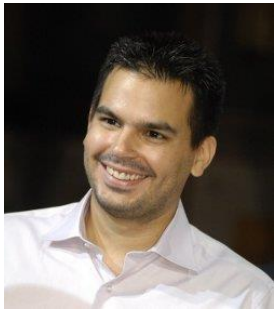
INTRO TO DATA SCIENCE AND DATA MINING

Introduction

Instructors

Aris (Aris Anagnostopoulos, lectures)



Federico (Federico Siciliano, lab)

Teaching assistants

Daniel

Loris

Mehrdad

Edo

Logistics

- Register to the mailing list: **Send email to Aris**
- Web page: **http://aris.me**
- Class hours
- Physical attendance (no remote attendance, sorry)
- Lab
- Office hours: send email
- Slack
- Books, notes
- Exam
  - Homeworks
  - Groups
  - Peer evaluation
  - Group evaluation
  - Class participation
- Collaboration policy

Algorithmic Data Mining (ADM)
What is this class about?

Basic concepts in computer science

- Basic computer architecture
- Data structures
- Algorithms and analysis of algorithms
- Complexity
- Programming

Data Mining Topics

- Text mining
- Clustering
- Graphs

What is data mining?

- After years of data mining there is still no unique answer to this question.

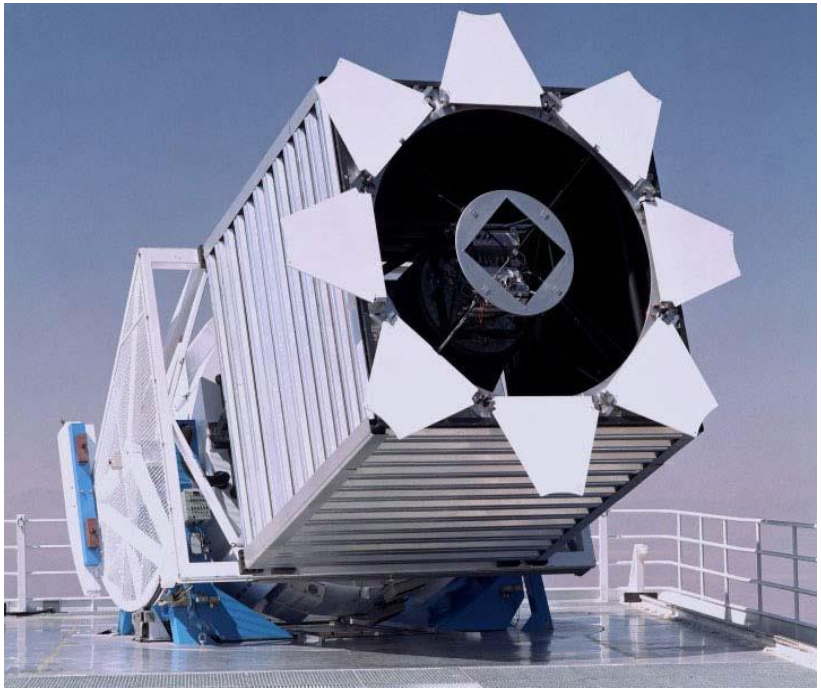
- A tentative definition:

Data mining is the use of efficient techniques for the analysis of very large collections of data and the extraction of useful and possibly unexpected patterns in data.

1. What is Data Mining?

- Large quantities of data are collected about all aspects of our lives
- This data contains interesting patterns
- Data Mining helps us to
  1. discover these patterns and
  2. use them for decision making across all areas of society, including
     - Business and industry
     - Science and engineering
     - Medicine and biotech
     - Governmen
     - Individuals

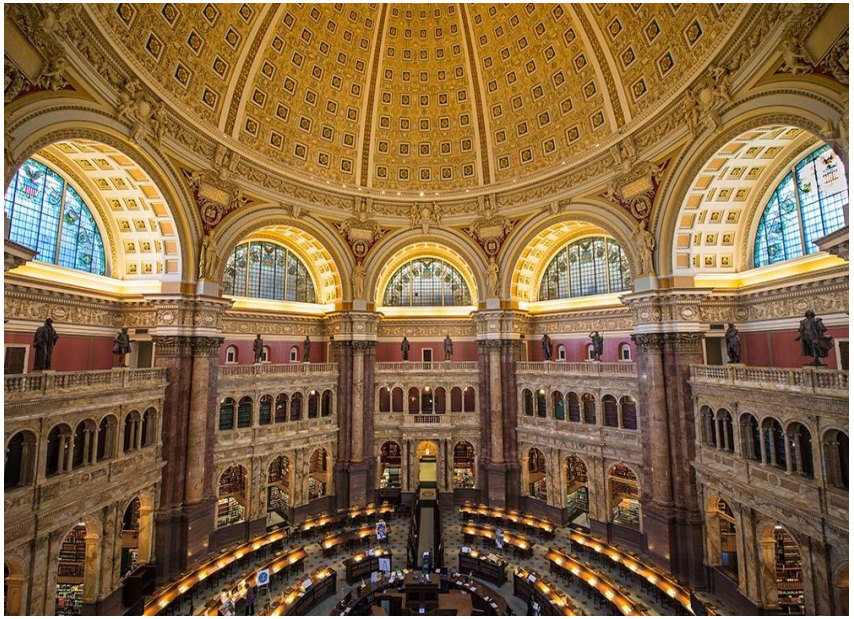
“We are Drowning in Data...”



Sloan Digital Sky Survey
≈ 200 GB/day
≈ 73 TB/year

Predict
- Type of sky object:
  Star or galaxy?

“We are Drowning in Data...”



US Library of Congress
≈ 235 TB archived
≈ 40 Wikipedias

Discover
- Topic distributions
- Historic trends*
- Citation networks

* Lansdall-Welfare, et al.: Content analysis of 150 years of British periodicals.PNSA, 2017.

“We are Drowning in Data...”

