CS61061: Data Analytics

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Know Your Professor!

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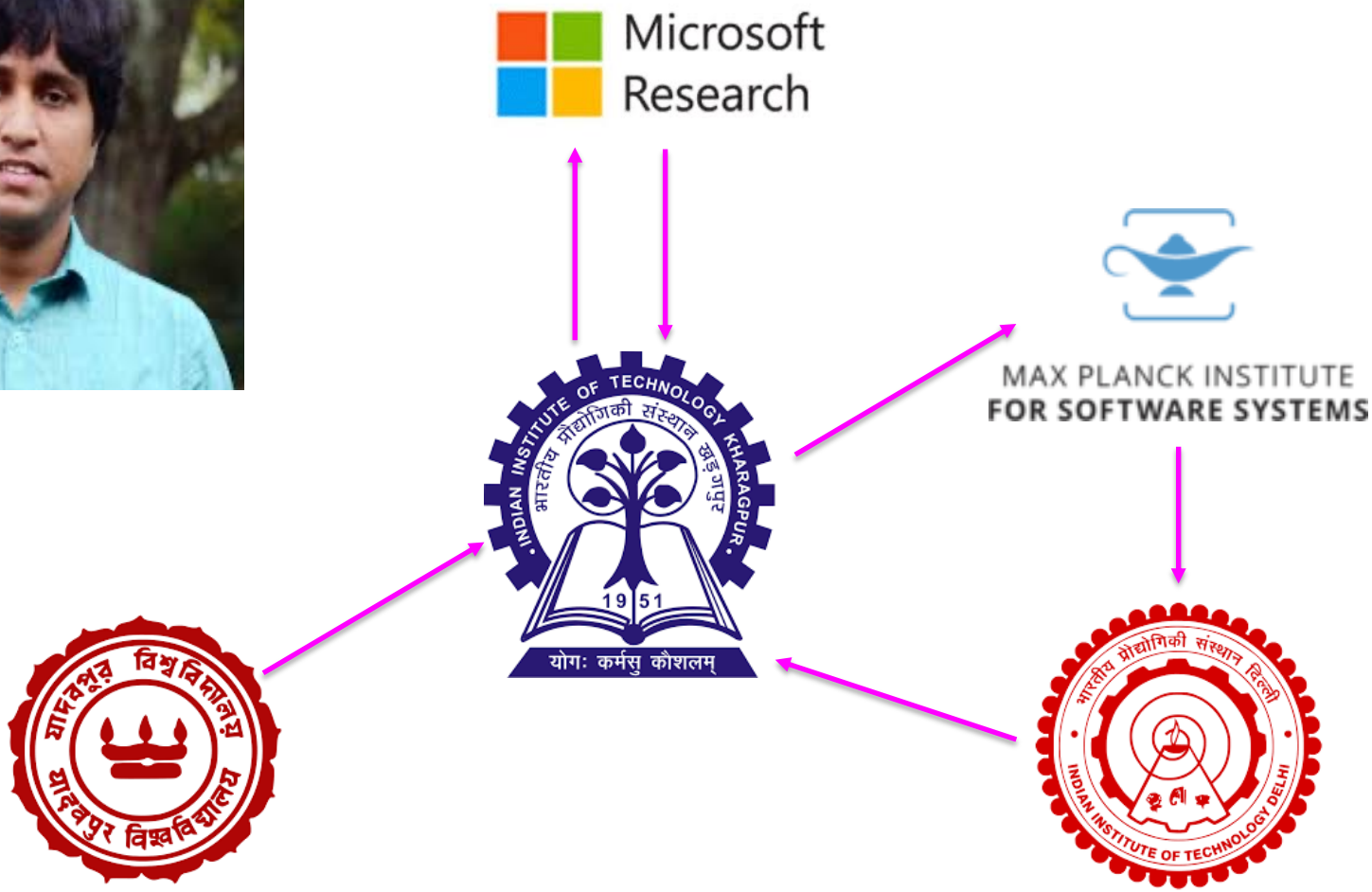


What you will learn in this course

- Data cleaning
- Searching and indexing
- Classification
- Clustering
- Association rule mining
- Anomaly detection
- …

May include guest lectures from industry practitioners

Grading

- Mid-term: 35%
- End-term: 40%
- Assignments: 20%
- Attendance and class participation: 5%

Assignments

- Form teams with 3 members
- Assignments will involve high amount of coding
  - Start early
  - No extension of deadlines will be given
- Plagiarism won't help
- Will conduct the experiments as competitions
- Will have specific set of evaluation metrics, including the running time
  - Top 10% teams will get perfect 10
  - Next 10% -> 9
  - …
  - Bottom 10% -> 1
- How to get zero?

Course material

- Slides
  - Will be available in Teams
- Reference books
  - "Introduction to Data Mining" by Tan, Steinbach, Karpatne and Kumar
  - "Data Mining: The Textbook" by Aggarwal
  - "Python for Data Analysis" by McKinney
- Relevant online tutorials

TAs

- Subhendu Khatuya
- Koyena Chowdhury
- Hritik Jaiswal

What do these have in common?

Stone

Clay

Papyrus

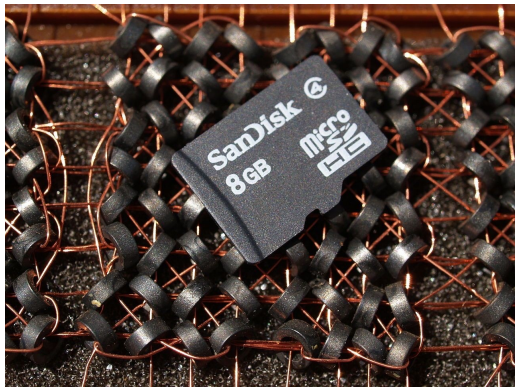
Paper

Wax cylinder

Tape

Vinyl

What do these have in common?



