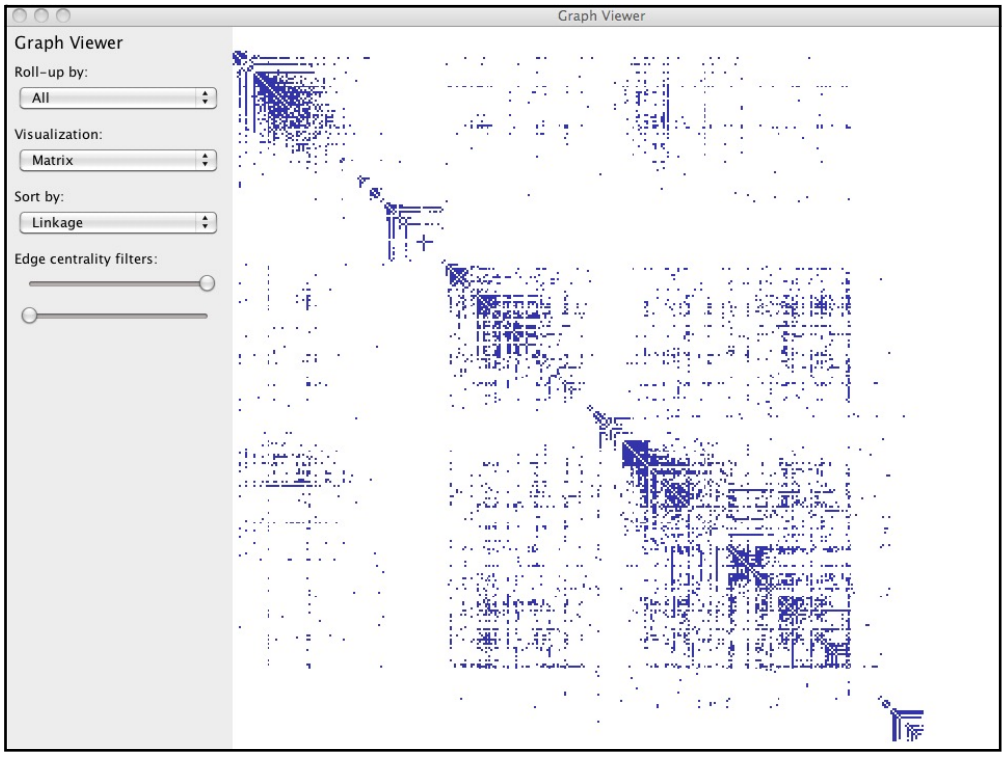
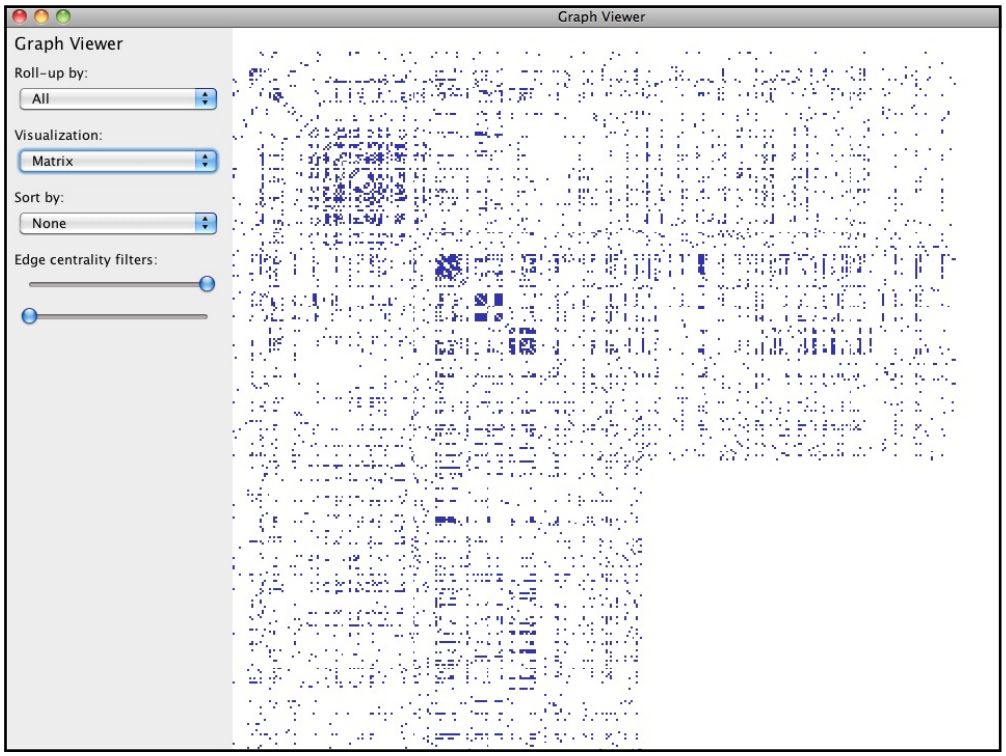