Facebook

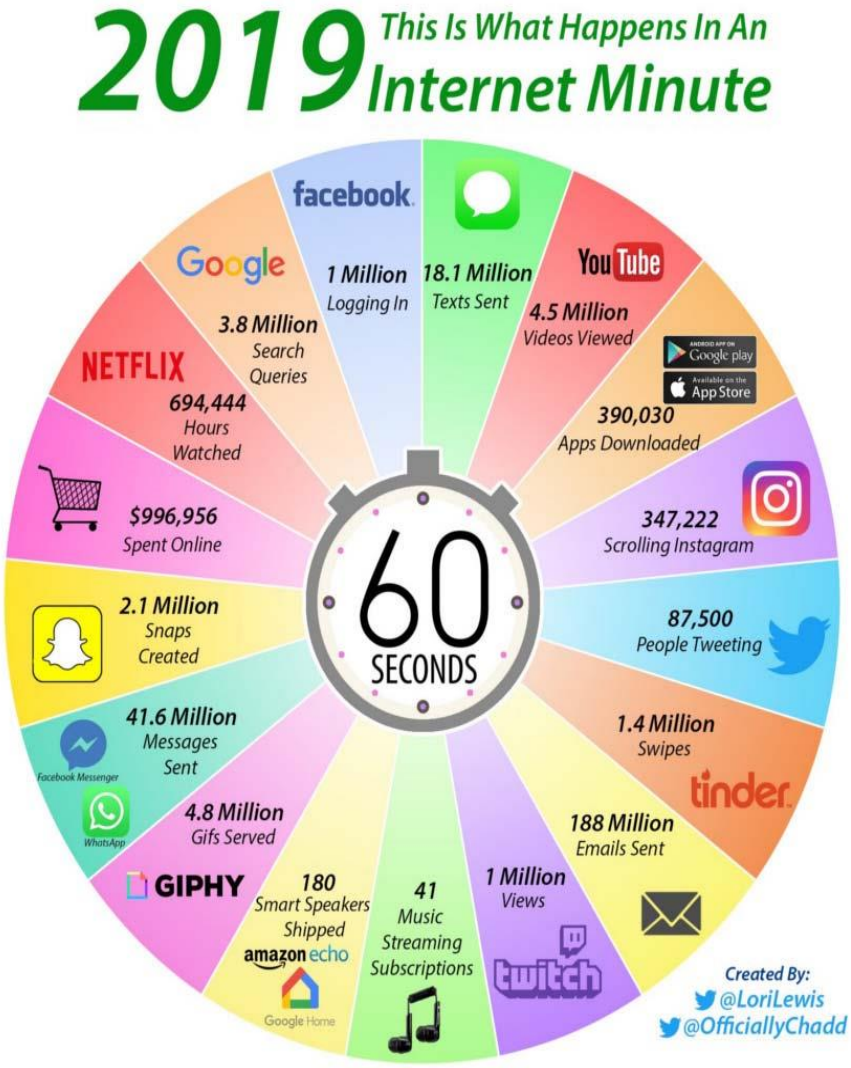
- 4 Petabyte of new data generated every day
- over 300 Petabyte in Facebook‘s data warehouse

Predict

- Interests and behavior of over one billion people

https://www.brandwatch.com/blog/facebook-statistics/
http://www.technologyreview.com/featuredstory/428150/what-facebook-knows/

“We are Drowning in Data...”



Predict

- Interests and behavior of mankind

“We are Drowning in Data...”

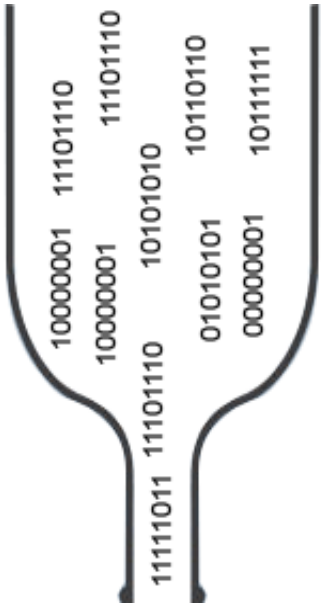
Law enforcement agencies collect unknown amounts of data from various sources

- Cell phone calls
- Location data
- Web browsing behavior
- Credit card transactions
- Online profiles (Facebook)
- …

Predict

- Terrorist or not?
- Trustworthiness

“...but starving for knowledge!”



← Amount of data that is collected

← Amount of data that can be looked at by humans

We are interested in the patterns, not the data itself!

Data Mining methods help us to

- discover interesting patterns in large quantities of data
- take decisions based on the patterns

Definitions of Data Mining

– Definitions

Exploration & analysis, of large quantities of data in order to discover meaningful patterns.

Non-trivial extraction of
- **implicit,**
- **previously unknown, and**
- **potentially useful**

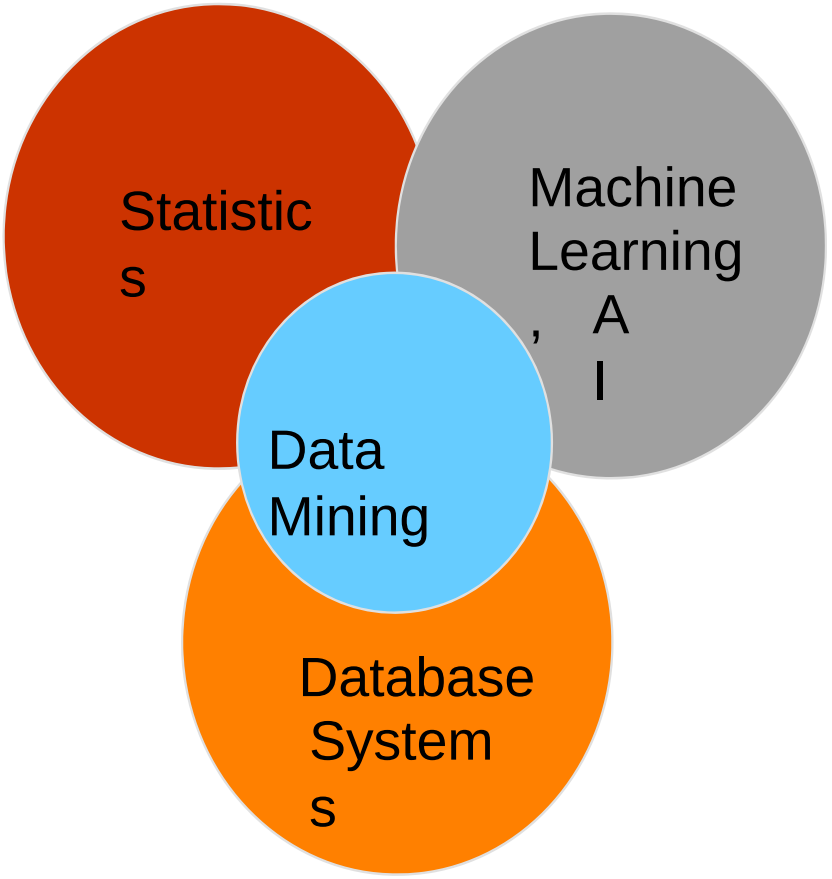
information from data.

– Data Mining methods

1. detect interesting patterns in large quantities of data
2. **support** human decision making by providing such patterns
3. **predict** the outcome of a future observation based on the patterns

Origins of Data Mining

- Data Mining combines ideas from statistics, machine learning, artificial intelligence, and database systems
- Tries to overcome short-comings of traditional techniques concerning
  - large amount of data
  - high dimensionality of data
  - heterogeneous and complex nature of data
  - explorative analysis beyond hypothesize-and-test paradigm



2. Tasks and Applications

- Descriptive Tasks
  - Goal: Find patterns in the data.
  - Example: W*hich products are often bought together?*
- Predictive Tasks
  - Goal: Predict unknown values of a variable
    - given observations (e.g., from the past)
  - Example: W*ill a person click a online advertisement?*
    - given her browsing history
- Machine Learning Terminology
  - descriptive = unsupervised
  - predictive = supervised

Why do we need data mining?

- Really, really huge amounts of raw data!!
  - In the digital age, TB of data are generated by the second
    - Mobile devices, digital photographs, web documents.
    - Facebook updates, Tweets, Blogs, User-generated content
    - Transactions, sensor data, surveillance data
    - Queries, clicks, browsing
  - Cheap storage has made possible to maintain this data
- Need to analyze the raw data to extract knowledge

Why do we need data mining?

- Large amounts of data can be more powerful than complex algorithms and models
  - Google has solved many Natural Language Processing problems, simply by looking at the data
  - Example: misspellings, synonyms
- Data is power!
  - Today, collected data is one of the biggest assets of an online company
    - Query logs of Google
    - The friendship and updates of Facebook
    - Tweets and follows of Twitter
    - Amazon transactions
  - We need a way to harness the collective intelligence
  - Data are transforming many other fields: politics, biology, sociology, marketting

Politics – Nate Silver (Obama-Romney)

Politics – Obama campaign

Obama performed a targeted campaign.

