

# Data science

## *The Big Data challenge*

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ELENA BARALIS

POLITECNICO DI TORINO

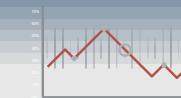
# Big data hype?



# Emergency management



UNMANNED AERIAL VEHICLES



HISTORICAL DATA



SEASONAL  
WEATHER FORECAST



SOCIAL MEDIA  
DATA STREAMS



Improving Resilience to Emergencies  
Through Advanced Cyber Technologies



i REACT

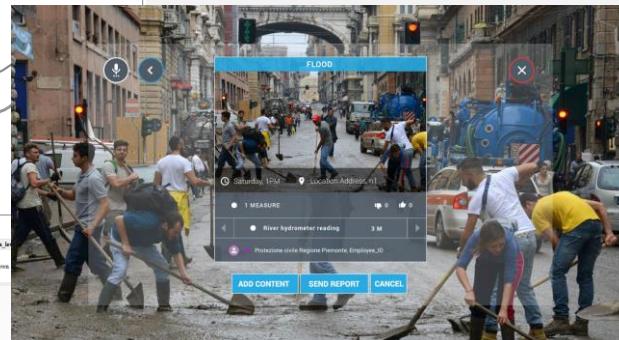
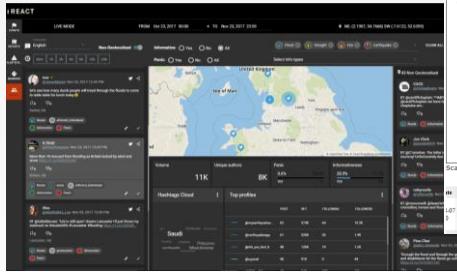
# Emergency management



FIRST RESPONDERS AND  
DECISION MAKERS



CITIZENS



Improving Resilience to Emergencies  
Through Advanced Cyber Technologies

 iREACT

# User engagement

2005



2013

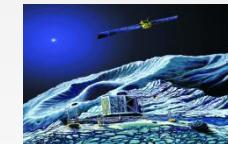


# Who generates big data?

- User Generated Content (Web & Mobile)
  - E.g., Facebook, Instagram, Yelp, TripAdvisor, Twitter, YouTube

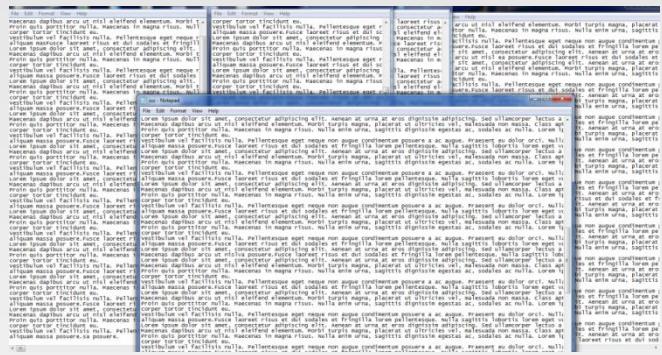
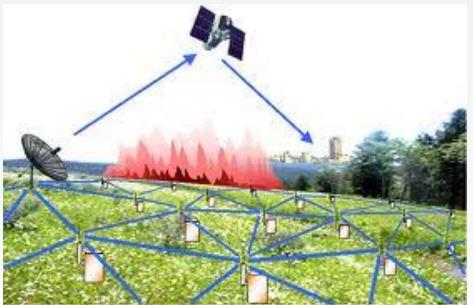


- Health and scientific computing



# Who generates big data?

- ❑ Log files
- ❑ Web server log files, machine syslog files
- ❑ Internet Of Things
- ❑ Sensor networks, RFID, smart meters



# What is big data?



- Many different definitions

*“Data whose scale, diversity and complexity require new architectures, techniques, algorithms and analytics to manage it and extract value and hidden knowledge from it”*

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# What is big data?