Graph Viewer
Graph Viewer
Roll-up by:
All
Visualization:
Matrix
Sort by:
Linkage
Edge centrality filters:

20



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Visualize Friends by School?

Berkeley	|||||||||||||||||||||||||||||||||
Cornell	||||
Harvard	|||||||||
Harvard University	|||||||
Stanford	||||||||||||||||||||
Stanford University	||||||||||
UC Berkeley	|||||||||||||||||||||||
UC Davis	||||||||||
Univ. of California at Berkeley	||||||||||||||||
Univ. of California, Berkeley	||||||||||||||||||||
Univ. of California, Davis	|||

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Data Quality Hurdles

Missing Data	no measurements, redacted, …?
Erroneous Values	misspelling, outliers, …?
Type Conversion	e.g., zip code to lat-lon
Entity Resolution	diff. values for the same thing?
Data Integration	effort/errors when combining data

LESSON: **Anticipate problems with your data. Many research problems around these issues!**

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Analysis Example: Motion Pictures Data

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Motion Pictures Data

Title	String (N)
IMDB Rating	Number (Q)
Rotten Tomatoes Rating	Number (Q)
MPAA Rating	String (O)
Release Date	Date (T)

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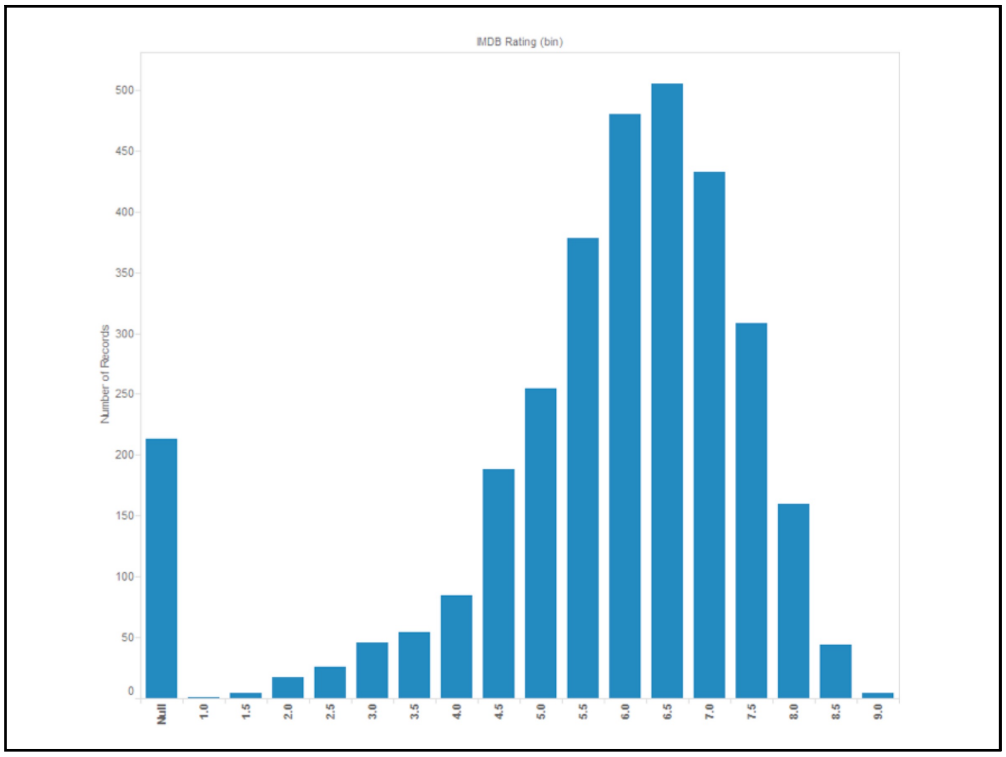