They gathered data and demographic info from voters

They controlled tweets

They would send related messages to voters

Recommender systems

You buy something in Amazon and they propose other items you may be interested in.

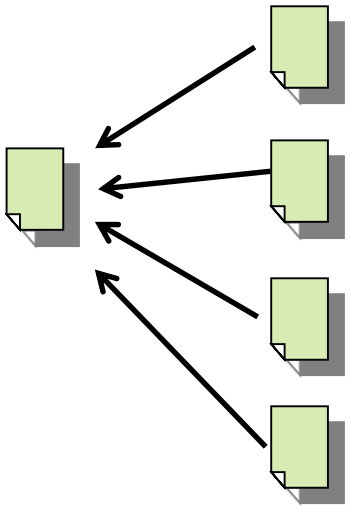
You watch youtube videos, it will recommend others.

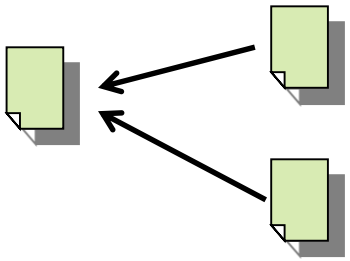
You make a google query, it will propose others.

How do they do it?

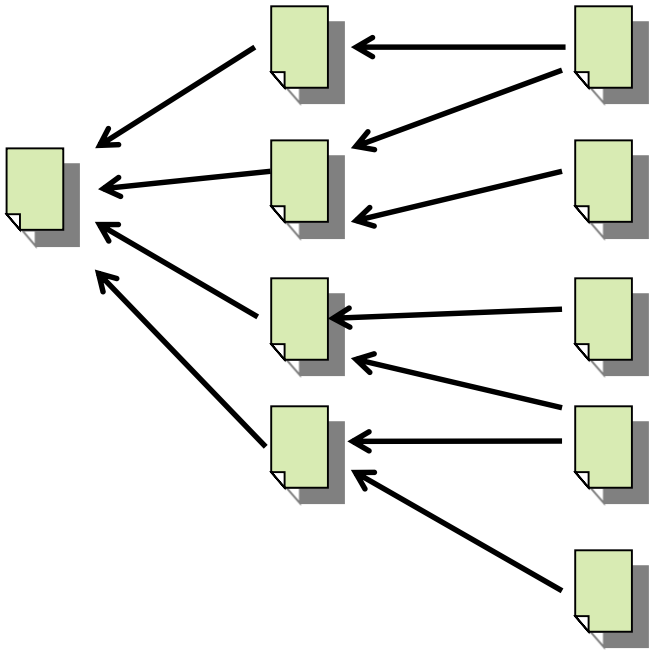
(They analyze what previous **similar** users have done!)