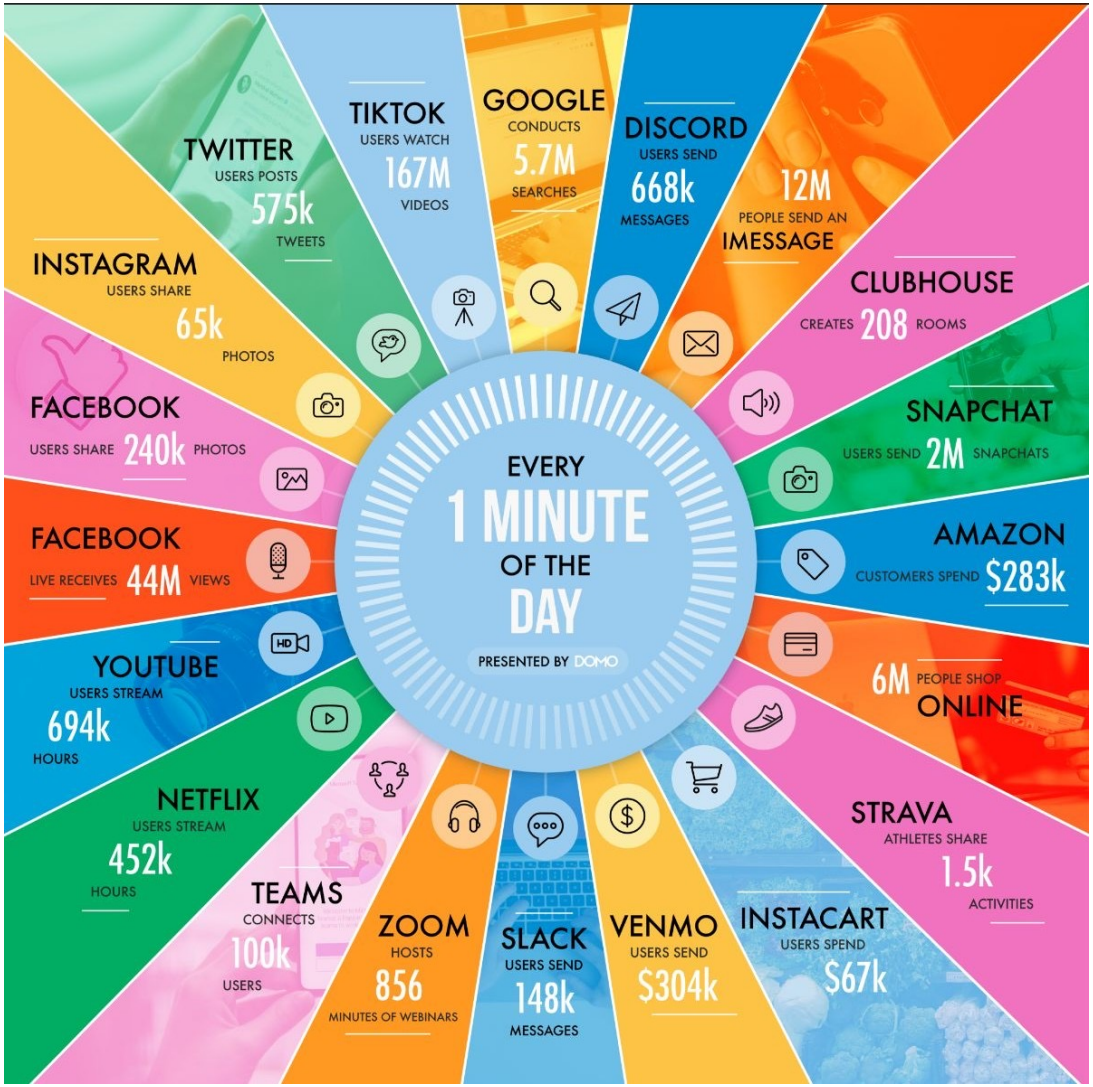
8GB (front)

Floppy disks (8”, 5 1/4”, 3 1/2”)

Compact disk

The age of "Big Data"

The co-evolution of storage capacity, transmission capacity, and processing capacity



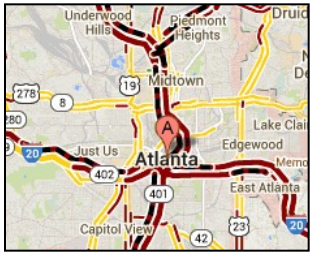
Visualcapitalist.com (2021)

Large scale data is everywhere!

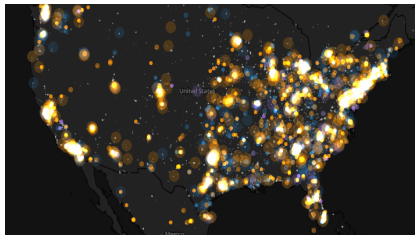
- Advances in data generation and collection technologies have led to significant growth in commercial and scientific databases
- New mantra
  - Gather whatever data you can, whenever and wherever possible
- Expectations
  - Gathered data will have value either for the purpose collected or for a purpose not envisioned

Cyber Security

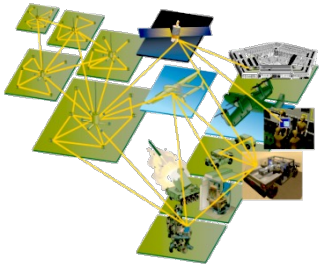
E-Commerce



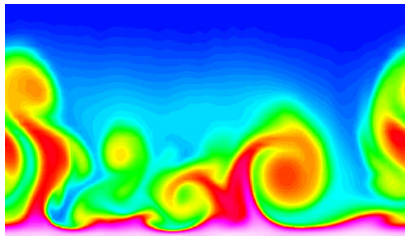
Traffic Patterns



Social Networking



Sensor Networks



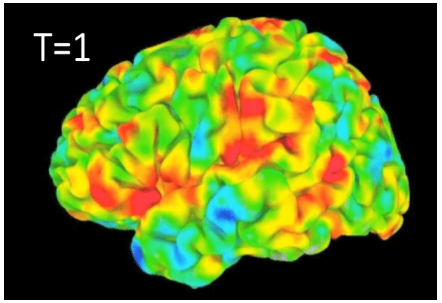
Computational Simulations

Why data analytics? commercial viewpoint

- Lots of data is being collected and warehoused
  - Web data
    - Google has Peta Bytes of web data
    - Facebook has billions of active users
  - Purchases at department/grocery stores, e-commerce
    - Amazon handles millions of visits/day
  - Bank/Credit Card transactions
- Computers have become cheaper and more powerful
- Competitive pressure is strong
  - Provide better, customized services (e.g., Customer Relationship Management)

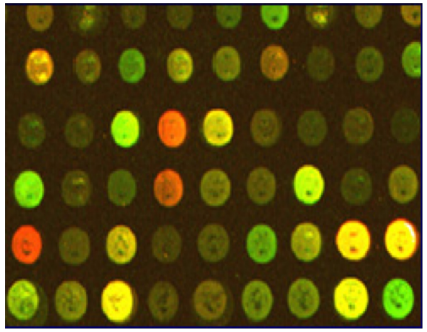
Why data analytics? scientific viewpoint

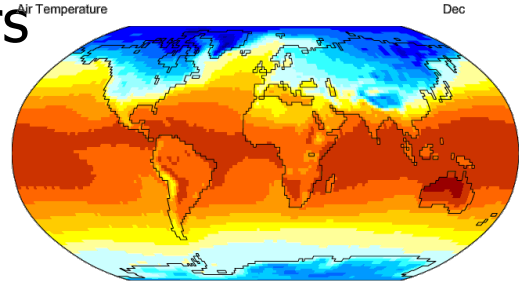
- Data collected and stored at enormous speeds
  - remote sensors on a satellite
    - archives over petabytes of earth science data / year
  - telescopes scanning the skies
    - Sky survey data
  - high-throughput biological data
  - scientific simulations
    - terabytes of data generated in a few hours
- Data analytics helps scientists
  - in automated analysis of massive datasets
  - in formation of hypothesis



fMRI Data from Brain


Sky Survey Data


Gene Expression Data



Surface Temperature of Earth

What is data analytics?