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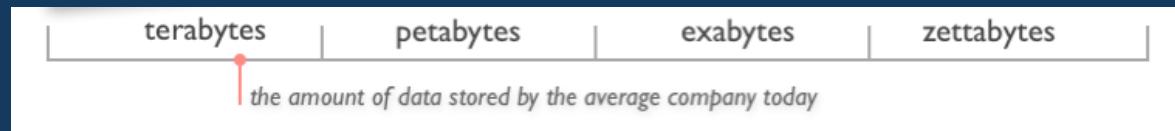
*“Data whose scale, diversity and complexity require new **architectures**, **techniques**, **algorithms** and **analytics** to manage it and extract value and hidden knowledge from it”*

# What is big data?



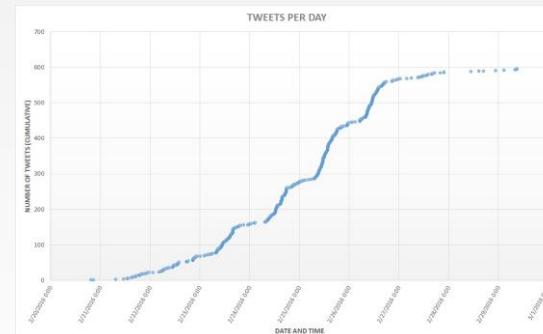
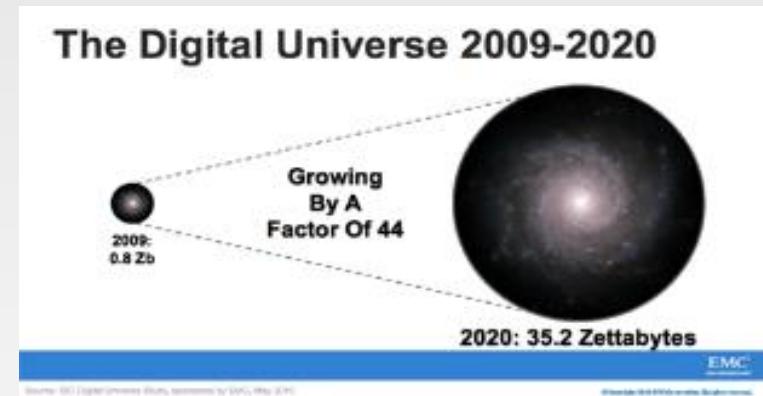
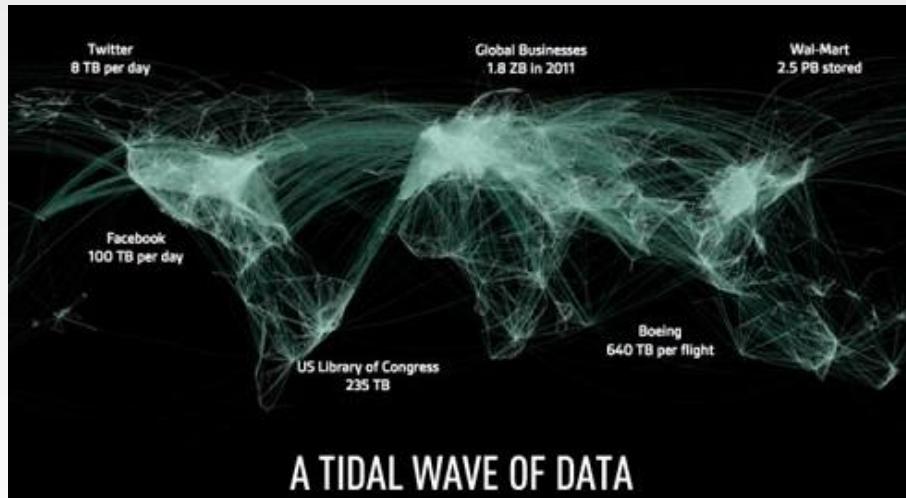
- Many different definitions

*“Data whose scale, diversity and complexity require new architectures, techniques, algorithms and analytics to manage it and extract **value** and hidden **knowledge** from it”*

