Overview of Big Data

CS1 Freshman Seminar
Spring 2018

A Bit About Myself

Ph.D., 2011

Associate Professor of Computer Science

Research Interests:

- Compiler and program analysis
- Runtime system
- Distributed system
- Big Data analytics

Regularly teach CS 111 -Operating System

What Does "Big Data" Mean?

(1) Collecting large amounts of data

Via computers, sensors, people, events …

(2) Doing something with it

Making decisions, confirming hypotheses, gaining insights, predicting future …

"Data Science" = Going from (1) to (2)

Big Data is Here to Stay

- Ability to collect data will only increase
- Ability to analyze data will only improve

What would go away?

This Overview

- Promises of Big Data
  - Applications and services
- Big Data tools and techniques
  - Database management systems
  - Data mining and machine learning
- Pitfalls of Big Data
  - Correlation and causation
  - Underfitting and overfitting
  - Privacy and a few others
- Big Data systems and platforms

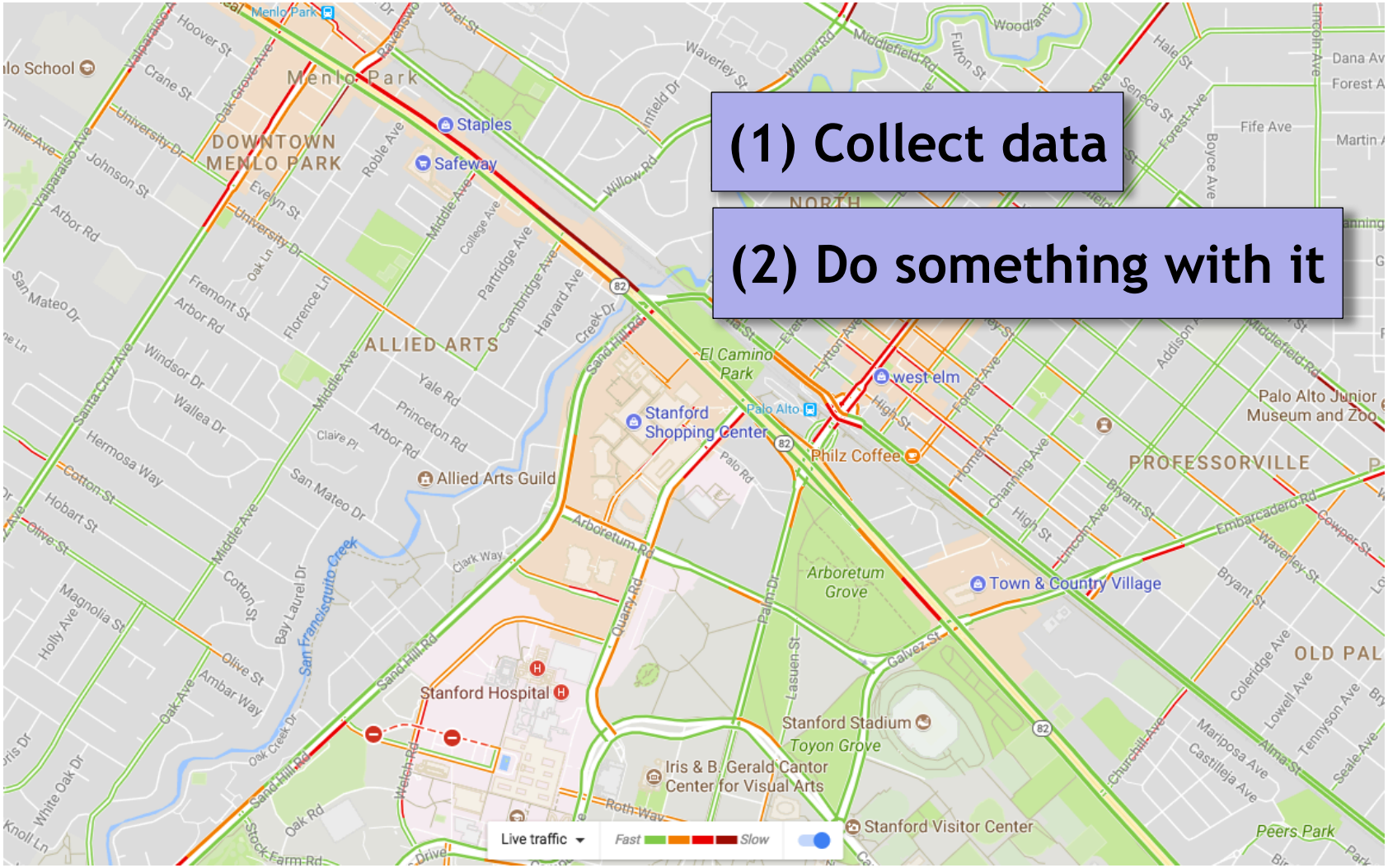
Promises of Big Data

(1) Collect large amounts of data

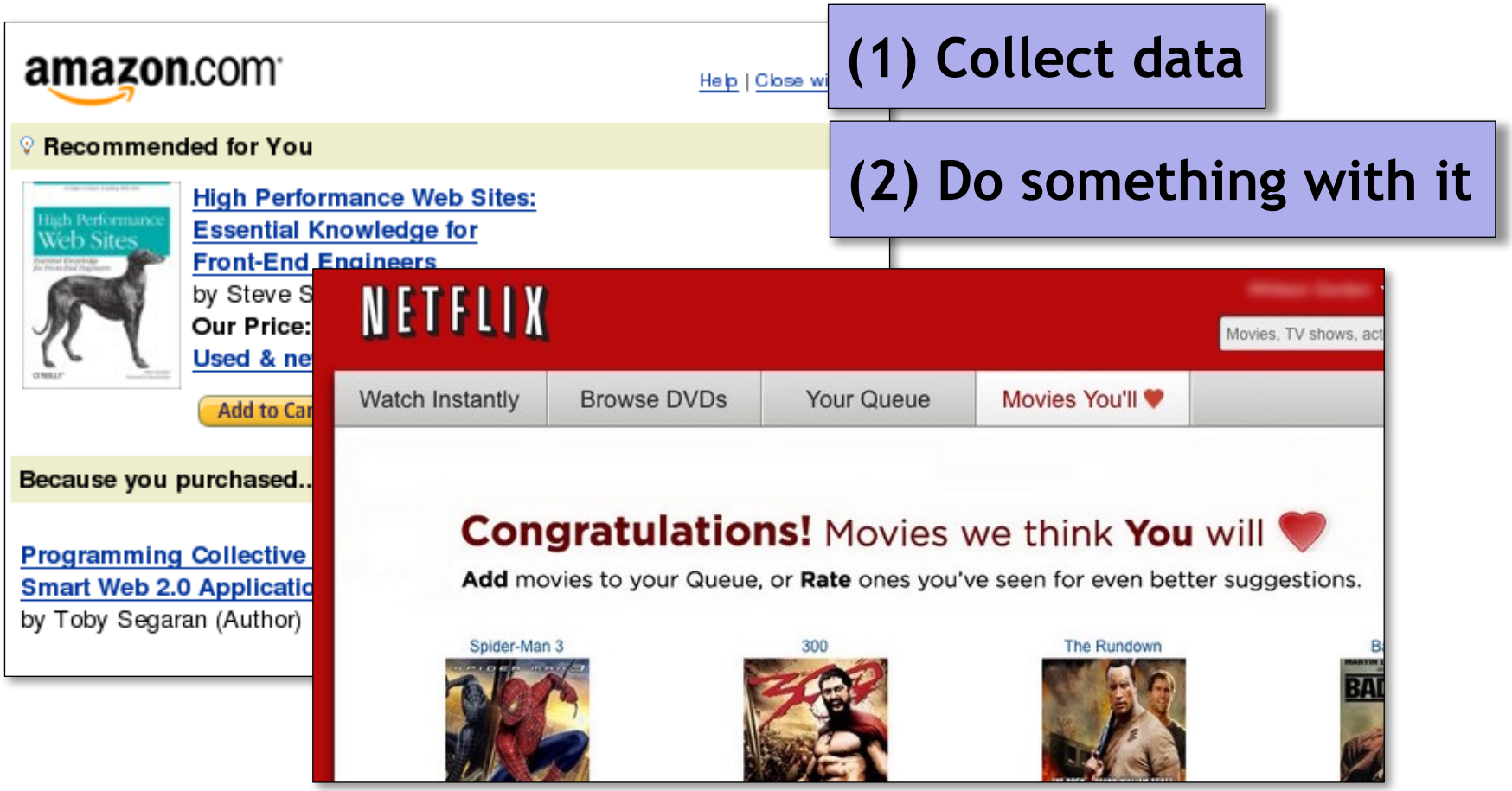
(2) Do something with it

beneficial

Traffic


(1) Collect data
(2) Do something with it
Menlo Park
DOWNTOWN MENLO PARK
ALLIED ARTS
Staples
Safeway
Allied Arts Guild
Stanford Shopping Center
El Camino Park
west elm
Philz Coffee
Palo Alto Junior Museum and Zoo
PROFESSORVILLE
Arboretum Grove
Town & Country Village
Stanford Hospital
Stanford Stadium
Toyon Grove
Iris & B. Gerald Cantor Center for Visual Arts
Stanford Visitor Center
Peers Park
OLD PAL
Live traffic
Fast
Slow

Recommender Systems

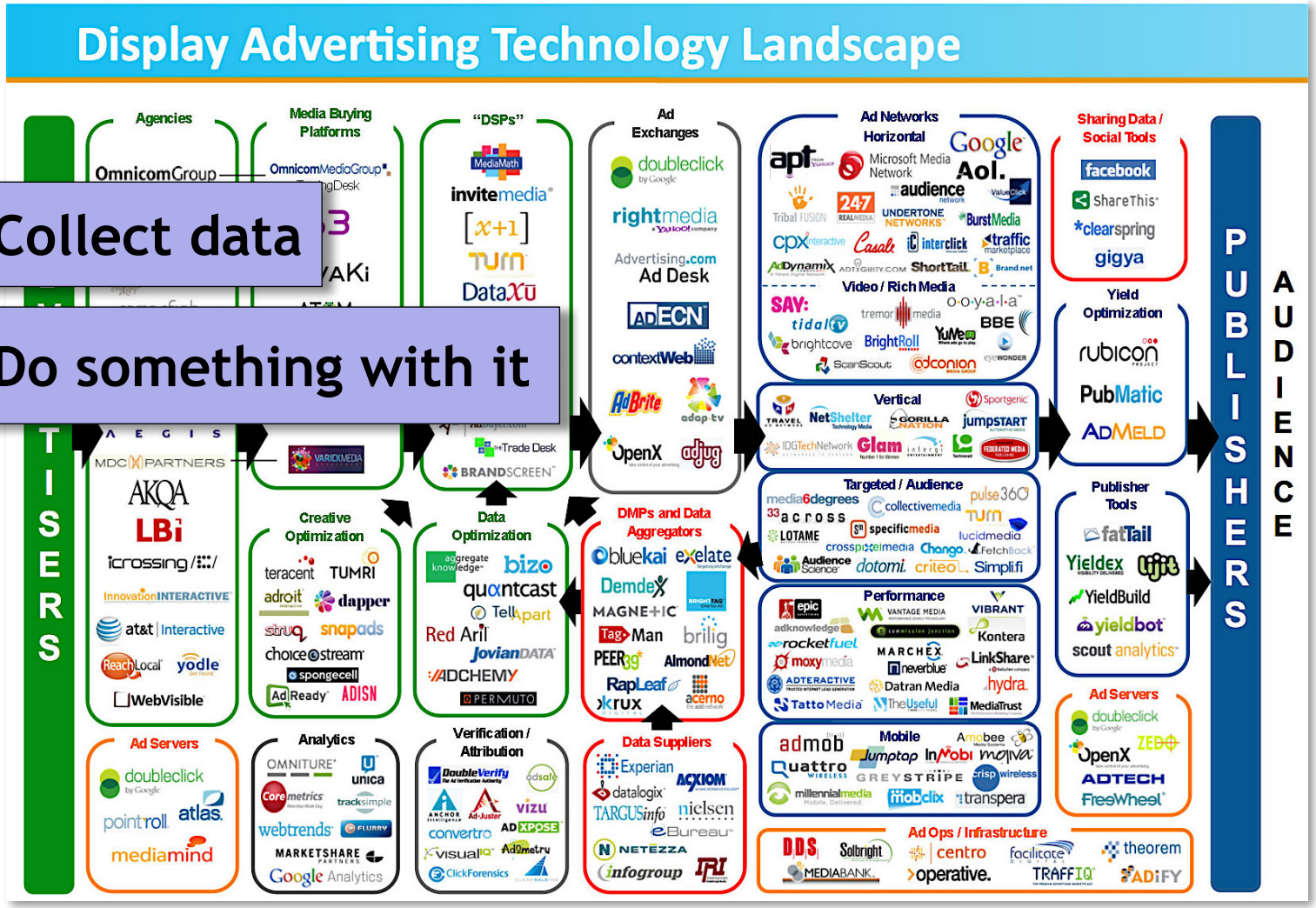


(1) Collect data

(2) Do something with it

+ music, news, friends, romantic partners, and many more!

Online Advertising

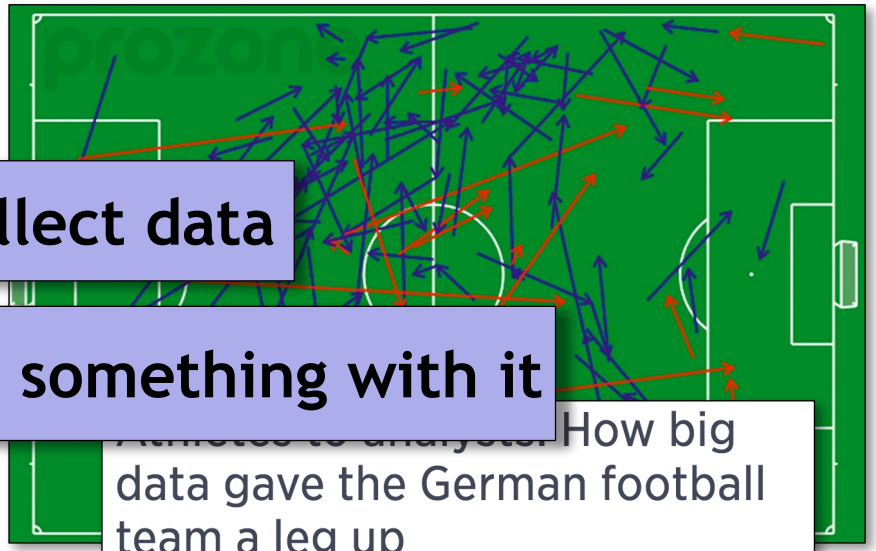


Sports

"Remember, the other team is counting on Big Data insights based on previous games. So, kick the ball with your other foot."