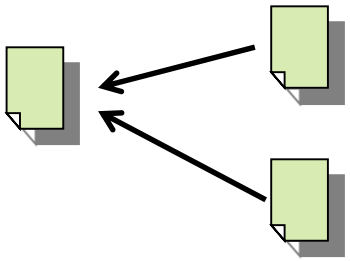
Google and PageRank



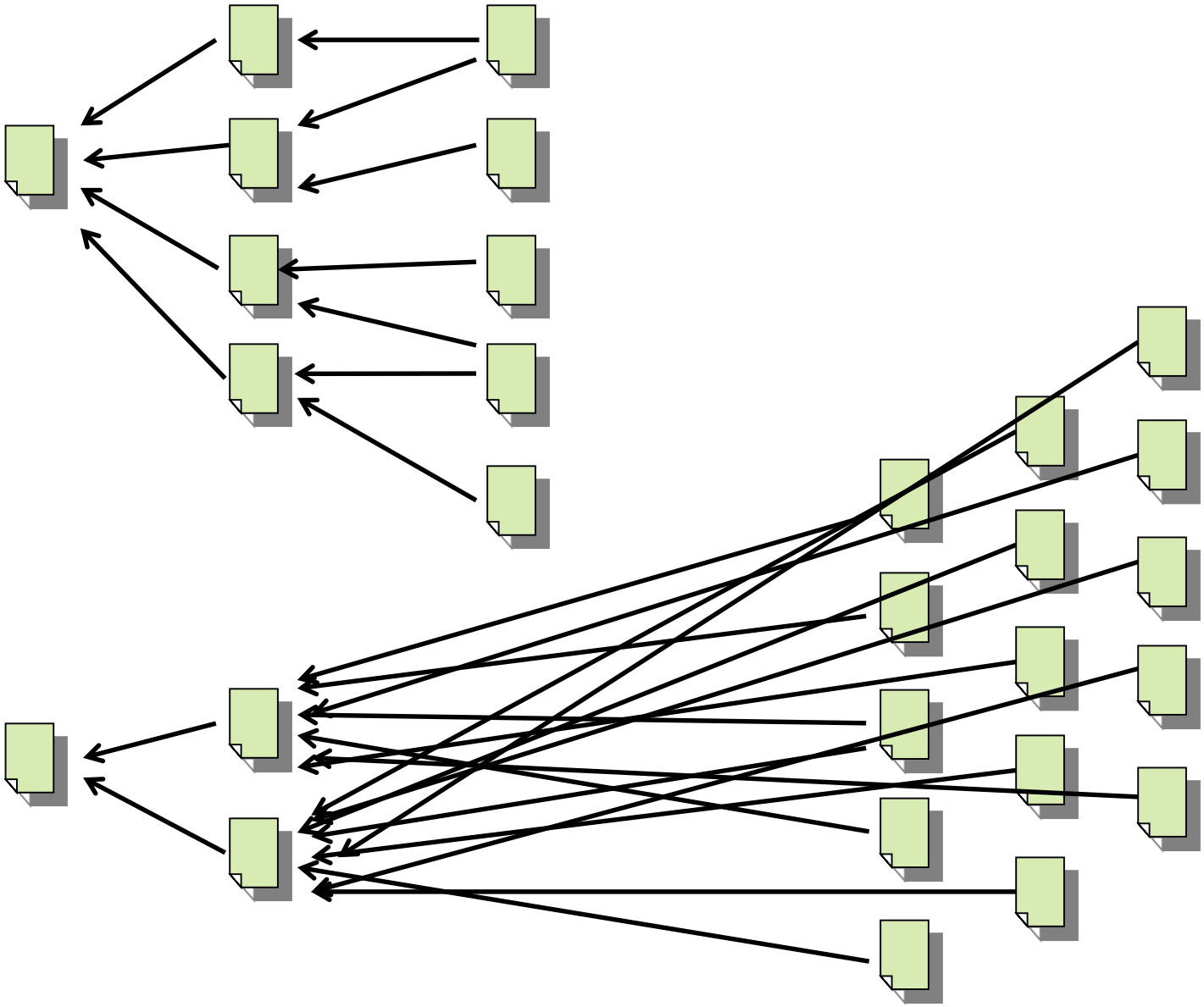


Google and PageRank

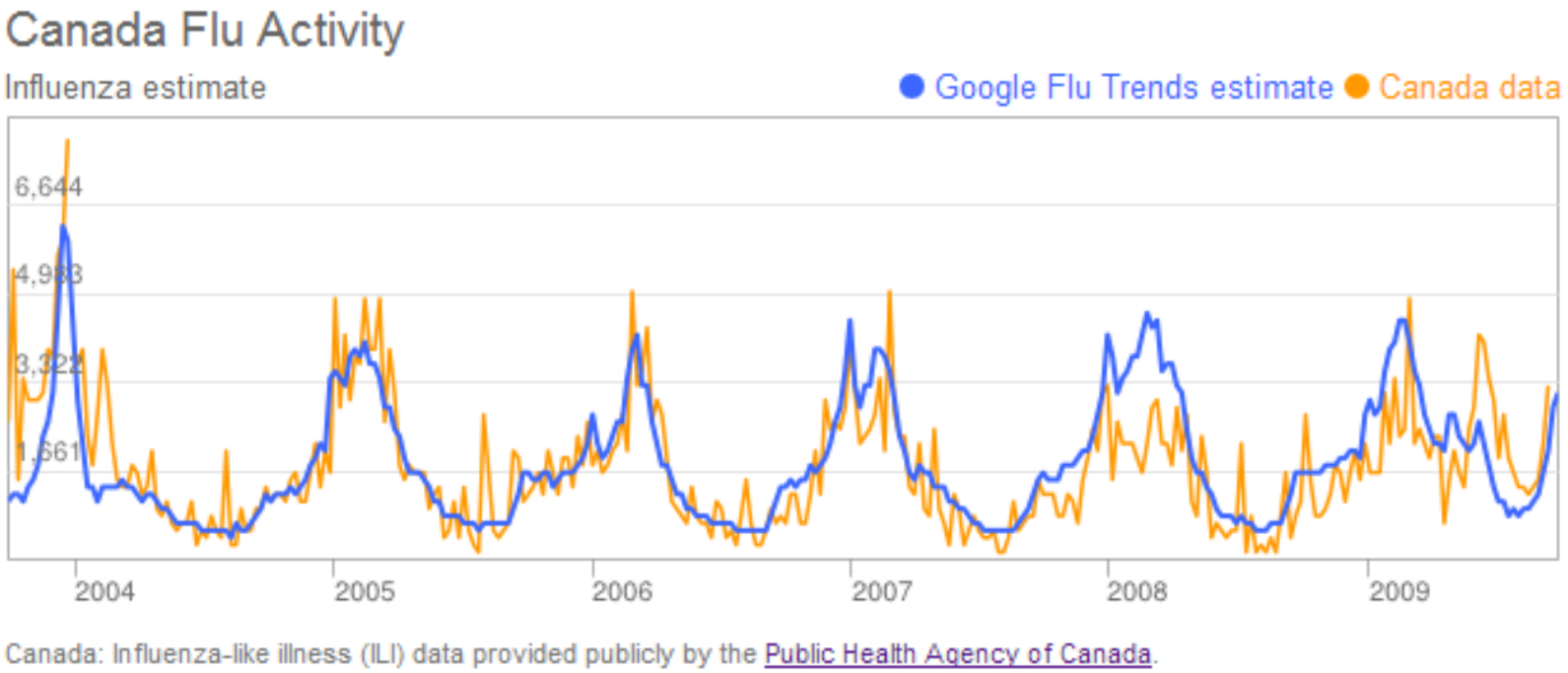




Google and PageRank



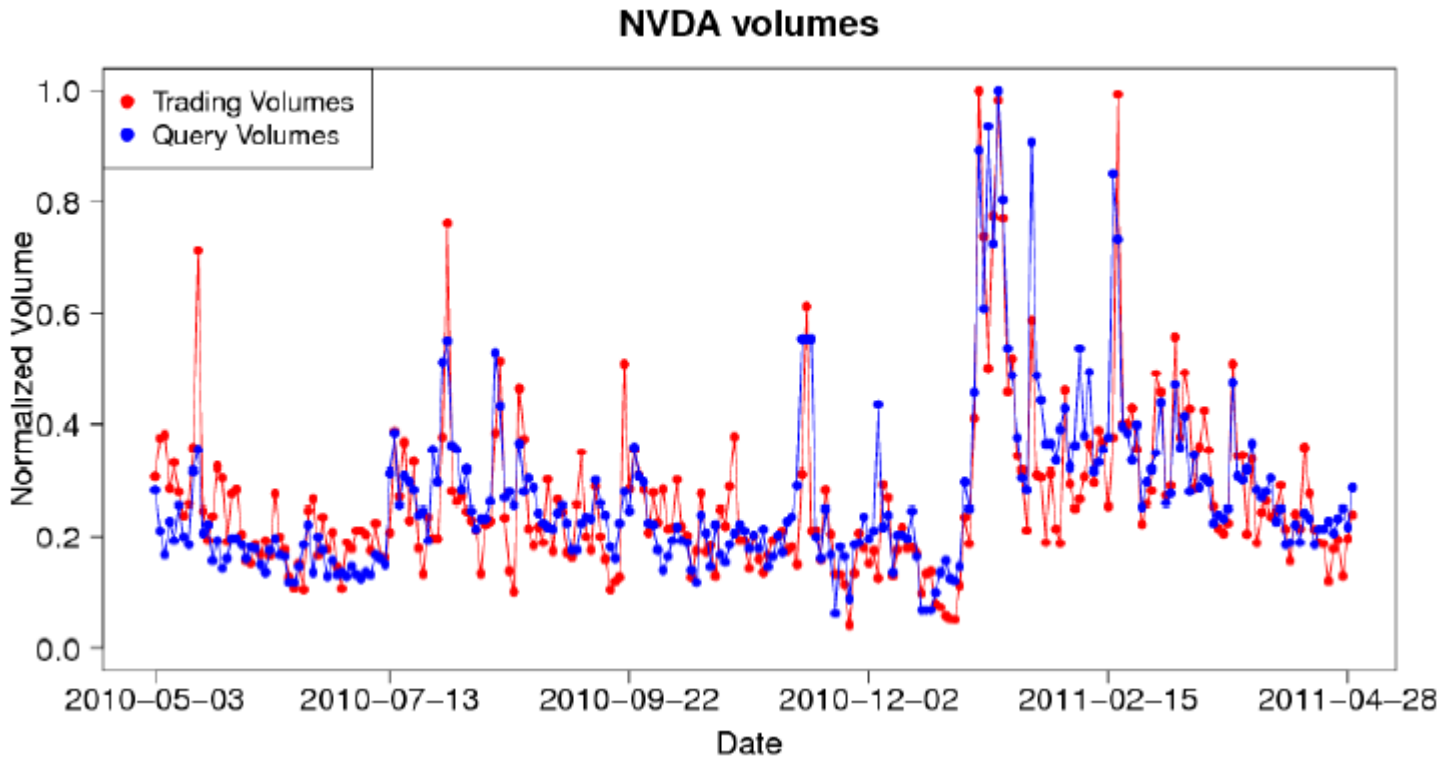
Google flu


Canada Flu Activity
Influenza estimate
Google Flu Trends estimate
Canada data
6,644
4,983
3,322
1,661
2004
2005
2006
2007
2008
2009
Canada: Influenza-like illness (ILI) data provided publicly by the Public Health Agency of Canada.