- Exploring and analyzing large datasets using automated or semi-automated methods to discover meaningful patterns
- Non-trivial extraction of previously unknown and potentially useful information from data

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Informal definition

Given lots of data, discover patterns and models that are:

- **Valid** hold on new data with some certainty
- **Useful** should be possible to act on them
- **Unexpected or novel** non-obvious
- **Understandable** interpretable
- **Complete** contain most of the interesting information

Example : 300 numbers

8.5998019	10.82452538	10.25496714	9.9264092	10.26304865	8.80526888	8.96569273	9.00883512	9.82813977	10.19311326
9.6545295	10.83958189	12.20970744	10.41521275	10.15902266	9.86904675	10.17021837	10.58768438	12.07341981	8.45713965
9.62152893	11.2494364	9.30073426	10.12753479	11.06429886	9.80406205	9.74418407	11.15815923	10.87659275	10.39190038
10.52911904	10.84125322	11.98925384	10.63545001	9.07420116	10.48011257	11.32273164	9.4831463	10.67973822	10.87064128
9.35940084	9.51149749	11.13211644	9.23292561	8.4767592	9.64339604	9.91374069	9.84184184	9.85576594	9.18523161
10.27107348	8.7511958	8.70297841	10.50609814	11.1908866	10.59484161	10.60027882	9.06375121	10.48534475	9.34253203
10.37303225	9.27441407	11.27229628	12.88441445	9.80825939	9.09844847	10.82873991	8.89169535	10.43092526	7.43215579
10.29787802	9.87946998	8.3799398	10.21263966	9.93826568	9.17325487	10.22256677	10.04892038	11.01233696	9.6145273
9.9495437	10.51474851	9.19288505	7.87728009	9.987364	10.94639021	10.01814962	9.40505023	8.87242546	10.23686131
8.90710325	10.31678617	10.4571519	9.04315227	9.85321707	11.89885306	6.99926999	10.71534924	10.29215034	10.59516732
9.8807174	9.01321711	8.45289144	9.1739316	7.90909364	9.42165081	10.37087284	9.57754821	9.60350044	10.75691005
8.24594836	10.33419146	9.7779209	9.51609087	10.25712725	12.1256587	9.53397549	9.44765209	9.53901558	9.8006768
9.633075	11.17692346	11.00022919	8.38767624	8.63908897	8.10049333	10.66422258	10.70986552	10.82945121	10.45206684
9.21578565	10.21230495	10.28984339	9.4130091	10.54597988	10.8042254	10.52795479	10.76288124	11.3554357	11.484667
10.36068758	8.18239896	11.20998409	9.88574571	9.8811874	10.64332788	8.67828643	9.23619936	10.71263899	9.36036772

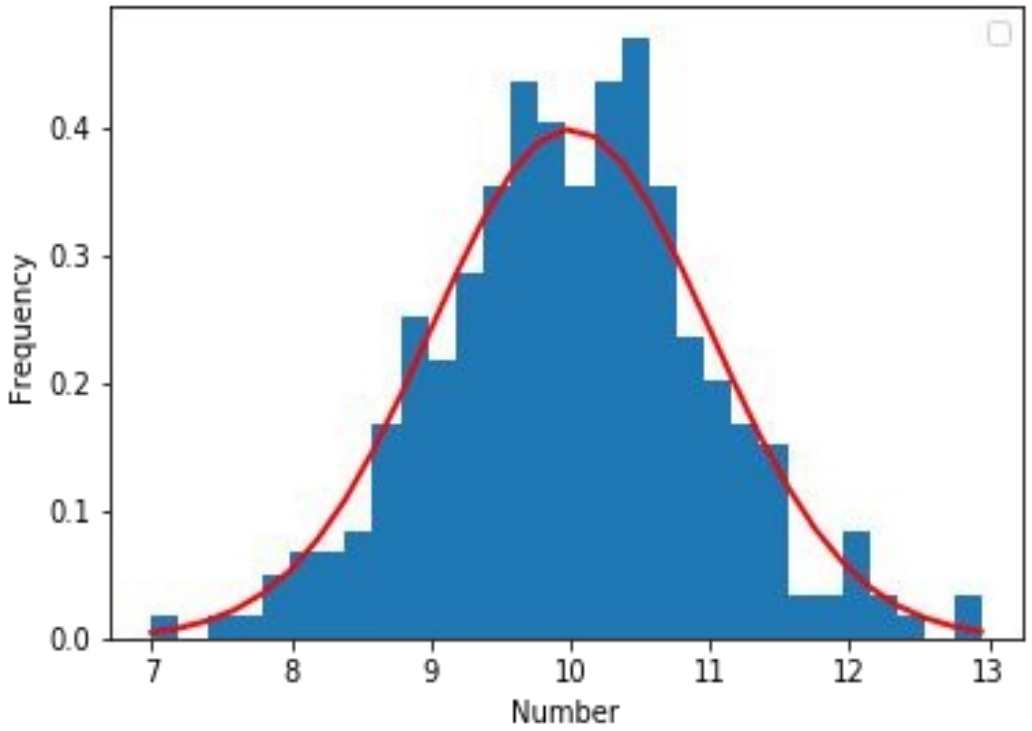
8.80204902	8.84117879	9.60177677	8.82383074	9.85787872	10.30883419	10.09771435	10.33417508	8.94003225	9.63795622
8.88926589	8.51484154	10.61543214	10.10520145	10.23046826	11.22923654	10.25575855	10.4210496	9.79970778	7.70796076
9.56309629	10.82893108	10.4055698	10.12121772	9.38935918	9.48947921	9.53357322	9.87589518	10.5455508	9.98665703
9.440398	9.67368819	12.94191966	10.01303924	12.14295086	9.58399348	10.92799244	10.4654533	10.14613624	9.29818262
9.25613292	11.59370587	8.62517536	10.29703335	9.11065832	10.68766309	9.86507094	10.58314944	10.65232968	8.13400366
11.0414868	10.16883849	10.23649503	11.51859843	9.4754405	10.88103754	8.6249062	9.64581983	8.80660132	10.3794072
11.7687303	9.6768357	10.83753706	12.39138541	9.45756373	10.4746549	11.44321655	10.70109831	8.36186335	8.99123853
10.7221973	9.25735885	10.11287178	9.77908247	10.05372548	12.32358117	9.09128196	10.27487412	8.31704578	9.67337192
11.1712355	11.33146049	10.44967579	9.58649468	9.5908432	10.53829167	10.16738708	10.45433891	10.79223358	11.3936216
9.27709756	8.91159056	8.67186161	7.83968452	11.00207472	10.61085929	11.15868605	10.13873855	9.29370024	10.49794191
10.49884897	9.77150045	8.80503866	10.08775177	11.38167004	10.42724794	11.11626475	10.68890453	10.49280739	9.53675721
9.74560138	10.34343033	10.19711682	9.20212506	9.06407316	10.07228419	11.06791431	12.10523742	8.72119193	10.04645774
11.47090441	8.92472486	10.04585273	10.41149437	9.90118185	9.02229964	8.66708035	11.53976046	11.40609367	9.73014878
8.94607876	11.562354	9.58552216	9.74172847	9.64220948	9.69459042	9.58460199	11.14917832	9.49543794	9.46369271
10.16544667	9.92277128	9.61975057	11.11679747	9.42894032	9.25751891	11.44948256	8.16601628	10.11500258	9.42431821

What are these numbers?