(1) Collect data

(2) Do something with it



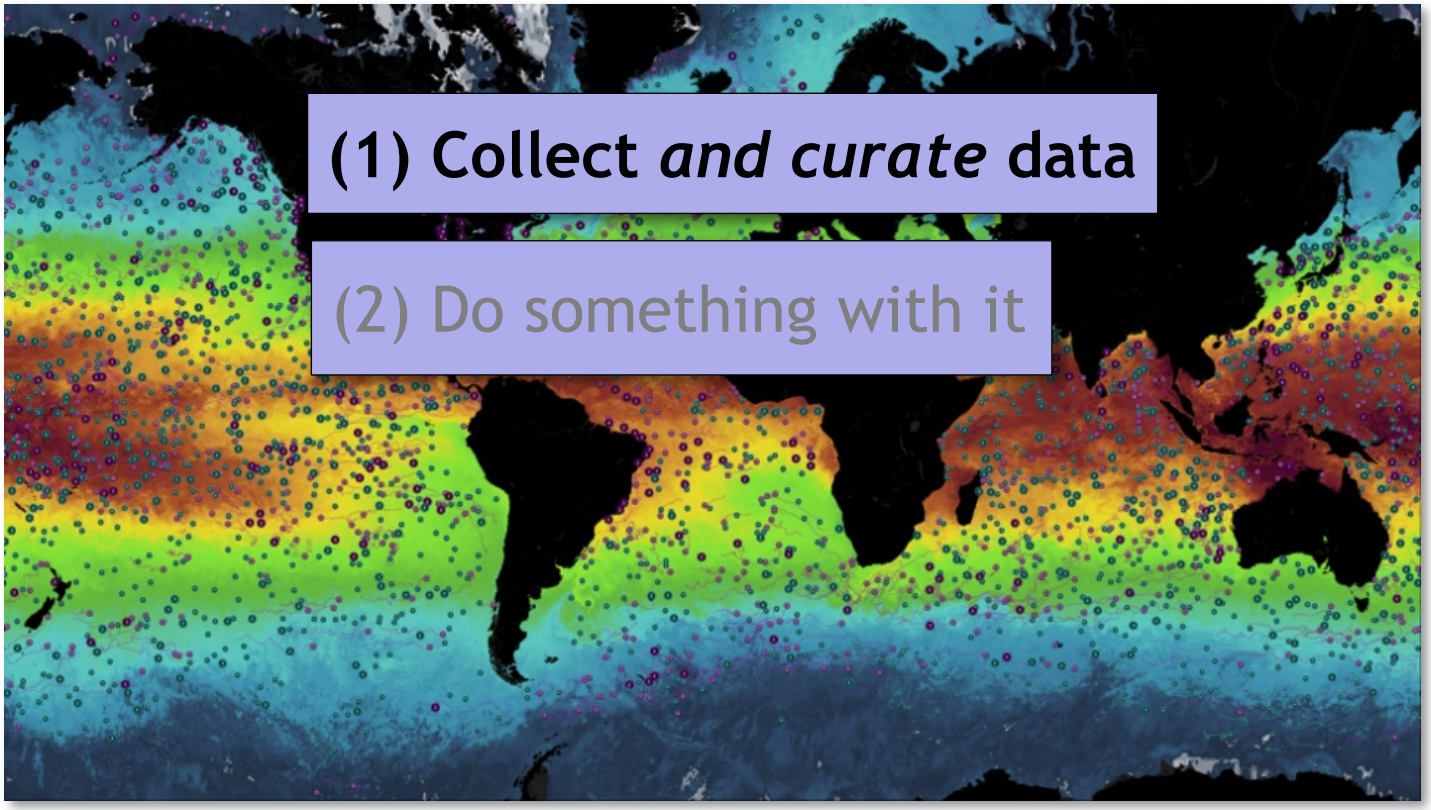
How big data gave the German football team a leg up

Saheli Roy Choudhury | @sahelirc
Thursday, 7 Jul 2016 | 12:39 AM ET

CNBC

How Big Data is Changing the World of Football

Ocean Health



44,000 sensors, over 2 billion measurements

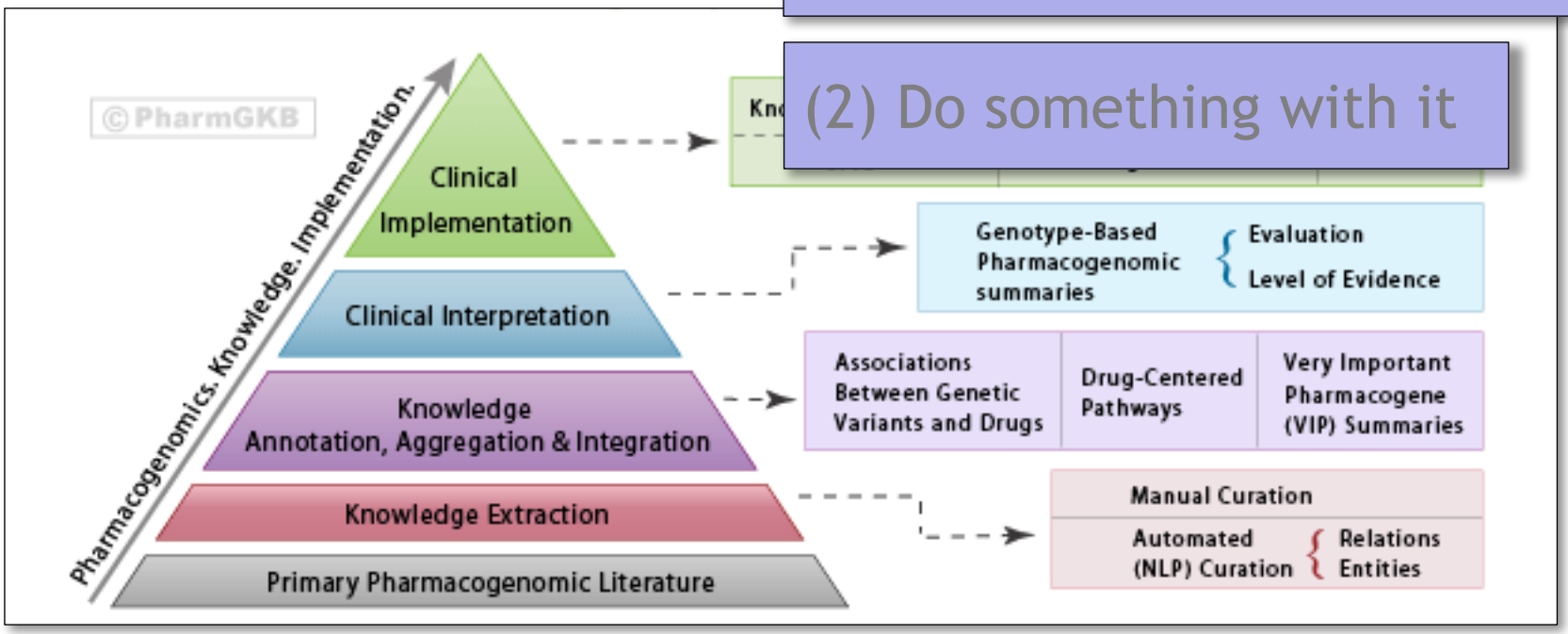
Physical, chemical, biological …

Genetics-Medicine Relationships

PharmGKB collects, curates, and disseminates knowledge about how human genetics affects response to medicines