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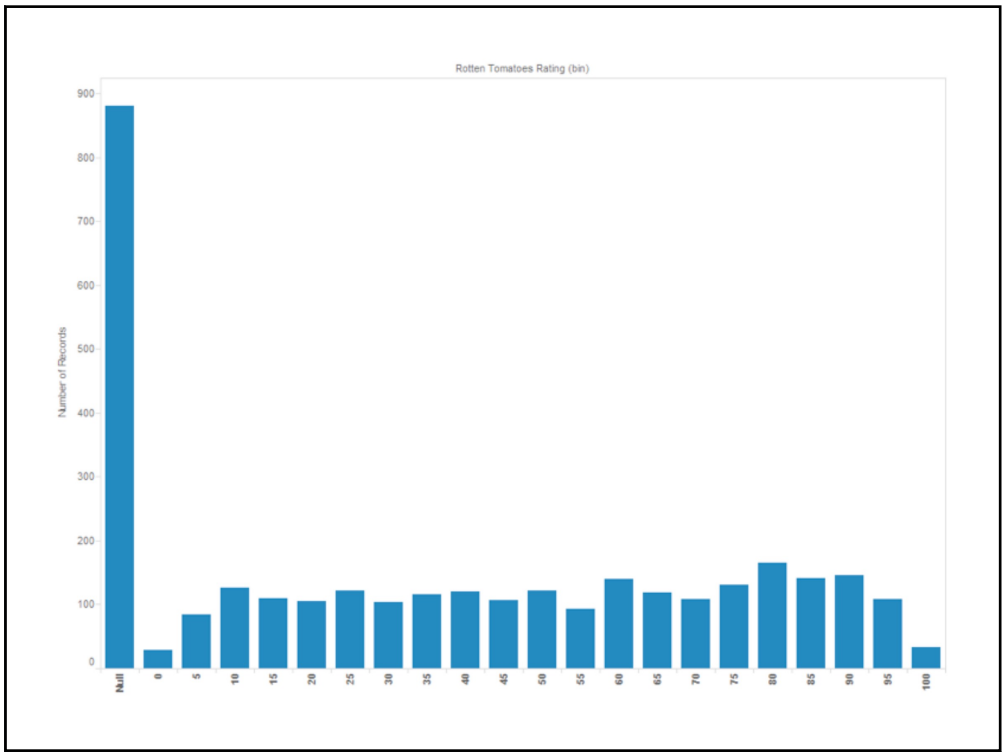