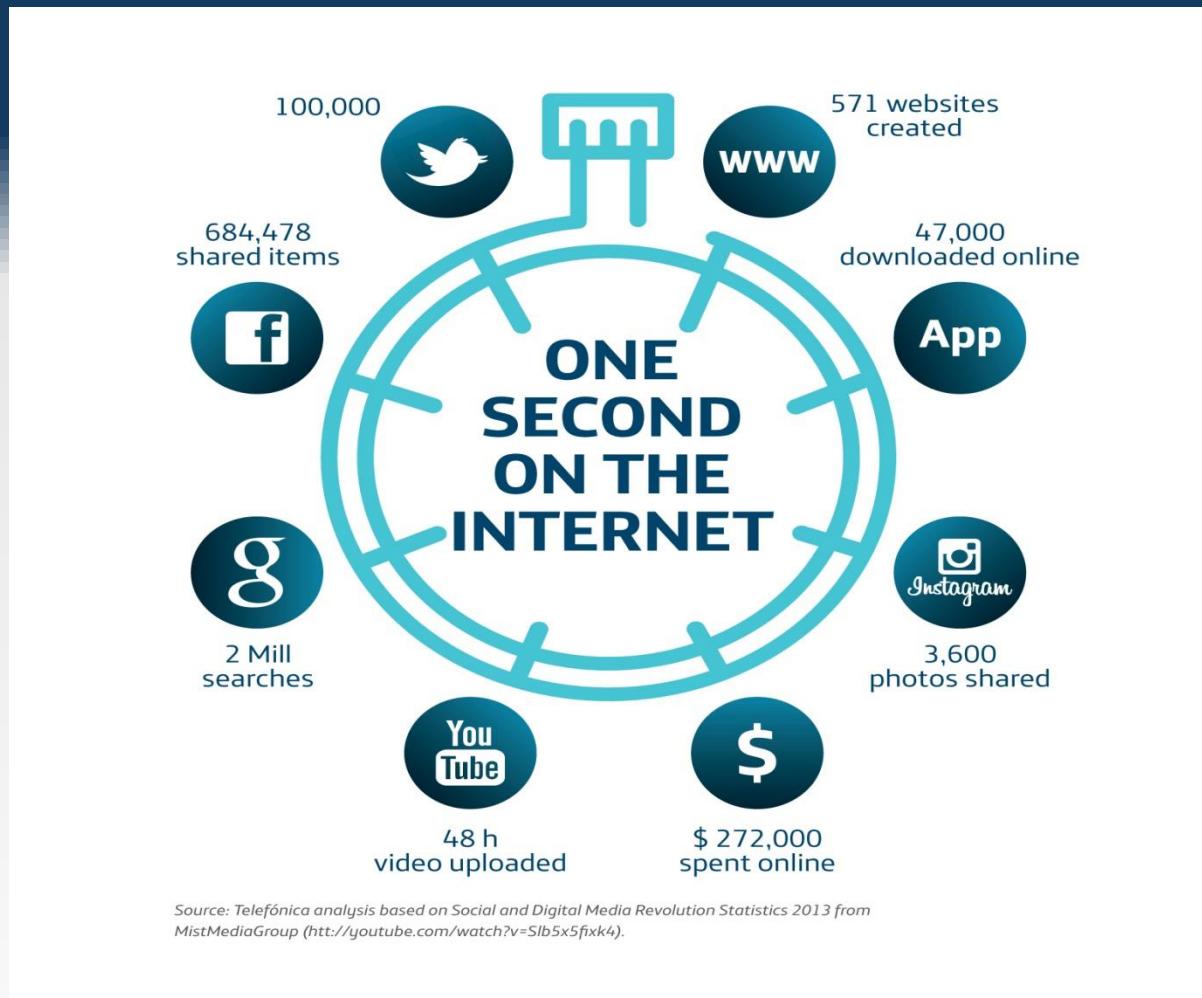


# The Vs of big data: Volume

- ❑ Data volume increases exponentially over time
  - ❑ 44x increase from 2009 to 2020
  - ❑ Digital data 35 ZB in 2020