(1) Collect *and curate* data

(2) Do something with it



And Many More

- Weather prediction
- Medical diagnosis
- Financial markets
- Resource management
- Computational social science
- Smart buildings and cities
-

The list goes on and on,
and it's still early days

Big Data Tools and Techniques

- Basic Data Manipulation and Analysis
  Performing well-defined computations or asking well-defined questions (“queries”)
- Data Mining
  Looking for patterns in data
- Machine Learning
  Using data to build models and make predictions
- Data Visualization
  Graphical depiction of data
- Data Collection and Preparation

Basic Data Manipulation and Analysis

Performing well-defined computations or asking well-defined questions ("queries")

- Average January low temperature for each country over last 20 years
- Number of items over $100 bought by females between ages 20 and 30
- Frequency of specific medicine relieving specific symptoms
- The ten stocks whose price varied the most over the past year

Basic Data Manipulation and Analysis

Performing well-defined computations or asking well-defined questions ("queries")

- Ave… …h cou…
- Nur… fen…
- Fre… specific symptoms
- The ten stocks whose price varied the most over the past year

- Spreadsheets
- Relational (SQL) database systems
- "NoSQL" / scalable systems
- Programming languages with big-data support (e.g., Python, R)

Data Mining

Looking for patterns in data

- Items X,Y,Z are bought together frequently
- People who like movie X also like movie Y
- Patients who respond well to medicines X and Y also respond well to medicine Z
- Students going to the same university are frequently online friends
- Wealthier people are moving from cities to suburbs

Data Mining

Looking for patterns in data

- Items X,Y,Z are bought together frequently
- People ... ie Y
- Patien ... es X and Y
- Studer ... are frequently online friends
- Wealthier people are moving from cities to suburbs

- Frequent item-sets
- Association rules
- Specialized techniques for networks, text, multimedia

Machine Learning

Using data to build models and make predictions

- Customers who are women over age 20 are likely to respond to an advertisement
- Students with good grades are predicted to do well on the SAT
- The temperature of a city can be estimated as the average of its nearby cities, unless some of the cities are on the coast or in the mountains

Machine Learning

Using data to build models and make predictions

- Customers w… over age 20 are likely to res… rtisement
- Students wi… re predicted to do well on the…

- Regression
- Classification
- Clustering

- Roughly: Basic data analysis and data mining give answers from the available data, while machine learning uses the available data to make predictions about missing or future data

Data Visualization

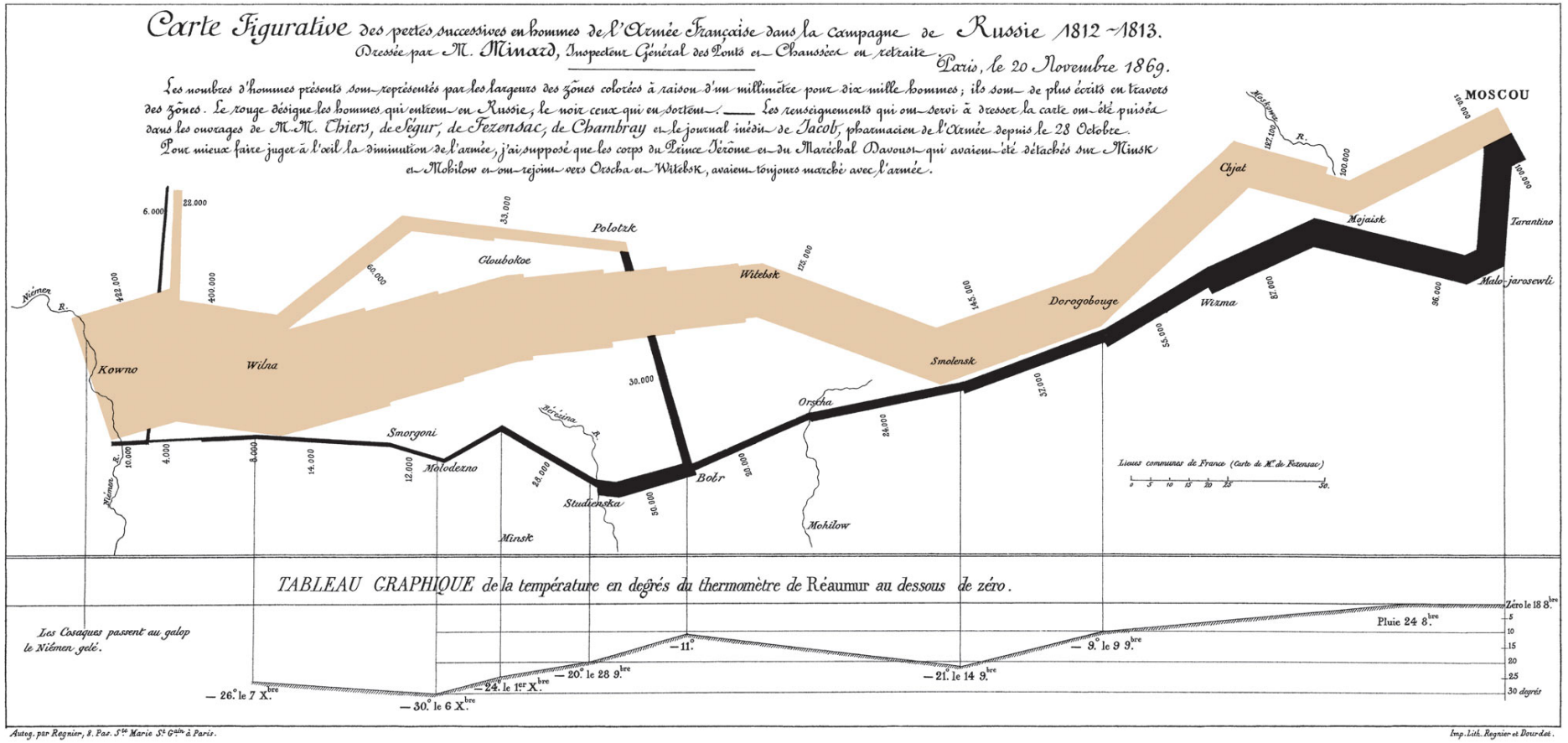
"A picture is worth a thousand words"