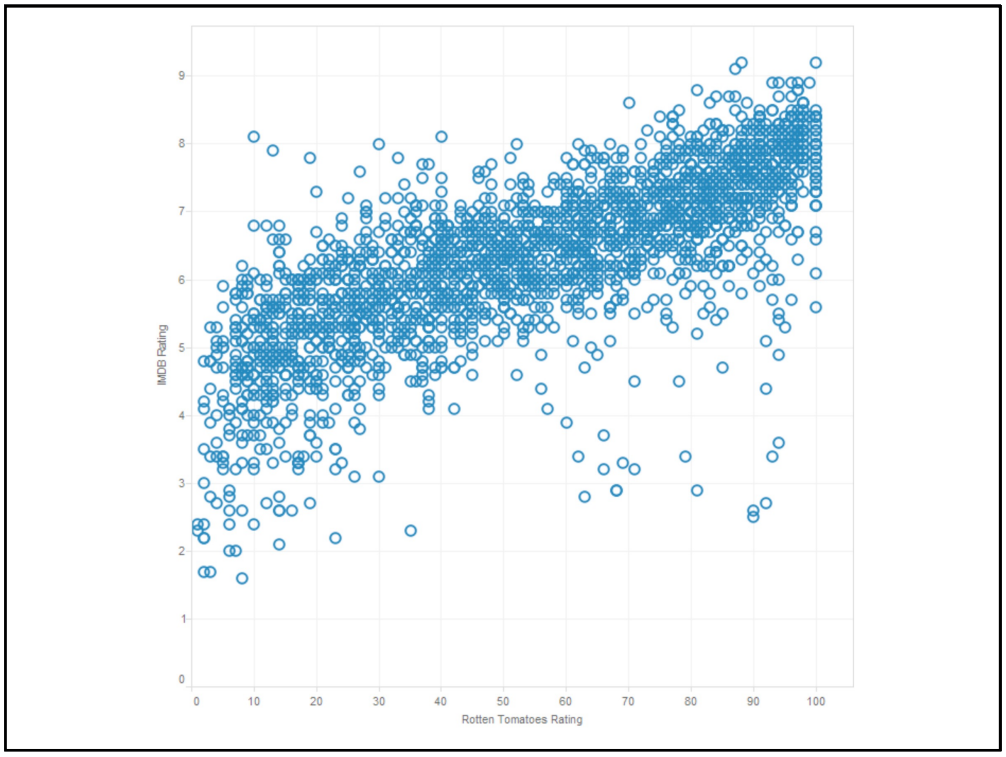
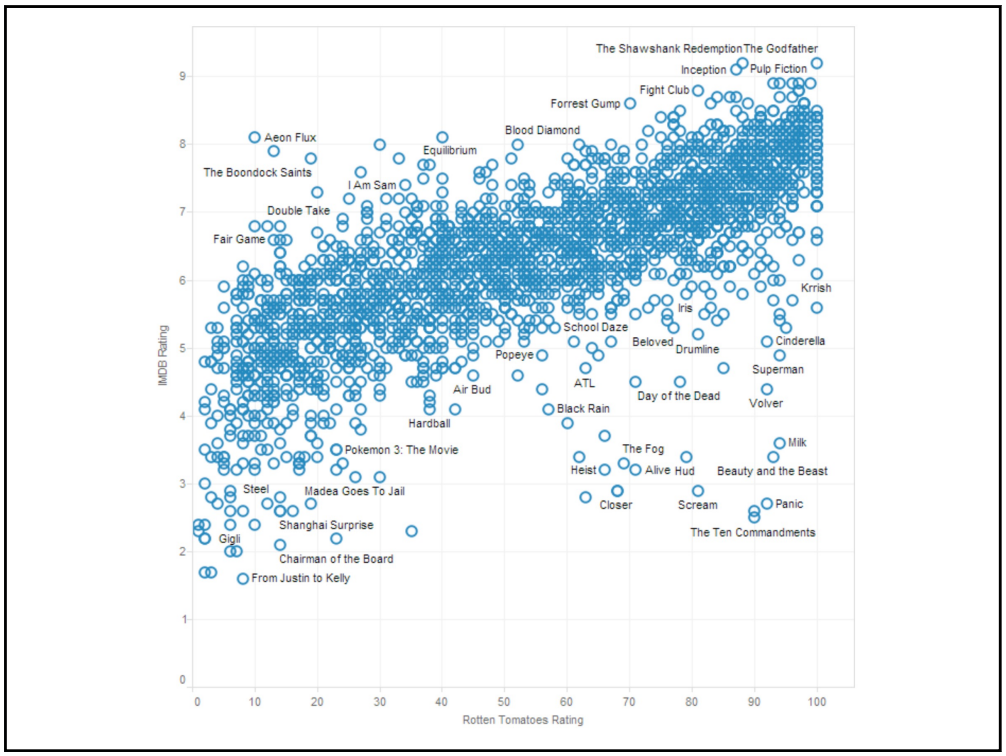