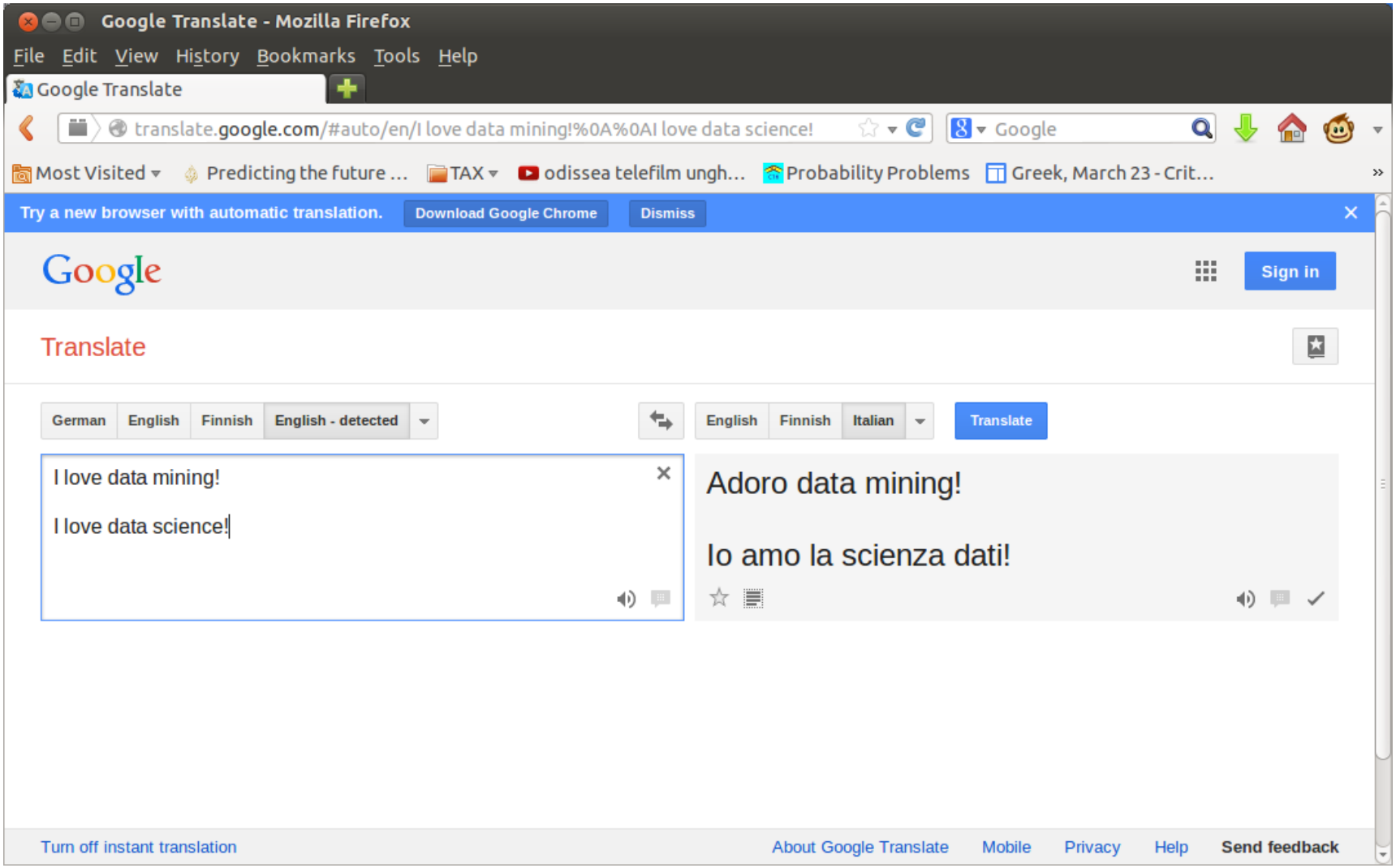
Google and stockmarket

Web Search Queries Can Predict Stock Market Volumes

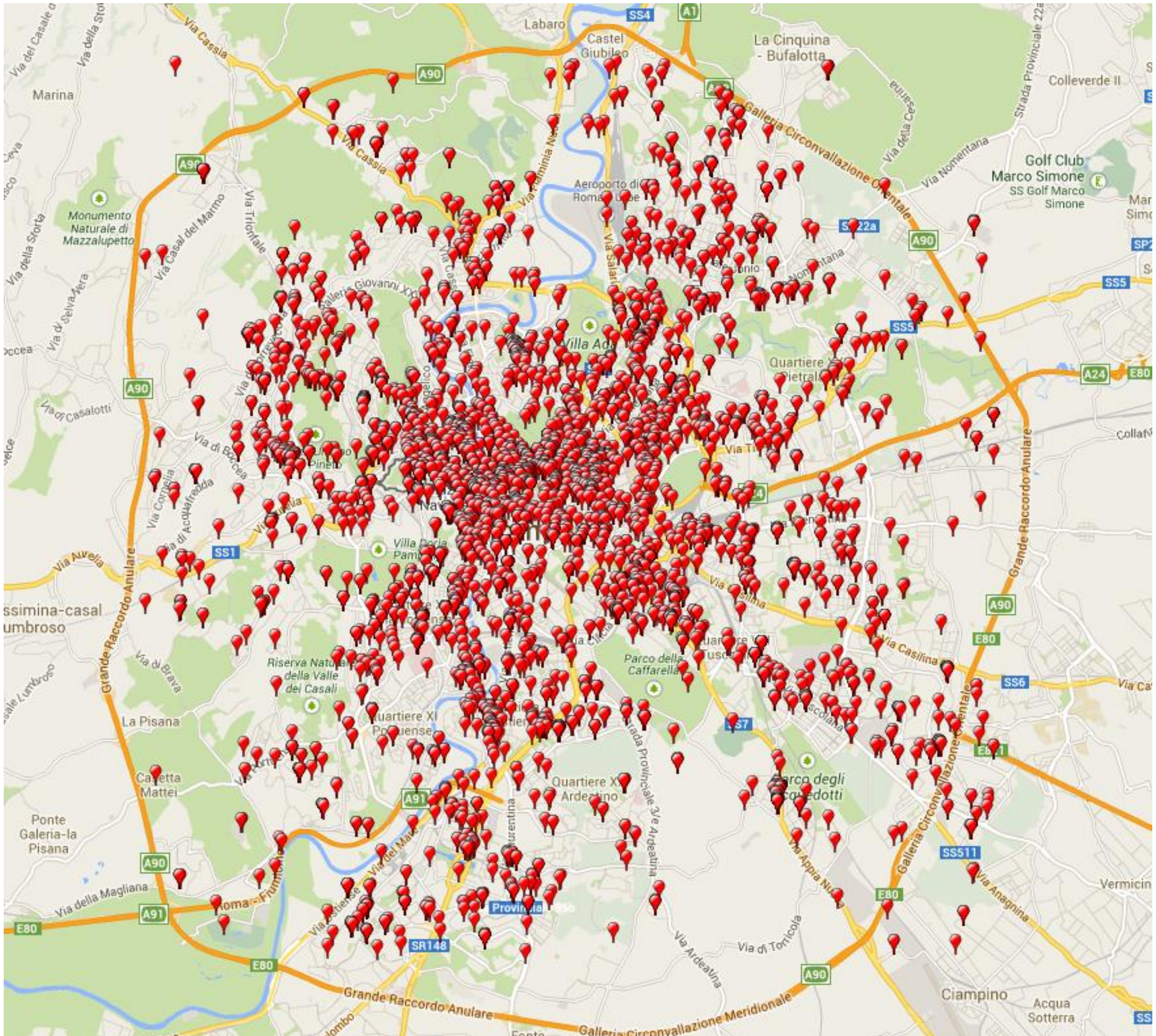
Ilaria Bordino[1], Stefano Battiston[2], Guido Caldarelli[3,4,5], Matthieu Cristelli[3]*, Antti Ukkonen[1], Ingmar Weber[1]