Data Visualization

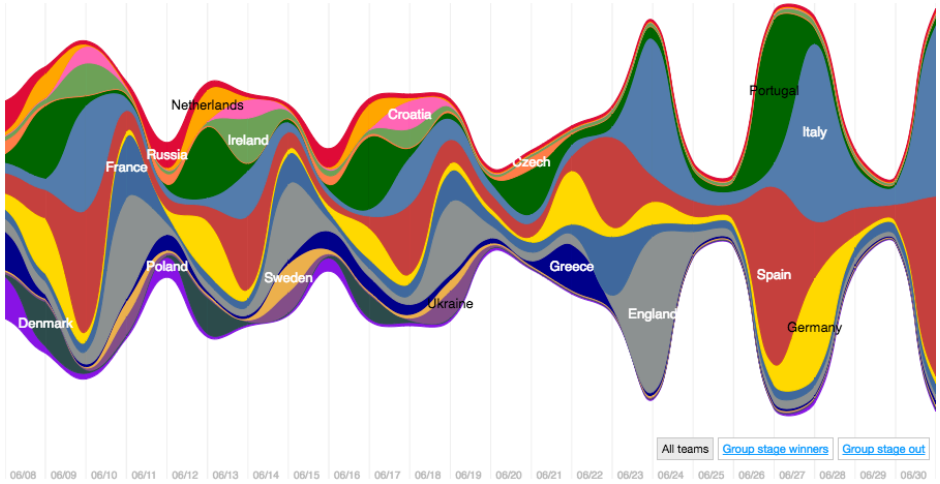
"A picture is worth a ~~thousand words~~"
trillion data points

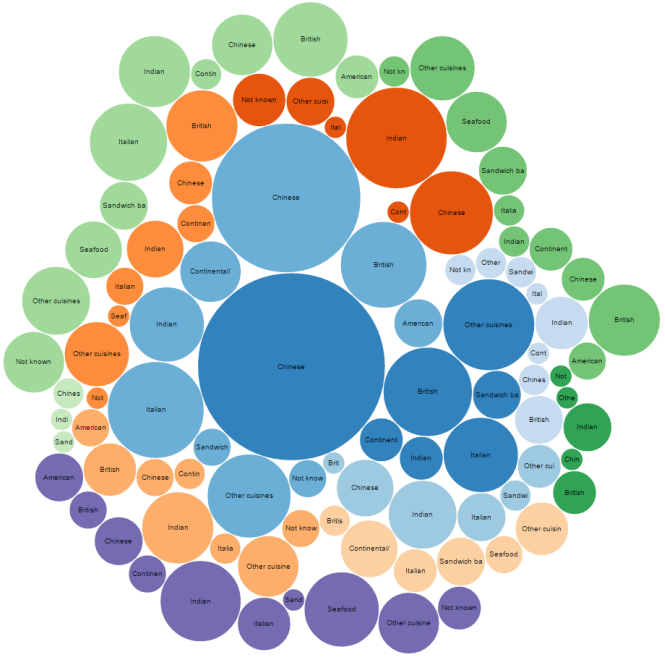
Early Data Visualization

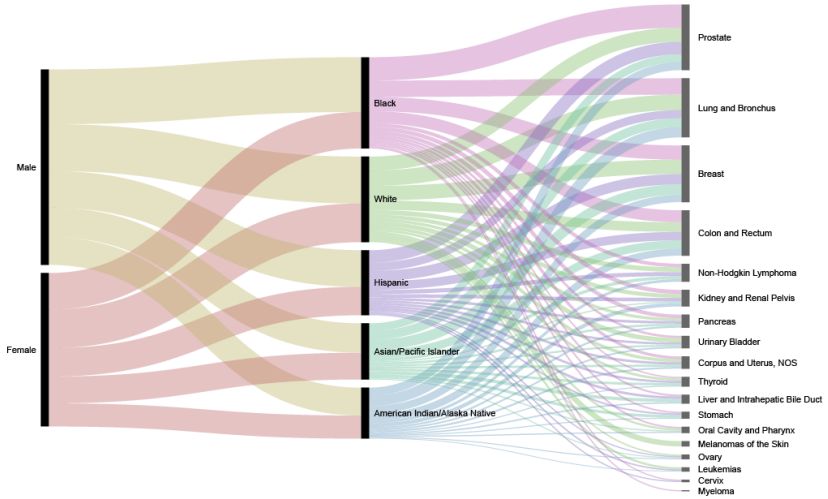
Napoleon's Army



Fancy Data Visualization



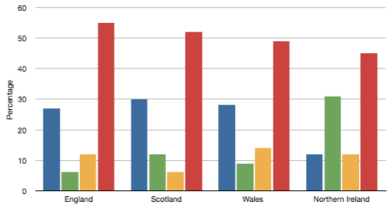


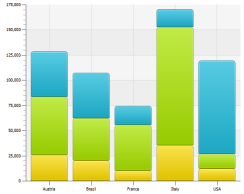


Basic Data Visualization

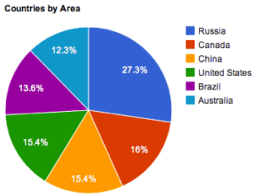
Don’t underestimate the power of basic visualizations

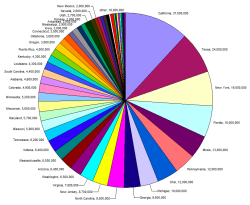
- Bar charts



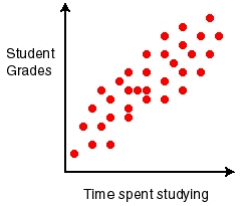


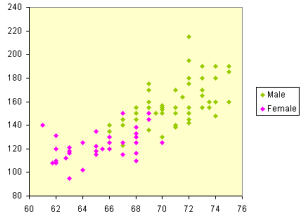
- Pie charts



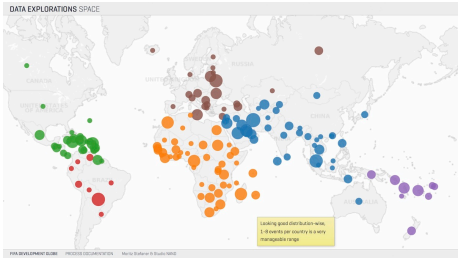


- Scatterplots





- Maps



Data Collection and Preparation

The “dirty” secret of Big Data

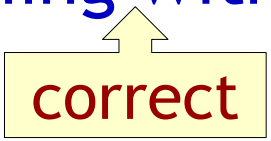
- Extracting data from difficult sources
- Filling in missing values
- Removing suspicious data
- Making formats, encoding, and units consistent
- De-duplicating and matching

Data preparation often consumes 80% or more of the effort in a Big Data project

Pitfalls of Big Data

(1) Collect large amounts of data

(2) Do something with it



Correlation and Causation

Data analysis, data mining, and machine learning can reveal relationships between data values

Correlation – Values track each other

- Height and Shoe Size
- Grades and SAT Scores

Causation – One value directly influences another

- Education Level → Starting Salary
- Temperature → Cold Drink Sales

Correlation and Causation

"Correlation does not imply causation"

Correlation – Values track each other

- Height and Shoe Size
- Grades and SAT Scores

Causation – One value directly influences another

- Education Level → Starting Salary
- Temperature → Cold Drink Sales

Correlation and Causation

"Correlation does not imply causation"

- Correlation can be result of causation from a hidden "confounding variable"
- A and B are correlated because there's a hidden C such that C → A and C → B
  - ❖ Homeless population and crime rate
    Confounding variable: unemployment
  - ❖ Forgetfulness and poor eyesight
    Confounding variable: age
  - ❖ Height and shoe size
  - ❖ Grades and SAT scores