Rotten Tomatoes Rating (bin)
Number of Records
900
800
700
600
500
400
300
200
100
0
Null
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100

27


IMDB Rating
9
8
7
6
5
4
3
2
1
0
0
10
20
30
40
50
60
70
80
90
100
Rotten Tomatoes Rating

28


The Shawshank Redemption
The Godfather
Inception
Pulp Fiction
Fight Club
Forrest Gump
Blood Diamond
Aeon Flux
Equilibrium
The Boondock Saints
I Am Sam
Double Take
Fair Game
Krrish
Iris
School Daze
Beloved
Drumline
Cinderella
Popeye
Superman
ATL
Air Bud
Day of the Dead
Volver
Black Rain
Hardball
Milk
The Fog
Pokemon 3: The Movie
Heist
Alive
Hud
Beauty and the Beast
Steel
Madea Goes To Jail
Closer
Scream
Panic
Shanghai Surprise
The Ten Commandments
Gigli
Chairman of the Board
From Justin to Kelly
IMDB Rating
Rotten Tomatoes Rating
0
1
2
3
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0
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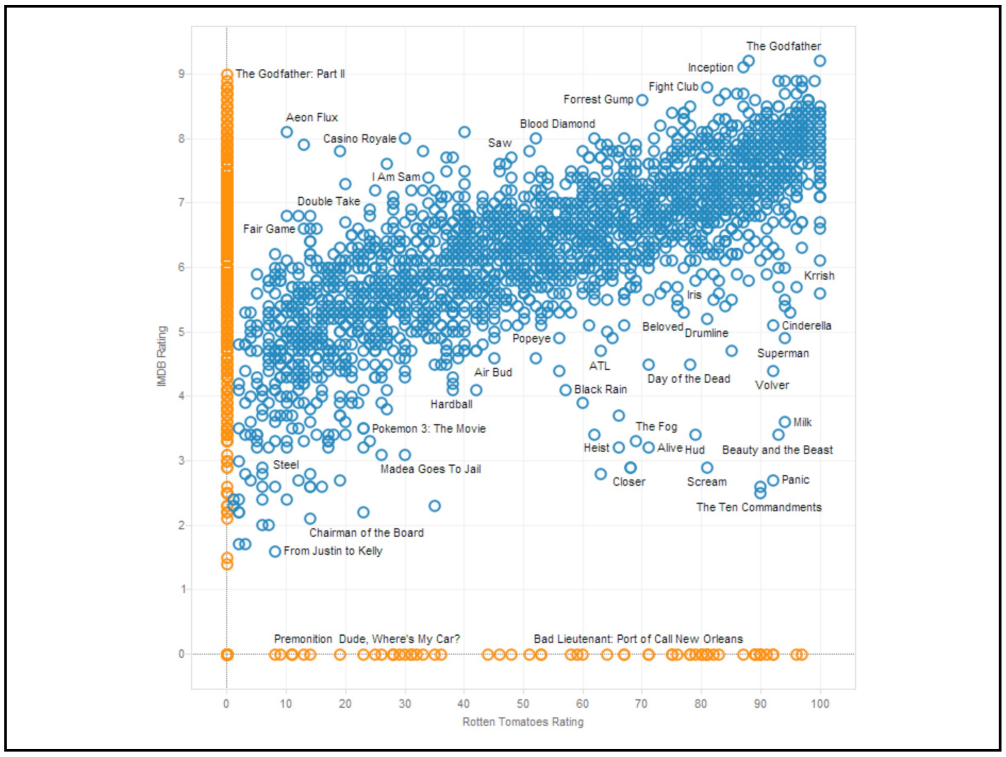
30
40
50
60
70
80
90
100

29


The Godfather
The Godfather: Part II
Inception
Fight Club
Forrest Gump
Aeon Flux
Blood Diamond
Casino Royale
Saw
I Am Sam
Double Take
Fair Game
Krrish
Iris
Beloved
Drumline
Cinderella
Popeye
Superman
ATL
Air Bud
Day of the Dead
Volver
Black Rain
Hardball
Milk
The Fog
Pokemon 3: The Movie
Heist
Alive
Hud
Beauty and the Beast
Steel
Madea Goes To Jail
Closer
Scream
Panic
The Ten Commandments
Chairman of the Board
From Justin to Kelly
Premonition
Dude, Where's My Car?
Bad Lieutenant: Port of Call New Orleans
IMDB Rating
Rotten Tomatoes Rating
0
1
2
3
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0
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30
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60
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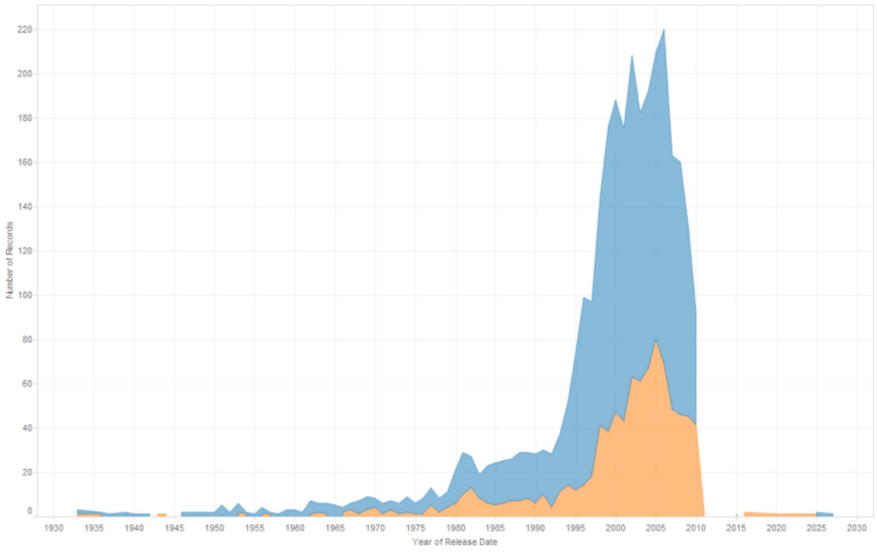
90
100