Example: 300 numbers (cont.)

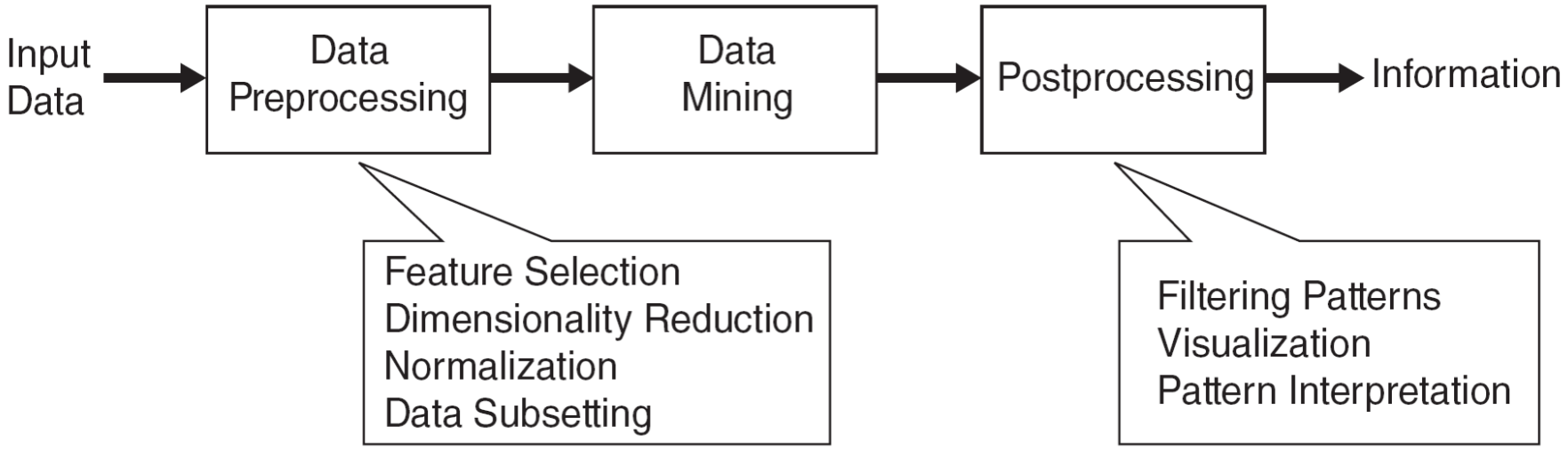
Through *statistical modeling* we can find the data comes from a Normal distribution with mean 10 and standard deviation 1

- Normal(μ=10,σ=1) is a *model* for the data



```
import numpy as np
import matplotlib.pyplot as plt
mu = 10
sigma = 1
sample = np.random.normal(mu, sigma, 300)
out, bins, ignored = plt.hist(sample, 30,
density=True)
plt.plot(bins, 1/(sigma*np.sqrt(2 * np.pi))*
np.exp(-(bins - mu)**2/(2*sigma**2)),
linewidth=2, color='r')
plt.xlabel("Number")
plt.ylabel("Frequency")
plt.show()
```

Data analytics steps

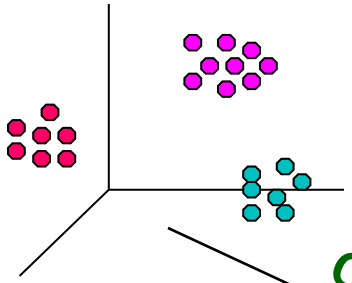


Data mining tasks

- Predictive Methods
  - Use some variables to predict unknown or future values of other variables
  - Example: Recommender systems

- Descriptive Methods
  - Find human-interpretable patterns that describe the data
  - Example: Clustering

Data mining tasks

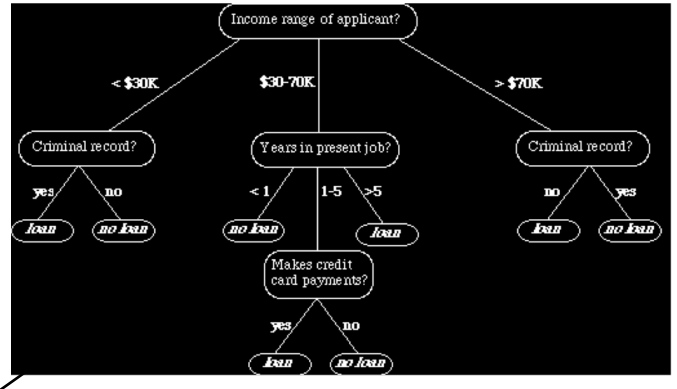


Clustering

Data

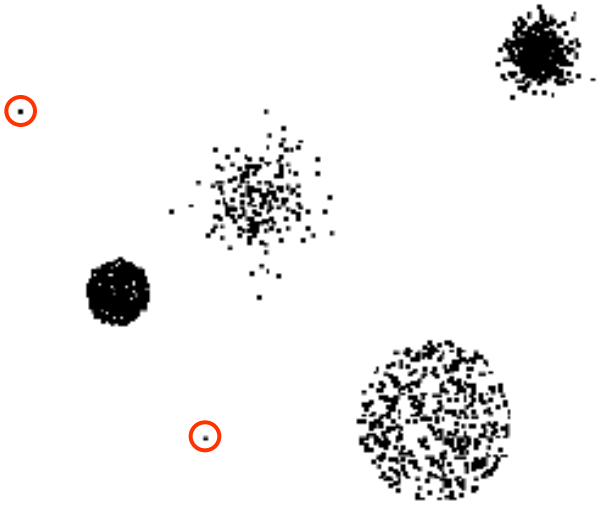
Tid	Refund	Marital Status	Taxable Income	Cheat
1	Yes	Single	125K	No
2	No	Married	100K	No
3	No	Single	70K	No
4	Yes	Married	120K	No
5	No	Divorced	95K	Yes
6	No	Married	60K	No
7	Yes	Divorced	220K	No
8	No	Single	85K	Yes
9	No	Married	75K	No
10	No	Single	90K	Yes
11	No	Married	60K	No
12	Yes	Divorced	220K	No
13	No	Single	85K	Yes
14	No	Married	75K	No
15	No	Single	90K	Yes