# On the Internet...

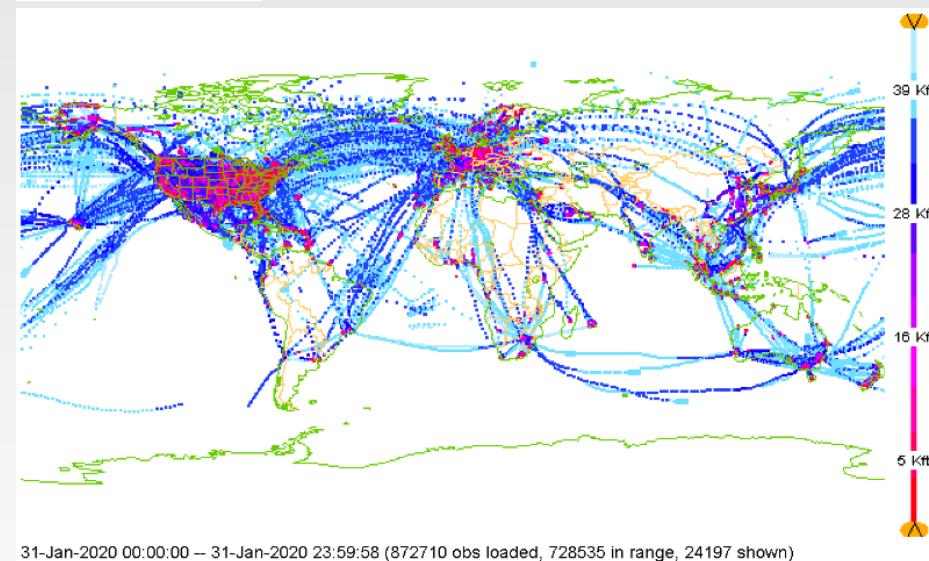


- <http://www.internetlivestats.com/>

# Weather forecast

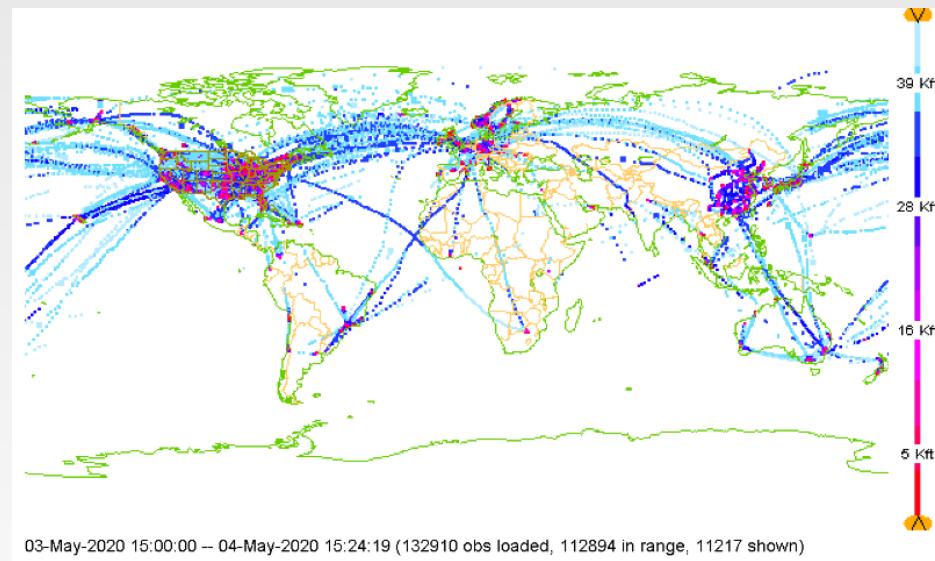


January 2020



31-Jan-2020 00:00:00 – 31-Jan-2020 23:59:58 (872710 obs loaded, 728535 in range, 24197 shown)