Correlation and Causation

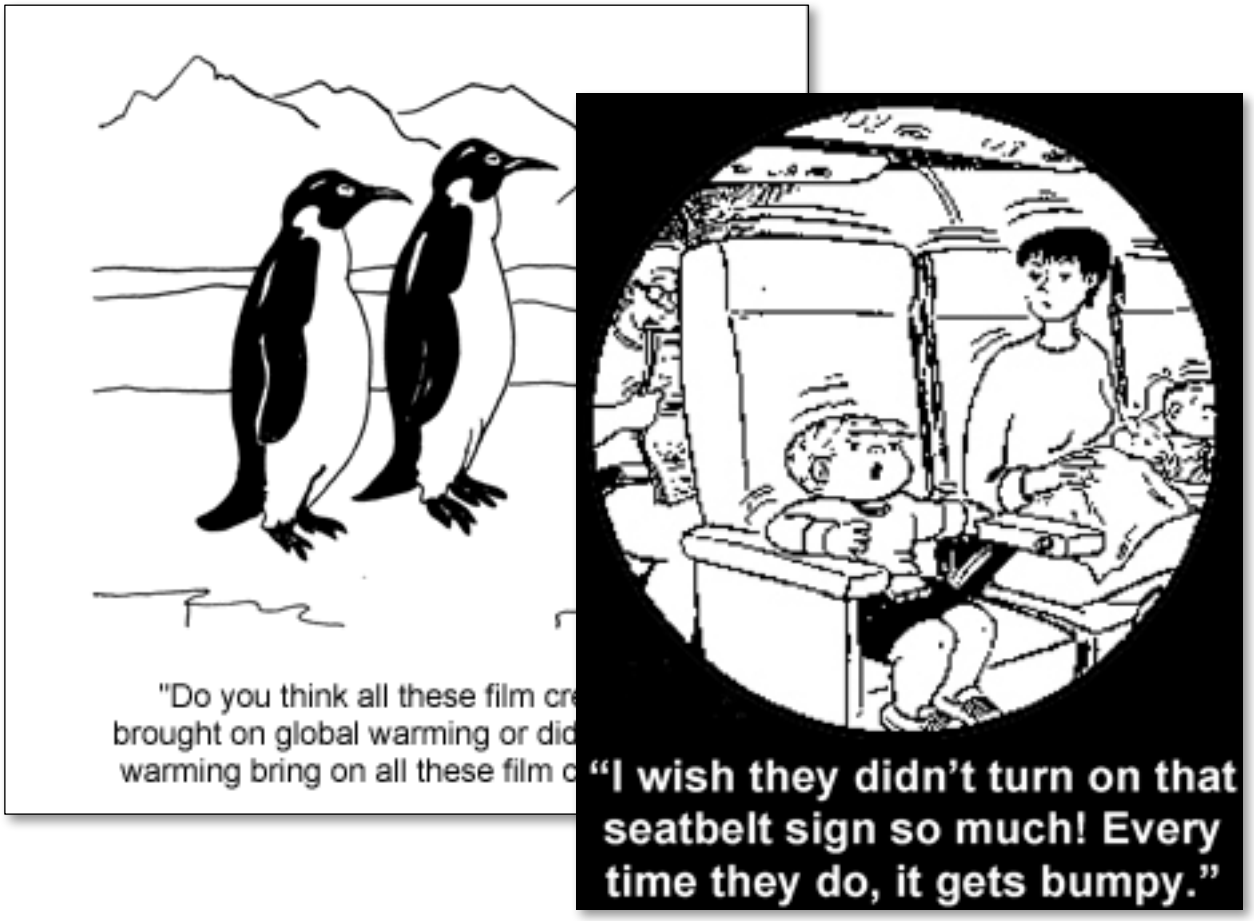
"Correlation does not imply causation"

- Correlation can be result of causation from a hidden "confounding variable"
- A and B are correlated because there's a hidden C such that C → A and C → B