Predictive Modeling



Association Rules

Anomaly Detection



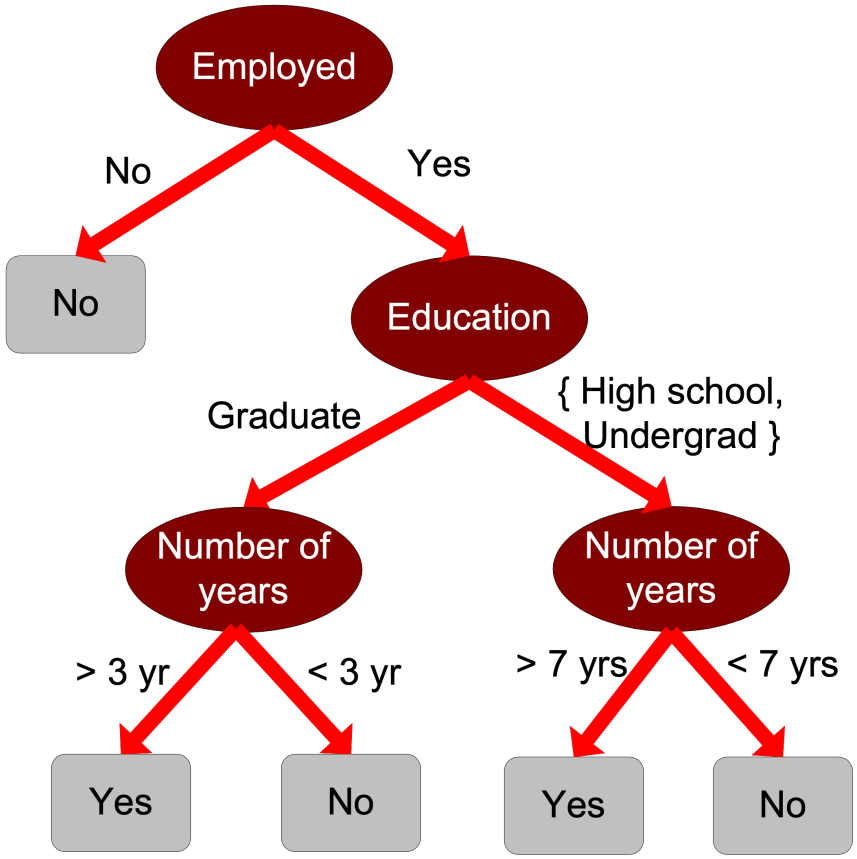
Predictive modelling: classification

- Find a model for class attribute as a function of the values of other attributes

Class

Tid	Employed	Level of Education	# years at present address	Credit Worthy
1	Yes	Graduate	5	Yes
2	Yes	High School	2	No
3	No	Undergrad	1	No
4	Yes	High School	10	Yes
…	…	…	…	…

Model for predicting creditworthiness

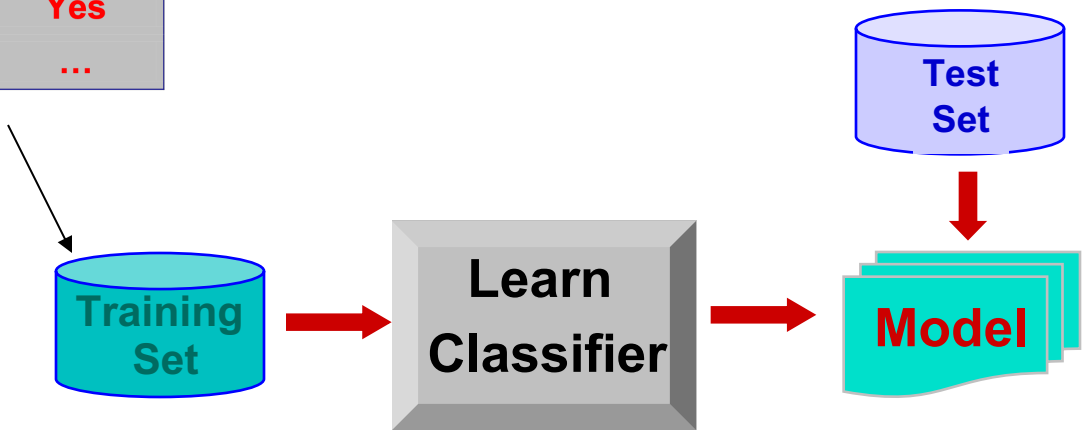


Classification example

categorical categorical quantitative class

Tid	Employed	Level of Education	# years at present address	Credit Worthy
1	Yes	Graduate	5	Yes
2	Yes	High School	2	No
3	No	Undergrad	1	No
4	Yes	High School	10	Yes
…	…	…	…	…

Tid	Employed	Level of Education	# years at present address	Credit Worthy
1	Yes	Undergrad	7	?
2	No	Graduate	3	?
3	Yes	High School	2	?
…	…	…	…	…



Examples of classification task

- Classifying credit card transactions as legitimate or fraudulent
- Classifying land covers (water bodies, urban areas, forests, etc.) using satellite data
- Categorizing news stories as finance, weather, entertainment, sports, etc.
- Identifying intruders in the cyberspace
- Predicting tumor cells as benign or malignant
- …