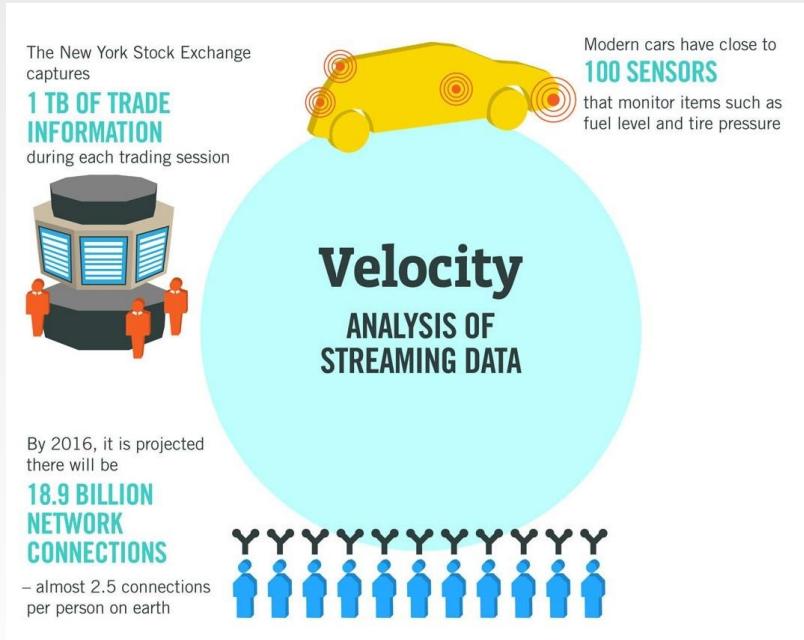
May 2020



03-May-2020 15:00:00 – 04-May-2020 15:24:19 (132910 obs loaded, 112894 in range, 11217 shown)

# The Vs of big data: Velocity

- Fast data generation rate
- Streaming data
- Very fast data processing to ensure timeliness



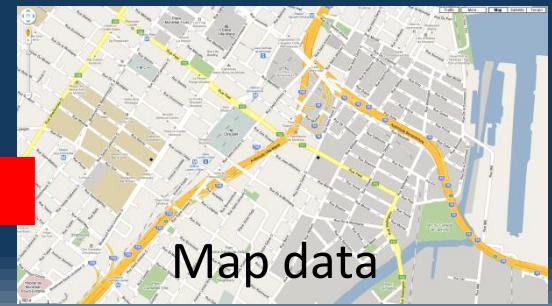
# (Near) Real time processing



Crowdsourcing



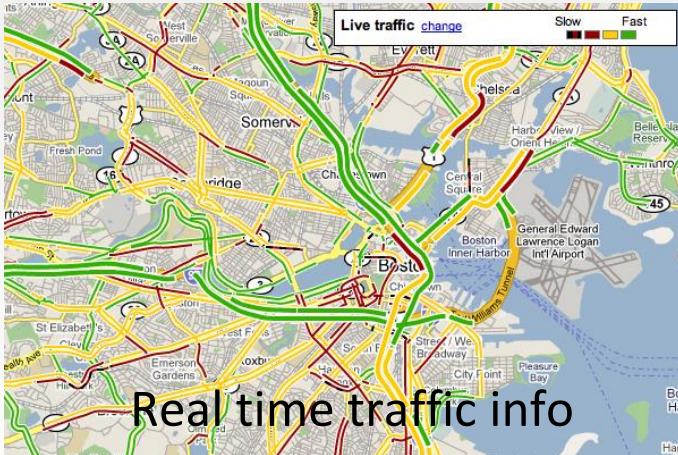
Computing



Map data



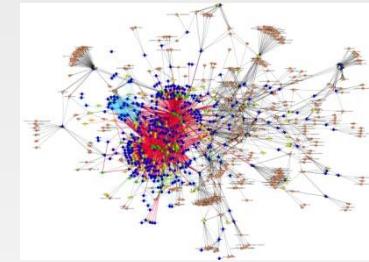
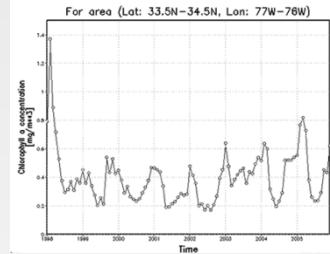
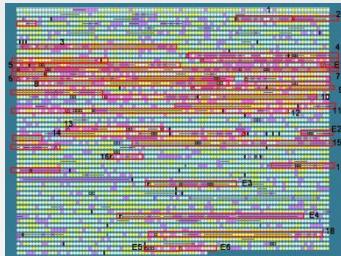
Sensing