- Correlation is usually "easy" to test
- Causation is impossible to test

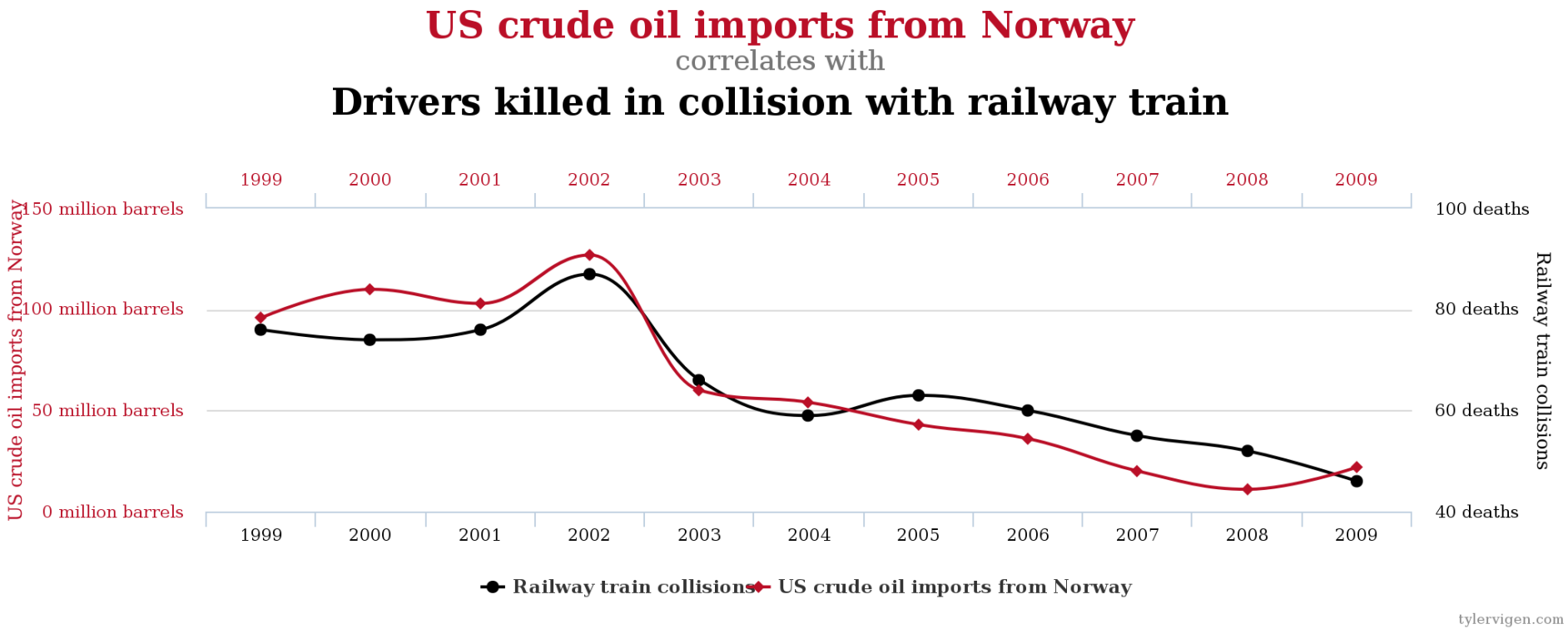
Correlation and Causation

Correlation and Causation

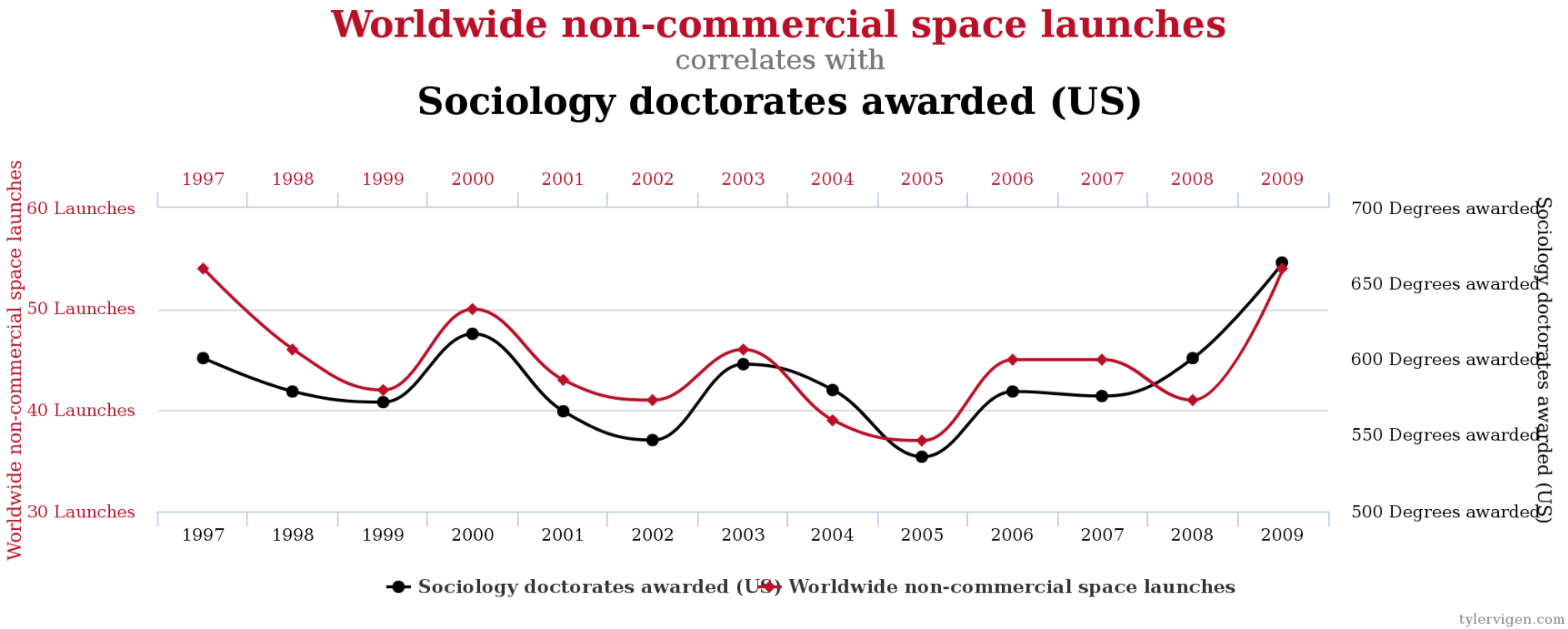


Correlation and Causation

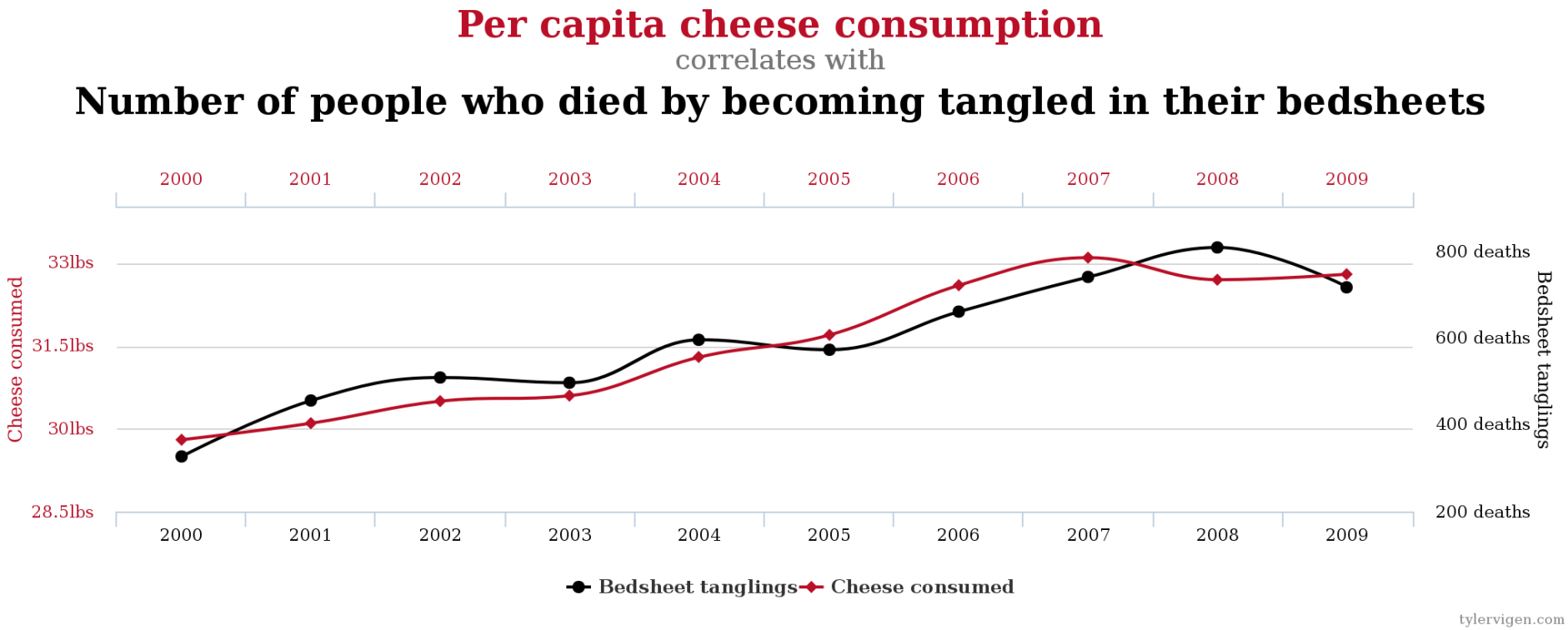
Surprising Correlation #1



Surprising Correlation #2



Surprising Correlation #3



Underfitting and Overfitting

Machine learning uses data to create a "model" and uses model to make predictions

- Customers who are women over age 20 are likely to respond to an advertisement
- Students with good grades are predicted to do well on the SAT
- The temperature of a city can be estimated as the average of its nearby cities, unless some of the cities are on the coast or in the mountains

Underfitting

Model used for predictions is **too simplistic**

- 60% of men and 70% of women responded to an advertisement, therefore all future ads should go to women
- If a furniture item has four legs and a flat top it is a dining room table
- The temperature of a city can be estimated as the average of its nearby cities, unless some of the cities are on the coast or in the mountains