Classification: Application

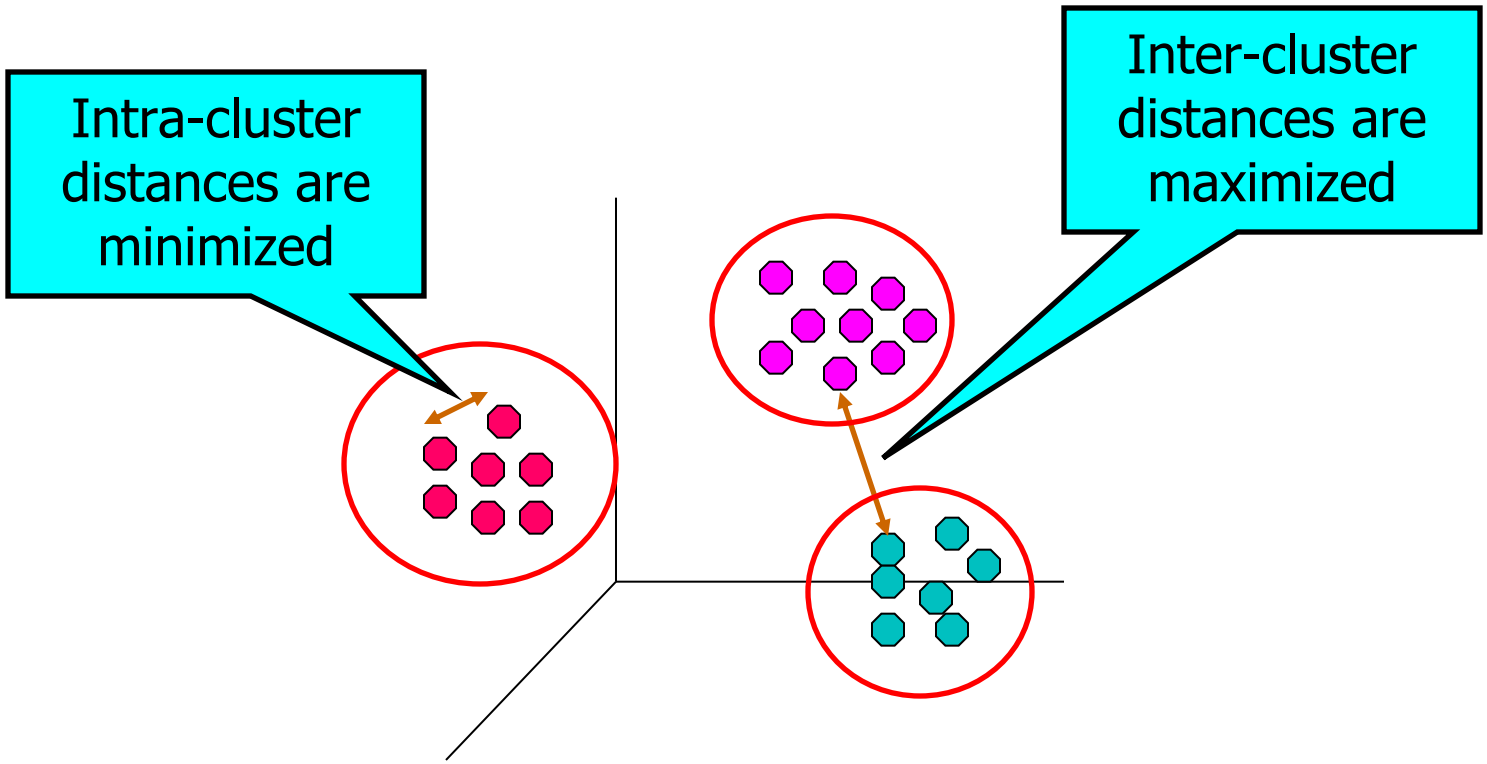
- Fraud Detection
  - **Goal: Predict fraudulent cases in credit card transactions**
  - **Approach:**
    - Use credit card transactions and the information on its account-holder as attributes
    - When does a customer buy, what does he buy, how often he pays on time, …
    - Label past transactions as fraud or fair transactions -> this forms the class attribute
    - Learn a model for the class of the transactions
    - Use this model to detect fraud by observing credit card transactions on an account

Regression

- Predict a value of a given continuous valued variable based on the values of other variables, assuming a linear or nonlinear model of dependency
- Examples:
  - Predicting sales amounts of new product based on advertising expenditure
  - Predicting wind velocities as a function of temperature, humidity, air pressure, etc.
  - Time series prediction of stock market indices

Clustering

- Finding groups of objects such that the objects in a group will be similar (or related) to one another and different from (or unrelated to) the objects in other groups



Examples of clustering task

- Customer profiling for targeted marketing
- Group related documents for browsing
- Group genes and proteins that have similar functionality
- Group stocks with similar price fluctuations

Clustering: Application 1

- Market Segmentation:
  - **Goal:** subdivide a market into distinct subsets of customers where any subset may conceivably be selected as a target with a distinct marketing mix
  - **Approach:**
    - Collect different attributes of customers based on their geographical and lifestyle related information
    - Find clusters of similar customers
    - Measure the clustering quality by observing buying patterns of customers in same cluster vs. those from different clusters

Clustering: Application 2

- Document Clustering:
  - **Goal:** To find groups of documents that are similar to each other based on the important terms appearing in them.
  - **Approach:**
    - To identify frequently occurring terms in each document
    - Form a similarity measure based on the frequencies of different terms
    - Use the same to cluster all documents

Association Rule Mining

- Given a set of records each of which contain some number of items from a given collection
  - Produce dependency rules which will predict occurrence of an item based on occurrences of other items

TID	*Items*
1	Bread, Coke, Milk
2	Beer, Bread
3	Beer, Coke, Diaper, Milk
4	Beer, Bread, Diaper, Milk
5	Coke, Diaper, Milk

Rules Discovered:

{Milk} --> {Coke}

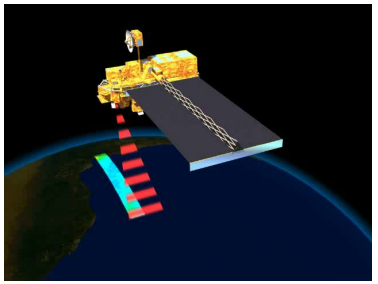
{Diaper, Milk} --> {Beer}

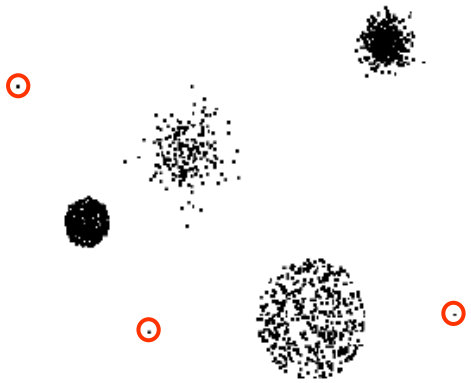
Association analysis: applications

- Market-basket analysis
  - Rules are used for sales promotion, shelf management, and inventory management
- Telecommunication alarm diagnosis
  - Rules are used to find combination of alarms that occur together frequently in the same time period
- Medical Informatics
  - Rules are used to find combination of patient symptoms and test results associated with certain diseases