Google translate



twitter

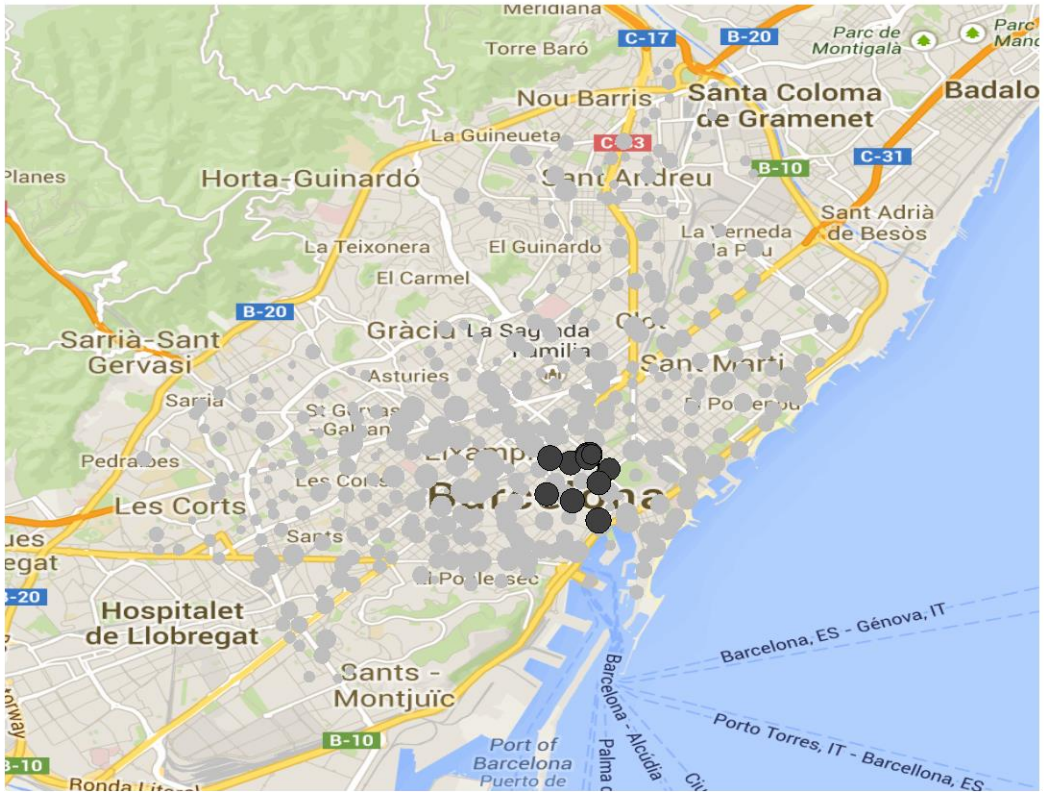


Labaro
Castel Giubileo
La Cinquina - Bufalotta
Colleverde II
Marina
Golf Club Marco Simone
SS Golf Marco Simone
Monumento Naturale di Mazzalupetto
Via Cassia
Via Trionfale
Aeroporto di Roma Urbe
Via Salaria
Via Nomentana
Galleria Circonvallazione Orientale
Quartiere XV Pietralata
Via Aurelia
Villa Doria Pamphili
Via di Casalotti
Via di Boccea
Riserva Naturale della Valle dei Casali
Quartiere XI Portuense
Parco della Caffarella
Via Casilina
La Pisana
Ponte Galeria-la Pisana
Via della Magliana
Quartiere XX Ardeatino
Parco degli Acquedotti
Via Ardeatina
Via di Torricola
Via Anagnina
Vermicino
Ciampino
Acqua Sotterra
Grande Raccordo Anulare
Galleria Circonvallazione Meridionale
Fonte

- People tweet about anything…
- Tweets provide a LOT of info

- Can we use it to obtain info about places, events, etc.?

Event detection with twitter



Psychology and Sociology

- Psychological and sociology studies have been revolutionalized with the incorporation of data science techniques
- Before based on surveys

- Now, with systems such as facebook, online games, etc. we can observe the behavior of hundreds of millions of people

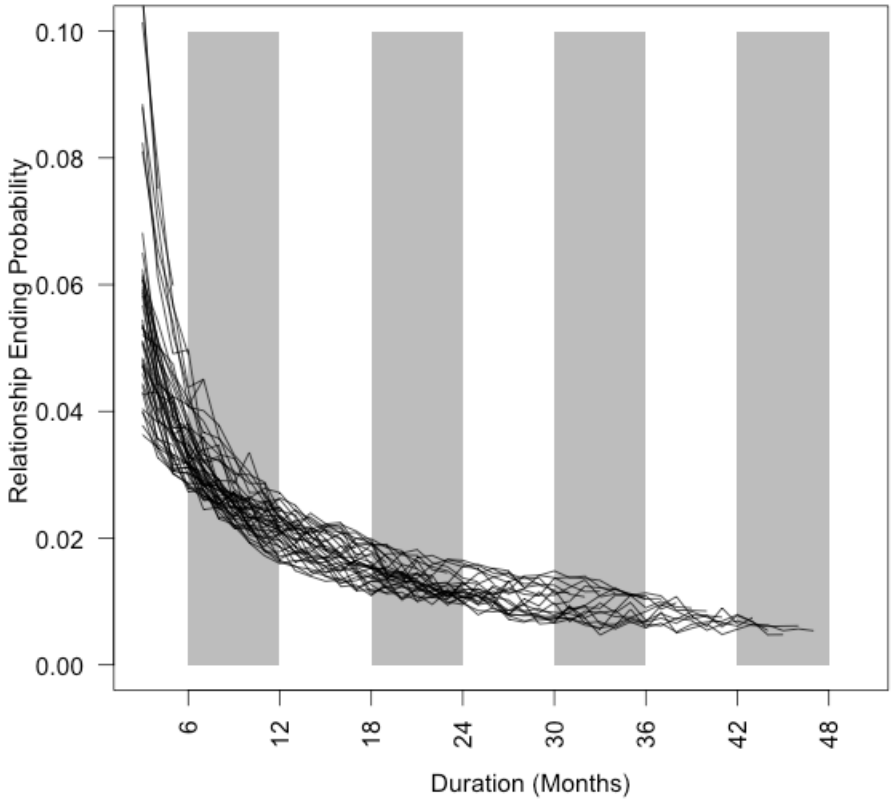
What can fb say about relationships?

Facebook Can Predict With Scary Accuracy If Your Relationship Will Last

The Huffington Post | by Alexis Kleinman

Follow Like 1.7k

Posted: 02/14/2014 10:37 am EST | Updated: 02/14/2014 4:59 pm EST



Are emotions contagious?