30



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LESSON: Exercise Skepticism

Check **data quality** and your **assumptions**

Start with **univariate summaries**, then consider **relationships between variables**

Avoid premature fixation!

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Announcements

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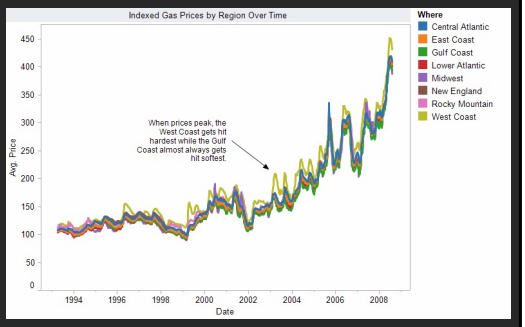
A2: Exploratory Data Analysis

Use Tableau or Vega-Lite to formulate & answer questions



First steps

- Step 1: Pick domain & data
- Step 2: Pose questions
- Step 3: Profile data
- Iterate as needed

Create visualizations

- See different views of data
- Refine questions

Author a report

- Screenshots of most insightful views (8+)
- Include titles and captions for each view

Due before class on Oct 11, 2021

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Analysis Example: Effectiveness of Antibiotics

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Antibiotic Effectiveness: The Data

Genus of Bacteria	String
Species of Bacteria	String
Antibiotic Applied	String
Gram-Staining	Pos / Neg
Min. Inhibitory Concent. (g)	Number

Collected prior to 1951

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What questions might we ask?

Table 1: Burtin's data.	Antibiotic			
Bacteria	Penicillin	Streptomycin	Neomycin	Gram Staining
Aerobacter *aerogenes*	870	1	1.6	negative
Brucella *abortus*	1	2	0.02	negative
Brucella *anthracis*	0.001	0.01	0.007	positive
Diplococcus *pneumoniae*	0.005	11	10	positive
Escherichia *coli*	100	0.4	0.1	negative
Klebsiella *pneumoniae*	850	1.2	1	negative
Mycobacterium *tuberculosis*	800	5	2	negative
Proteus *vulgaris*	3	0.1	0.1	negative
Pseudomonas *aeruginosa*	850	2	0.4	negative
Salmonella (Eberthella) *typhosa*	1	0.4	0.008	negative
Salmonella *schottmuelleri*	10	0.8	0.09	negative
Staphylococcus *albus*	0.007	0.1	0.001	positive
Staphylococcus *aureus*	0.03	0.03	0.001	positive
Streptococcus *fecalis*	1	1	0.1	positive
Streptococcus *hemolyticus*	0.001	14	10	positive
Streptococcus *viridans*	0.005	10	40	positive

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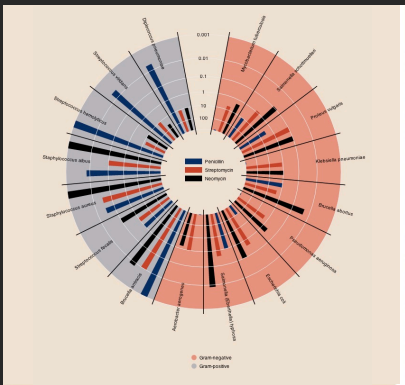
Will Burtin, 1951