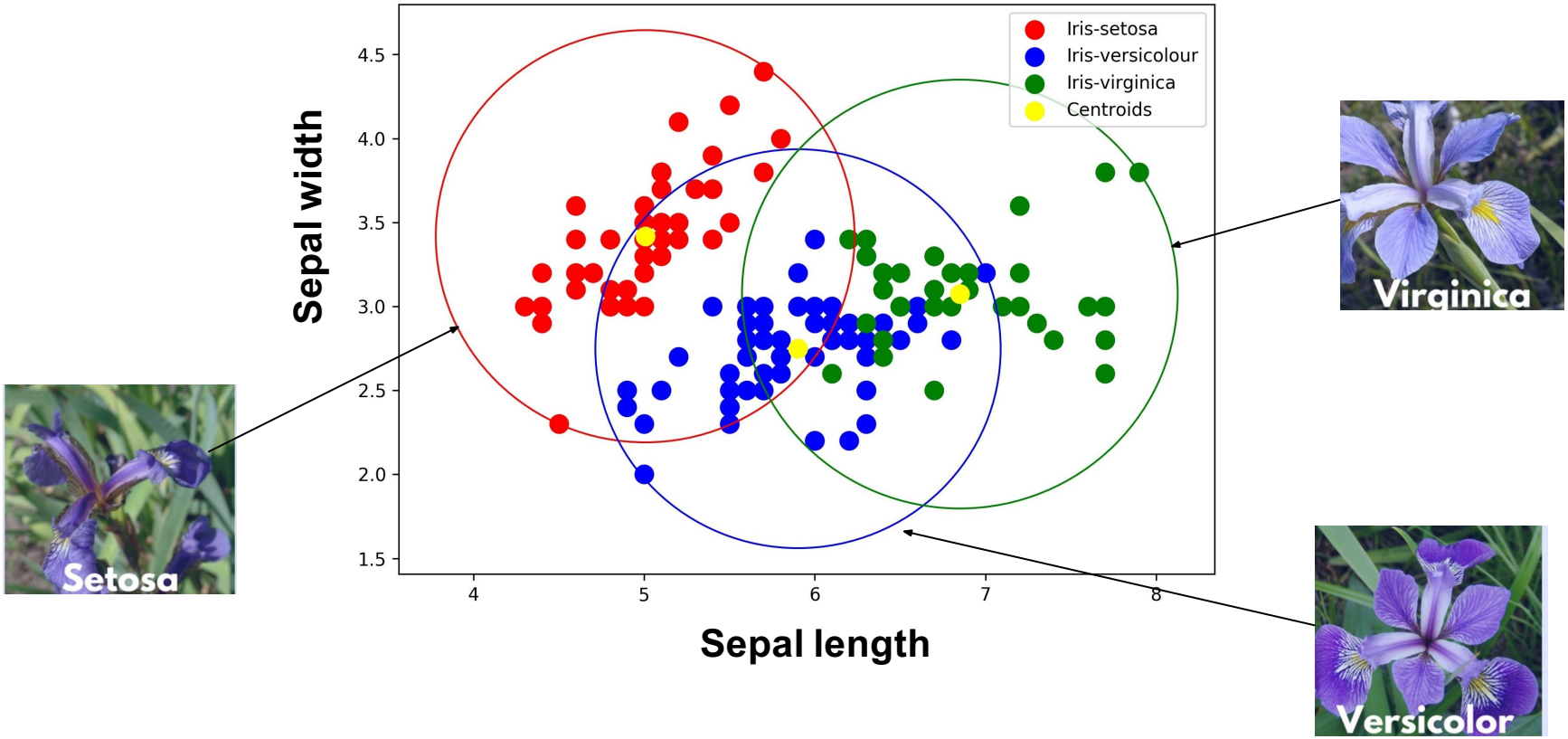
Deviation/anomaly/change detection

- Detect significant deviations from normal behavior
- Applications:
  - Fraudulent transaction detection
  - Network intrusion detection
  - Identify anomalous behavior from sensor networks for monitoring and surveillance
  - Detecting changes in the global forest cover





Picking the right features



Picking the right features

- Representing these flowers by their *petal length* and *sepal length* was key
  - These are good features for this task
- Other features such as color or number of leaves may not be so good
- Feature selection is key!

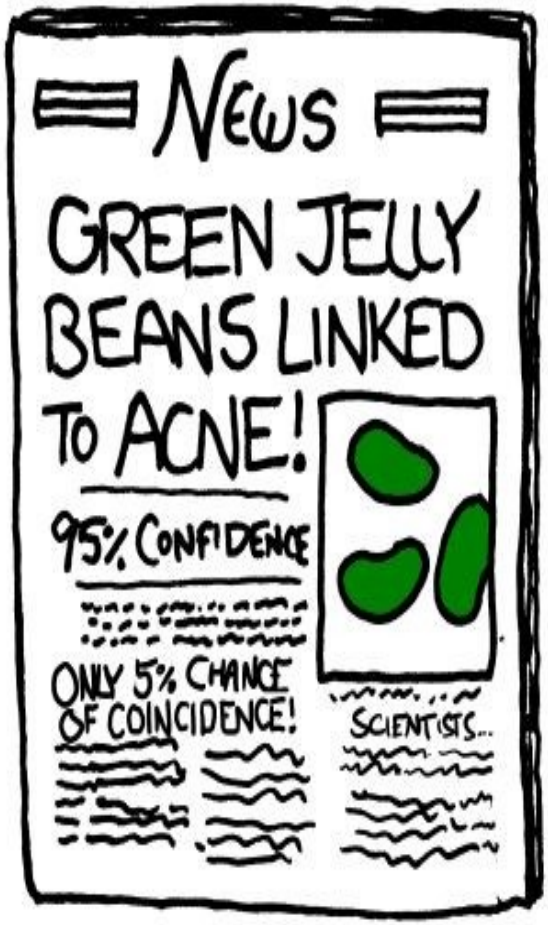
Another pattern-finding example

Risk #1: Spurious patterns

- A risk with data analytics is that an analyst can "discover" patterns that are meaningless
- If you look in more places for interesting patterns than your amount of data will support, you are bound to find something (~Bonferroni principle)