Real time traffic info

# The Vs of big data: Variety

- ❑ Various formats, types and structures
- ❑ Numerical data, image data, audio, video, text, time series



- ❑ A single application may generate many different formats

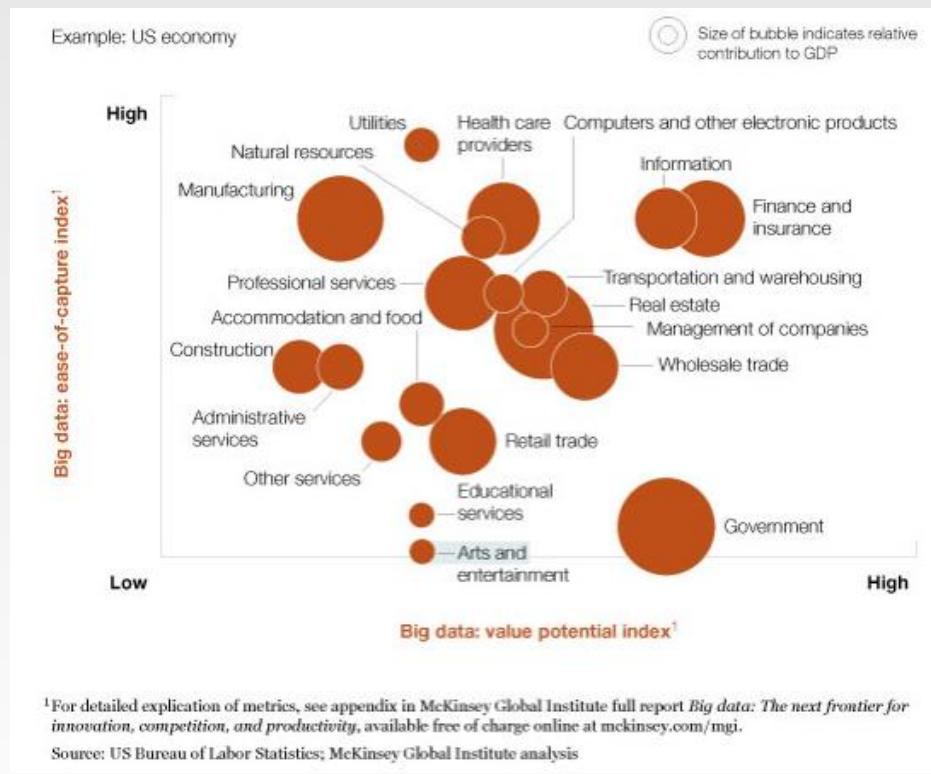
# The Vs of big data: Veracity

Data quality



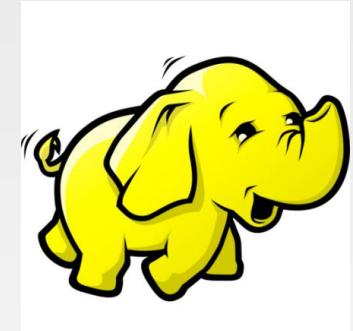