Bacteria	Penicillin	Antibiotic Streptomycin	Neomycin	Gram stain
Aerobacter aerogenes	870	1	1.6	–
Brucella abortus	1	2	0.02	–
Bacillus anthracis	0.001	0.01	0.007	+
Diplococcus pneumoniae	0.005	11	10	+
Escherichia coli	100	0.4	0.1	–
Klebsiella pneumoniae	850	1.2	1	–
Mycobacterium tuberculosis	800	5	2	–
Proteus vulgaris	3	0.1	0.1	–
Pseudomonas aeruginosa	850	2	0.4	–
Salmonella (Eberthella) typhosa	1	0.4	0.008	–
Salmonella schottmuelleri	10	0.8	0.09	–
Staphylococcus albus	0.007	0.1	0.001	+
Staphylococcus aureus	0.03	0.03	0.001	+
Streptococcus fecalis	1	1	0.1	+
Streptococcus hemolyticus	0.001	14	10	+
Streptococcus viridans	0.005	10	40	+

How do the drugs compare?

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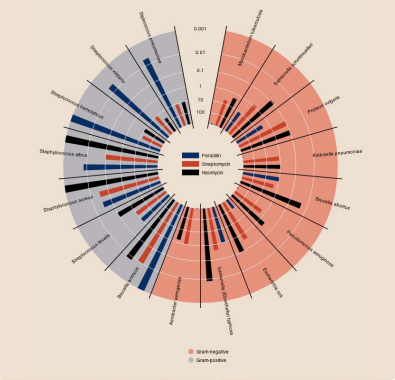
Will Burtin, 1951



Bacteria	Penicillin	Antibiotic Streptomycin	Neomycin	Gram stain
Aerobacter aerogenes	870	1	1.6	–
Brucella abortus	1	2	0.02	–
Bacillus anthracis	0.001	0.01	0.007	+
Diplococcus pneumoniae	0.005	11	10	+
Escherichia coli	100	0.4	0.1	–
Klebsiella pneumoniae	850	1.2	1	–
Mycobacterium tuberculosis	800	5	2	–
Proteus vulgaris	3	0.1	0.1	–
Pseudomonas aeruginosa	850	2	0.4	–
Salmonella (Eberthella) typhosa	1	0.4	0.008	–
Salmonella schottmuelleri	10	0.8	0.09	–
Staphylococcus albus	0.007	0.1	0.001	+
Staphylococcus aureus	0.03	0.03	0.001	+
Streptococcus fecalis	1	1	0.1	+
Streptococcus hemolyticus	0.001	14	10	+
Streptococcus viridans	0.005	10	40	+

Radius: 1/log(MIC)
Bar Color: Antibiotic
Background Color: Gram Staining

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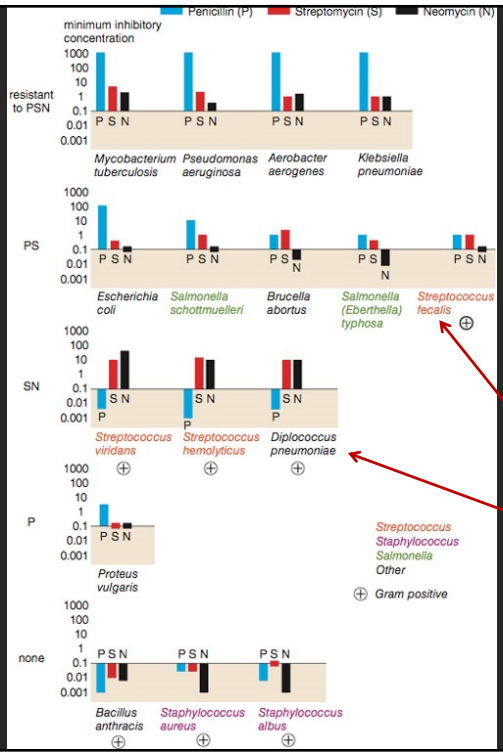

Do bacteria group by antibiotic resistance?

Not a streptococcus!
(realized ~30 yrs later)

Really a streptococcus!
(realized ~20 yrs later)

Wainer & Lysen
American Scientist, 2009

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Lessons

Exploratory Process

1. **Construct graphics to address questions**
2. **Inspect "answer" and assess new questions**
3. **Repeat!**

Transform the data appropriately (e.g., invert, log)

"Show data variation, not design variation"

-Tufte

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Tableau / Polaris

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Tableau

Research at Stanford: "Polaris" by Stolte, Tang & Hanrahan.