If you interrogate data hard enough it will tell you what you want to hear

Risk #1: Spurious patterns



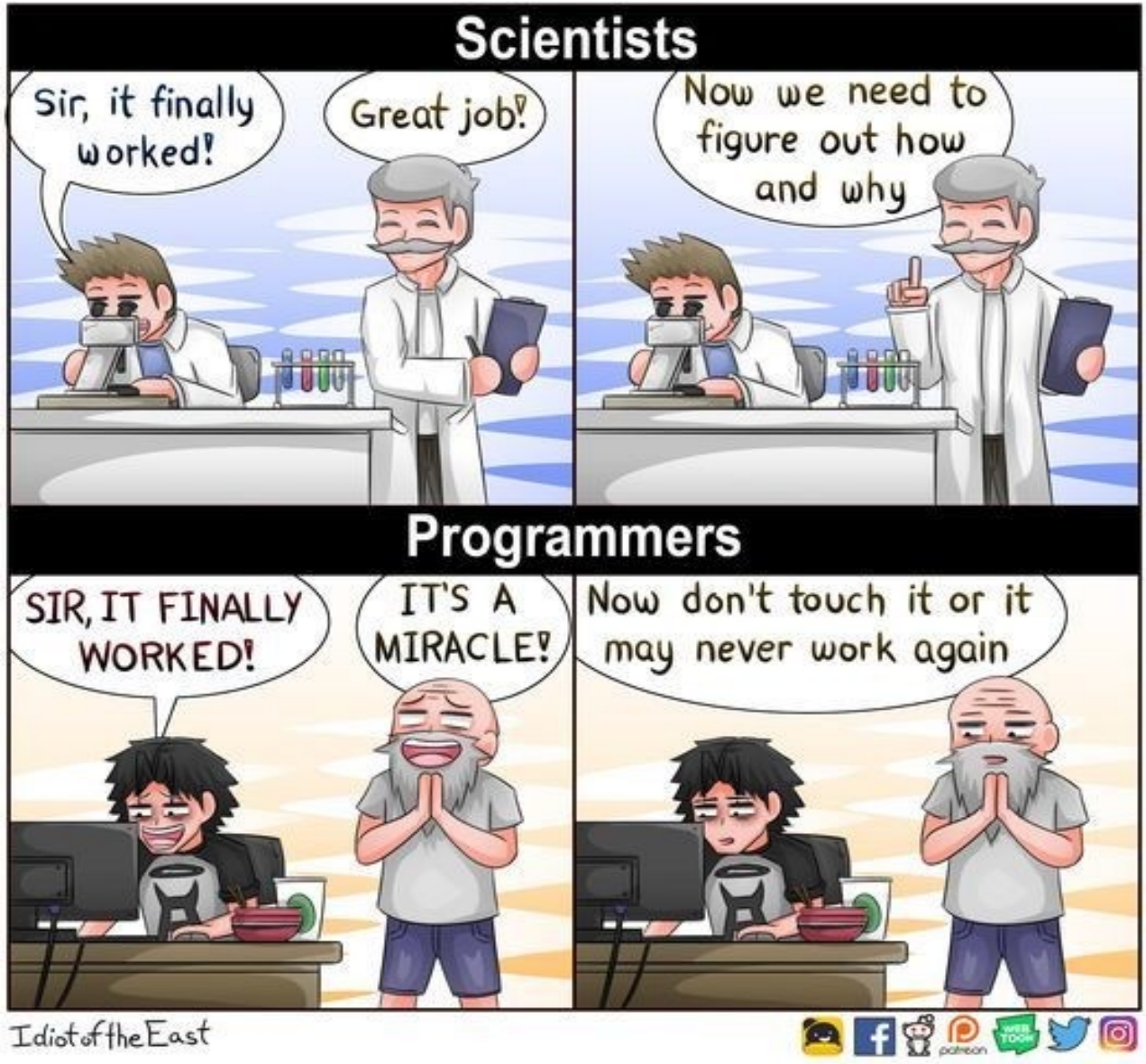
Risk #2: Surveillance state

- Attention-grabbing evil actions are also very rare, with consequences:
  - Suppose 1 in a million is a suicide bomber
  - Catching one suicide bomber a year on average means examining 999999 innocent people
- A system with 1% false positive rate will flag ~10K people as potential suicide bombers

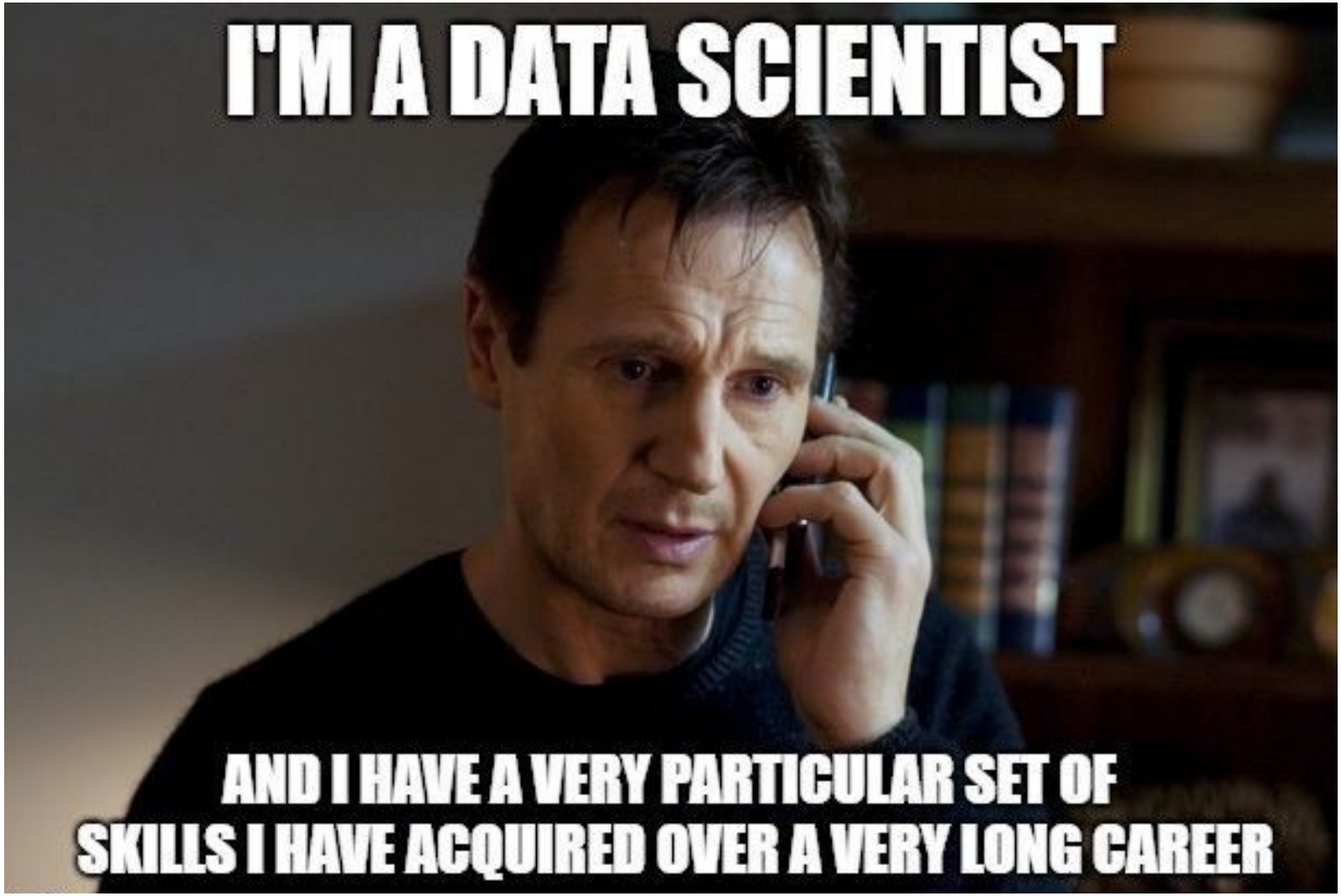
Knowledge Discovery from Data

- KDD, a popular acronym
  - "Discovery" is Data Mining
- Other names:
  knowledge mining from data, knowledge extraction, pattern analysis

Which way?


Scientists
Sir, it finally worked!
Great job!
Now we need to figure out how and why
Programmers
SIR, IT FINALLY WORKED!
IT'S A MIRACLE!
Now don't touch it or it may never work again
Idiot of the East

At the end of the course (hopefully)



Taken (2008)

Thank You

Slides Courtesy
1. Introduction to Data Mining, 2nd Edition by Tan, Steinbach, Karpatne, Kumar
2. Prof. Carlos Castillo, UPF Barcelona
3. Prof. ABC, lost somewhere in Hijli jail