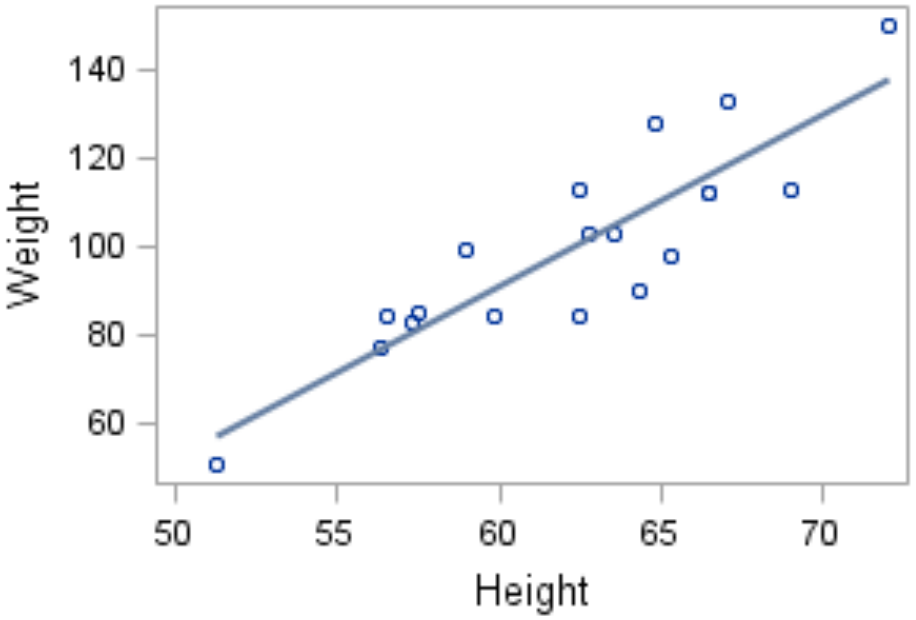
Overfitting

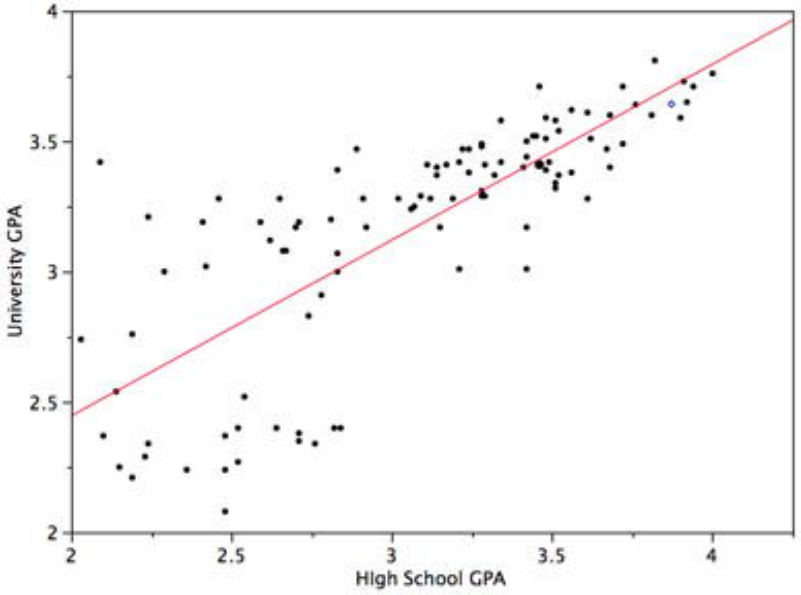
Model used for predictions is **too specific**

- The best targets for an advertisement are married women between 25 and 27 years with short black hair, one child, and one pet dog
- If a furniture item has four 100 cm legs with decoration and a flat polished wooden top with rounded edges then it is a dining room table

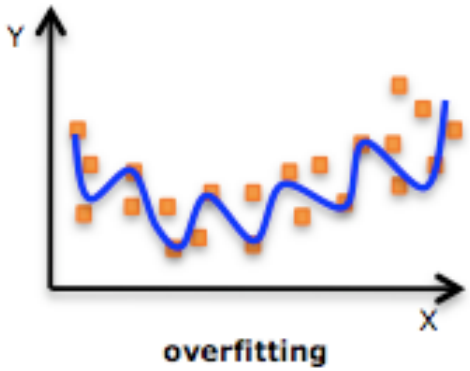
Regression

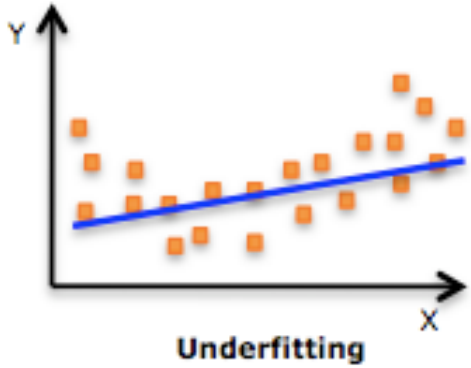
- Fit a line or curve to a set of points (model)
- Use model to predict values for new points

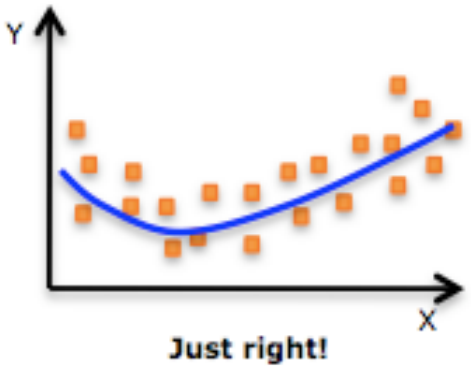




Underfitting and Overfitting







Big Data Scam: Soccer Match Prediction

- Friday: receive email from "Psychic Sally" predicting which teams will be the winners in the weekend's five soccer matches. She's right about all of them!
- Same thing the following weekend: five games, all winners predicted correctly
- And the following one: five more correct
- Fourth Friday: Sally offers to give you her predictions for the coming weekend's games, for a fee

Should you do it?

Big Data Scam: Soccer Match Prediction

How many contacts must Sally start with on week one to ensure she has 100 potential buyers by week four, i.e., 100 people who received 15 correct predicted winners?

(Assume no draws)

Data Privacy

- Individual data collected covertly
  - Edward Snowden, “metadata” argument
- Individual data collected legally but used questionably
  - Individual “digital footprints” are enormous
  - Target stores pregnancy mailing
  - Engagement ring purchase broadcast on Facebook
- Individual data deduced from “anonymous” public data
  - Governor of Massachusetts health record

Languages, Systems, Platforms

- Spreadsheets

  Surprisingly versatile and powerful for data analysis tasks, but not truly big data

- Programming languages with big-data support
  - R Language – powerful statistical features
  - Python – general-purpose language with R-like add-ons (Pandas, SciPy, scikit-learn)

Languages, Systems, Platforms

- Relational Database Management Systems
  - Also called RDBMS, SQL Systems
  - Long-standing solution for reliability, efficiency, powerful query processing
  - Works for all but truly extreme data sizes, or highly unstructured data
- "NoSQL" Systems
  - Distributed/scalable processing, unstructured data
  - Key-value row stores (e.g., Cassandra, Dynamo)
  - Document databases (e.g., MongoDB, CouchDB)
  - Graph databases (e.g., Neo4J, Giraph)

Languages, Systems, Platforms

- Specialized languages on scalable systems
  - MapReduce / Hadoop
  - Spark generalized data flow
- Systems for data preparation
- Systems for data visualization

Languages, Systems, Platforms

- Data processing in the cloud
  - Amazon Web Services, Google Cloud, Microsoft Azure
  - Data storage
  - Data processing: SQL, Hadoop, Spark
  - Machine learning libraries
  - Integration with visualization systems

Big Data: How Big is Big?

Complete works of William Shakespeare
- 5 megabytes

Average individual
- 50 gigabytes (10,000 Shakespeares)

USA Library of Congress
- 10 terabytes (2 million Shakespeares)

Uploaded to Facebook daily
- 1 petabyte (200 million Shakespeares)

Produced by humanity daily
- 2.5 exabytes (500 trillion Shakespeares)

Questions?