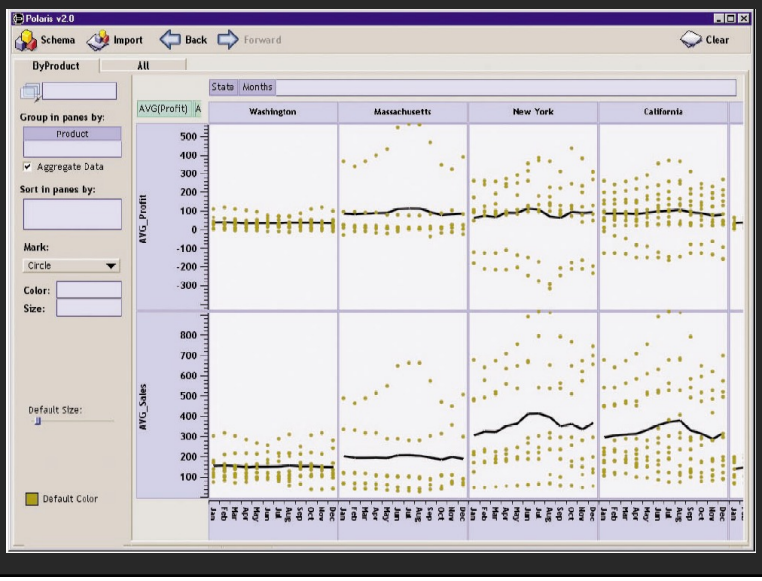

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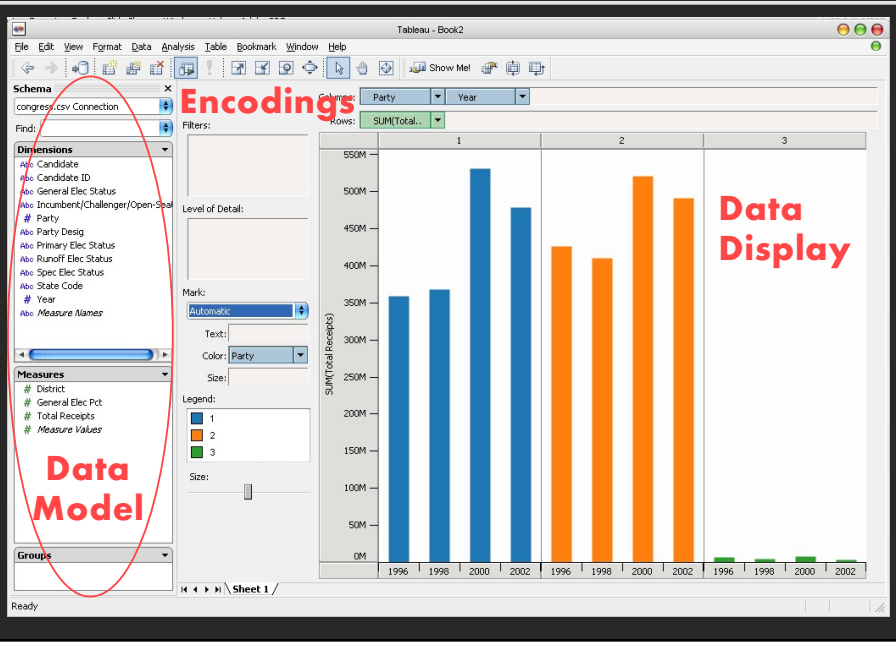
Tableau



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Polaris/Tableau Approach

Insight: simultaneously specify both database queries and visualization

Choose data, then visualization, not vice versa

Use smart defaults for visual encodings

Can also suggest more encodings upon request (ShowMe – Like APT)

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Dataset

- **Federal Elections Commission Receipts**
- **Every Congressional Candidate from 1996 to 2002**
- **4 Election Cycles**
- **9216 Candidacies**

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Data Set Schema

- Year (Qi)
- Candidate Code (N)
- Candidate Name (N)
- Incumbent / Challenger / Open-Seat (N)
- Party Code (N) [1=Dem,2=Rep,3=Other]
- Party Name (N)
- Total Receipts (Qr)
- State (N)
- District (N)

- This is a subset of the larger data set available from the FEC, but should be sufficient for the demo

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Hypotheses?

What might we learn from this data?

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Hypotheses?

What might we learn from this data?

- Have receipts increased over time?
- Do democrats or republicans spend more?
- Candidates from which state spend the most money?

Tableau Demo

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