- In 2014, some FB researchers studied if emotions spread in FB
- They selected 150K users (group P) and they increased the number of positive posts that they see
- They selected other 150K users (group N) and they increase the number of negative posts that they see
- They studied what messages do these 300K users post

- Finding: users in group P, increased the number of positive posts and decreased the number of negative
- The opposite happened to group N

Journalism

- Journalism is based on more and more data
- Twitter
- Wikileaks

Topics of this class

- Basic computer science concepts
  - Computer architecture
  - Data structures
  - Algorithms
- Basic data mining techniques
  - Text mining
  - Clustering
  - Classification
  - Graphs
- Lab
  - Python
  - AWS

Types of Data

- Structured
  - 5-10% of the data
  - SQL
- Semi-structured
  - 5-10% of the data
  - XML, CSV, JSON
- Unstructured
  - 80% of the data

The data are also very complex

- Multiple types of data: tables, time series, images, graphs, etc.
- Spatial and temporal aspects
- Interconnected data of different types:
  - From the mobile phone we can collect, location of the user, friendship information, check-ins to venues, opinions through twitter, images though cameras, queries to search engines

Example: transaction data

- Billions of real-life customers:
  - WALMART: 20 million transactions per day
  - AT&T 300 million calls per day
  - Credit card companies: billions of transactions per day.
- The point cards allow companies to collect information about specific users

Example: document data

- Web as a document repository: estimated 50 billions of web pages
- Wikipedia: 5 million english articles (and counting)
- Online news portals: steady stream of 100’s of new articles every day
- Twitter: >500 million tweets every day

Example: network data

- Web: Google indexes over 50 billion pages, linked via hyperlinks
- Facebook: 2.7 billion users
- Twitter: 330 million active users
- Instagram: ~1 billion users
- WhatsApp: 2 billion users

- Blogs: 600 million blogs worldwide, presidential candidates run blogs

Example: genomic sequences

- There exist databases that contain the genome sequence of a lot of people
- Such data can be used to find correlations between diseases and gene mutations

- Example: UKBiobank: Mutations for 500K people

Example: environmental data

- Climate data (just an example)

http://www.ncdc.noaa.gov/ghcnm/

- “A database of temperature, precipitation and pressure records managed by the National Climatic Data Center, Arizona State University and the Carbon Dioxide Information Analysis Center”

- “6000 temperature stations, 7500 precipitation stations, 2000 pressure stations”
  - Spatiotemporal data

Example: behavioral data

- Mobile phones today record a large amount of information about the user behavior
  - GPS records position
  - Camera produces images
  - Communication via phone and SMS
  - Text via facebook updates
  - Association with entities via check-ins
- Amazon collects all the items that you browsed, placed into your basket, read reviews about, purchased.
- Google and Bing record all your browsing activity via toolbar plugins. They also record the queries you asked, the pages you saw and the clicks you did.
- Data collected for millions of users on a daily basis

So, what is “Data”?

- Collection of data objects and their attributes

- An attribute is a property or characteristic of an object
  - Examples: eye color of a person, temperature, etc.
  - Attribute is also known as variable, field, characteristic, or feature
- A collection of attributes describe an object
  - Object is also known as record, point, case, sample, entity, or instance

Attributes

Objects

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

Size: Number of objects
Dimensionality: Number of attributes
Sparsity: Number of populated object-attribute pairs

Types of Attributes

There are different types of attributes

- Binary
  - Example: yes/no, exists/not exists
- Categorical
  - Examples: eye color, zip codes, words, rankings (e.g, good, fair, bad), height in {tall, medium, short}
- Numeric
  - Examples: dates, temperature, time, length, value, count.
  - Discrete (counts) vs Continuous (temperature)

Numeric Record Data

- If data objects have the same fixed set of numeric attributes, then the data objects can be thought of as points in a multi-dimensional space, where each dimension represents a distinct attribute

- Such data set can be represented by an n-by-d data matrix, where there are n rows, one for each object, and d columns, one for each attribute

	#doors	Horsepower	weight (kg)	price	length (m)	Final speed (km/h)	0-100m (sec)
Car 1	3	120	1520	15,000	3.10	195	13.7
Car 2	4	210	1660	29,000	4.22	248	8.2
Car 3	5	158	2100	32,500	4.92	210	11.4

Categorical Data

- Data that consists of a collection of records, each of which consists of a fixed set of categorical attributes

Tid	Refund	Marital Status	Taxable Income	Cheat
1	Yes	Single	High	No
2	No	Married	Medium	No
3	No	Single	Low	No
4	Yes	Married	High	No
5	No	Divorced	Medium	Yes
6	No	Married	Low	No
7	Yes	Divorced	High	No
8	No	Single	Medium	Yes
9	No	Married	Medium	No
10	No	Single	Medium	Yes

Document Data

- Each document becomes a `term' vector,
  - each term is a component (attribute) of the vector,
  - the value of each component is the number of times the corresponding term occurs in the document.
  - Bag-of-words representation – no ordering

	team	coach	play	ball	score	game	win	lost	timeout	season
Document 1	3	0	5	0	2	6	0	2	0	2
Document 2	0	7	0	2	1	0	0	3	0	0
Document 3	0	1	0	0	1	2	2	0	3	0

Transaction Data

- Each record (transaction) is a set of items.

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

- A set of items can also be represented as a binary vector, where each attribute is an item.
- A document can also be represented as a set of words (no counts)

Sparsity: average number of products bought by a customer

Ordered Data

- Genomic sequence data

```
GGTTCCGCCTTCAGCCCCGCGCC
CGCAGGGCCCGCCCCGCGCCGTC
GAGAAGGGCCCGCCTGGCGGGCG
GGGGGAGGCGGGGCCGCCCGAGC
CCAACCGAGTCCGACCAGGTGCC
CCCTCTGCTCGGCCTAGACCTGA
GCTCATTAGGCGGCAGCGGACAG
GCCAAGTAGAACACGCGAAGCGC
TGGGCTGCCTGCTGCGACCAGGG
```

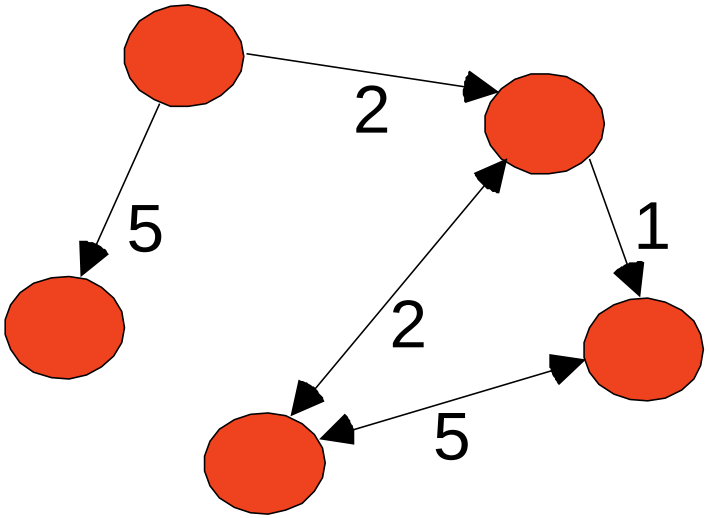
- Data is a long ordered string

Ordered Data

- Time series
  - Sequence of ordered (over “time”) numeric values.