# The most important V: Value

- Translate data into business advantage



# Big data challenges

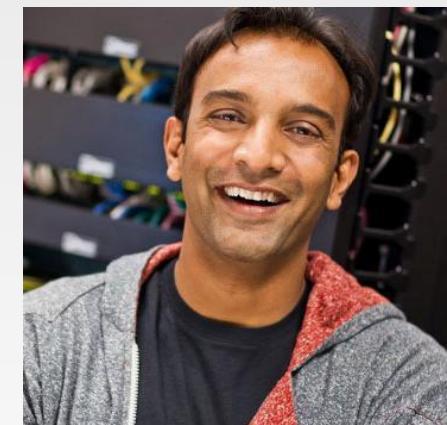
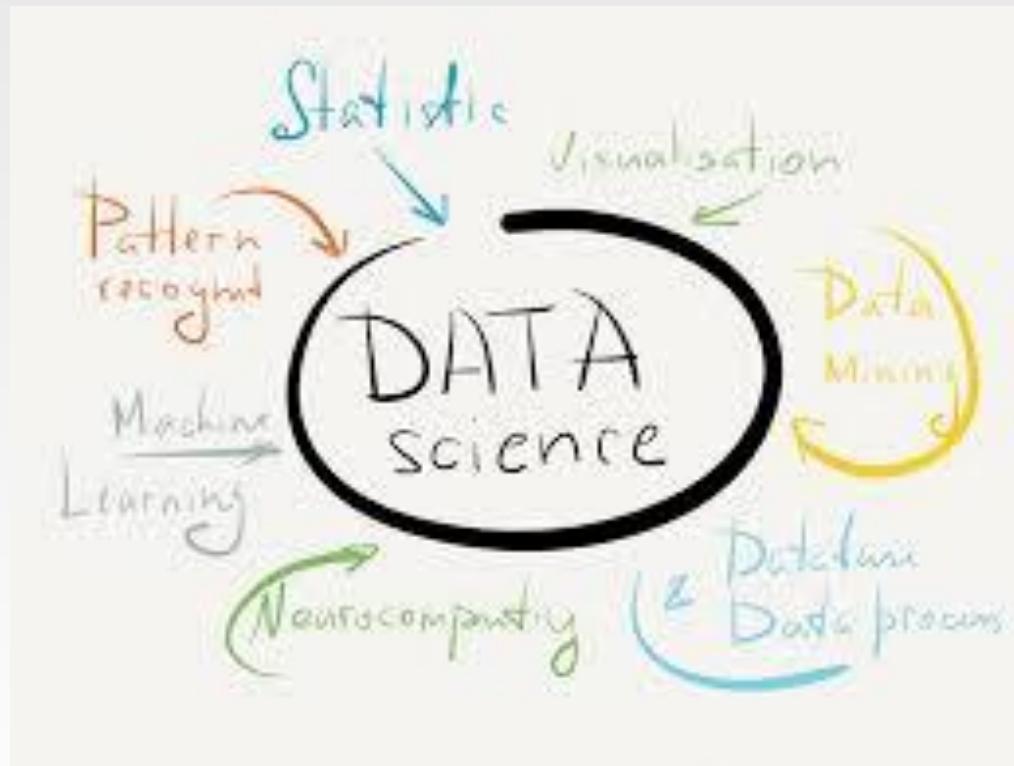
- ❑ Technology & infrastructure
  - ❑ New architectures, programming paradigms and techniques  
*Transfer the processing power to the data*
- ❑ Apache Hadoop/Spark ecosystem
- ❑ Data management & analysis
- ❑ New emphasis on “data”