Graph Data

- Examples: Web graph and HTML Links




```
<a href="papers/papers.html#bbbb">
Data Mining </a>
<li>
<a href="papers/papers.html#aaaa">
Graph Partitioning </a>
<li>
<a href="papers/papers.html#aaaa">
Parallel Solution of Sparse Linear System of Equations </a>
<li>
<a href="papers/papers.html#ffff">
N-Body Computation and Dense Linear System Solvers
```

Types of data

- Numeric data: Each object is a point in a multidimensional space
- Categorical data: Each object is a vector of categorical values
- Set data: Each object is a set of values (with or without counts)
  - Sets can also be represented as binary vectors, or vectors of counts
- Ordered sequences: Each object is an ordered sequence of values.
- Graph data

What can you do with the data?

- Suppose that you are the owner of a supermarket and you have collected billions of market basket data. What information would you extract from it and how would you use it?

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

Product placement

Catalog creation

Recommendations

- What if this was an online store?

What can you do with the data?

- Suppose you are a search engine and you have a toolbar log consisting of
  - pages browsed,
  - queries,
  - pages clicked,
  - ads clicked

Ad click prediction

Query reformulations

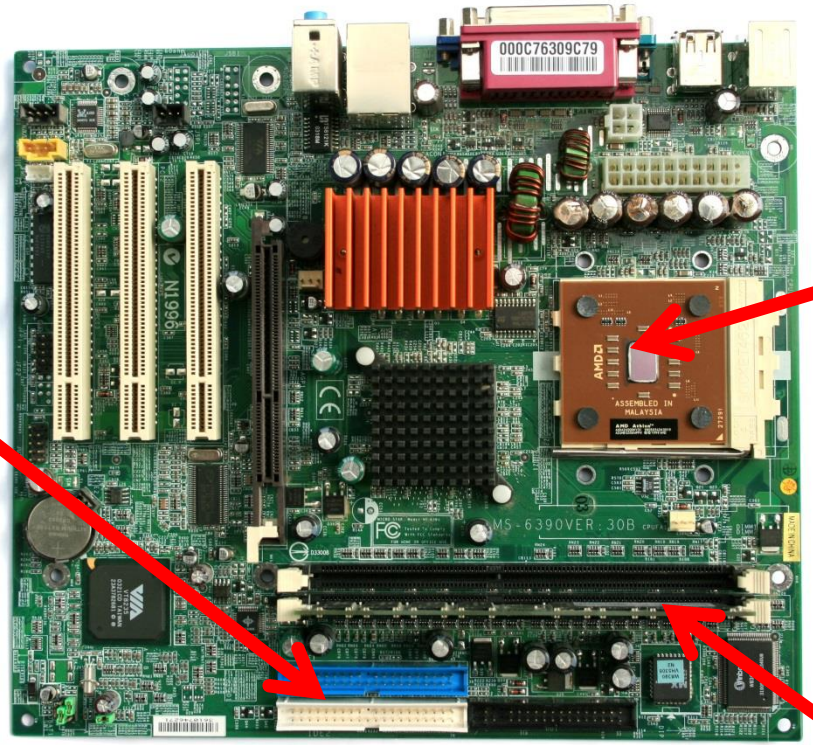
each with a user id and a timestamp. What information would you like to get our of the data?

What can you do with the data?

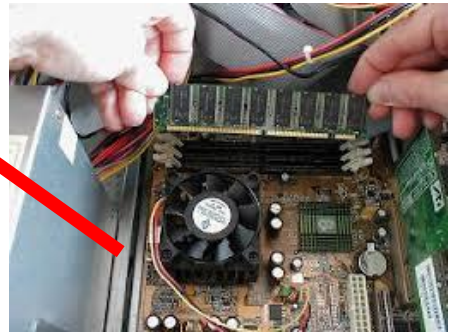
- Suppose you are a stock broker and you observe the fluctuations of multiple stocks over time. What information would you like to get our of your data?

Basics of Computer Architecture

Hard Disk (HD)



Processor (CPU)



Memory (RAM)

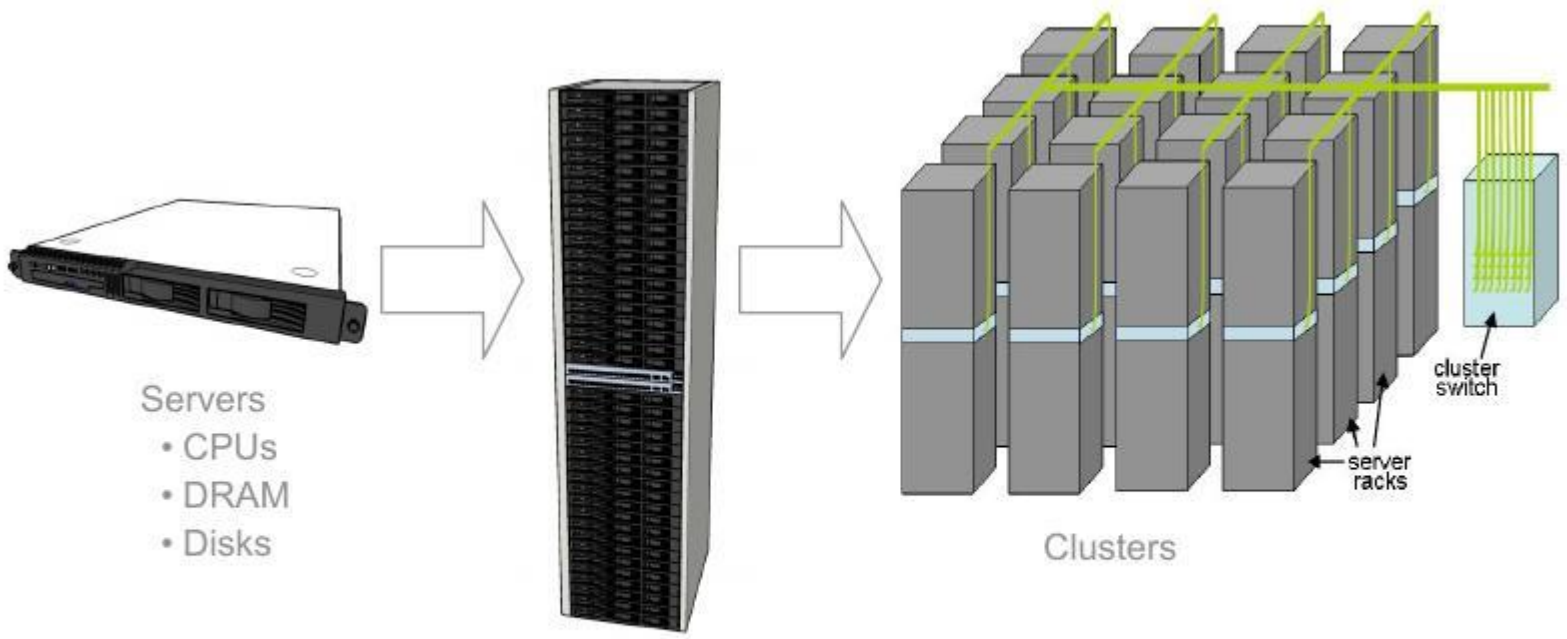
The Cloud

There exist large datacenters for storing data and making computations

- Gmail, dropbox, …

The Cloud

The Cloud


Servers
• CPUs
• DRAM
• Disks
Racks
• 40-80 servers
• Ethernet switch
cluster switch
server racks
Clusters