→ ***Data science***

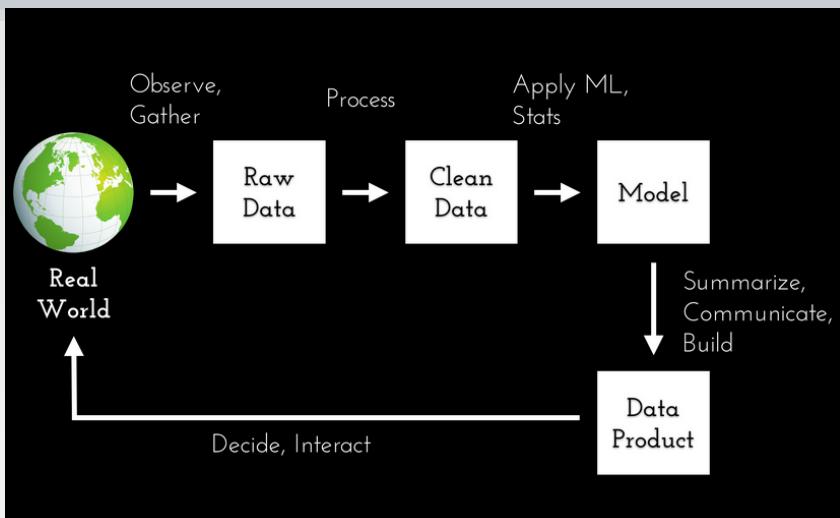
# Data science

“Extracting meaning from very large quantities of data”

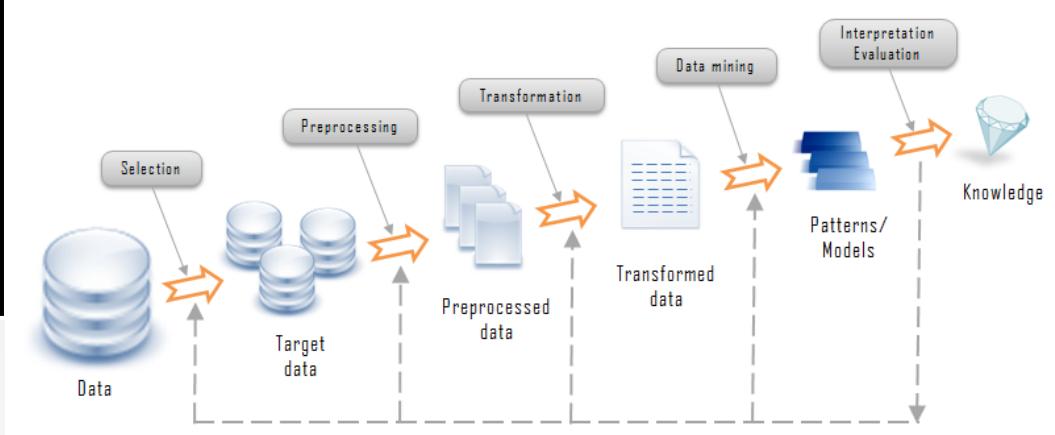


D.J. Patil coined the word *data scientist*

# The data science process



AKA *KDD* process  
Knowledge Discovery in Databases



Generation

Acquisition

Storage

Analysis

# Generation

- ❑ Passive recording
  - ❑ Typically structured data
  - ❑ Bank trading transactions, shopping records, government sector archives
- ❑ Active generation
  - ❑ Semistructured or unstructured data
  - ❑ User-generated content, e.g., social networks
- ❑ Automatic production
  - ❑ Location-aware, context-dependent, highly mobile data
  - ❑ Sensor-based Internet-enabled devices (IoT)



# Acquisition

## ❑ Collection

- ❑ Pull-based, e.g., web crawler
- ❑ Push-based, e.g., video surveillance, click stream

## ❑ Transmission

- ❑ Transfer to data center over high capacity links

## ❑ Preprocessing

- ❑ Integration, cleaning, redundancy elimination



# Storage

## ❑ Storage infrastructure

- ❑ Storage technology, e.g., HDD, SSD
- ❑ Networking architecture, e.g., DAS, NAS, SAN

## ❑ Data management

- ❑ File systems (HDFS), key-value stores (Memcached), column-oriented databases (Cassandra), document databases (MongoDB)

## ❑ Programming models

- ❑ Map reduce, stream processing, graph processing



# Analysis

## ❑ Objectives

- ❑ Descriptive analytics, predictive analytics, prescriptive analytics

## ❑ Methods

- ❑ Statistical analysis, machine learning and data mining, text mining, network and graph data mining

- ❑ Association analysis, classification and regression, clustering

## ❑ Diverse domains call for customized techniques



# Machine learning and data mining

❑ Non trivial extraction of

- ❑ implicit
- ❑ previously unknown
- ❑ potentially useful

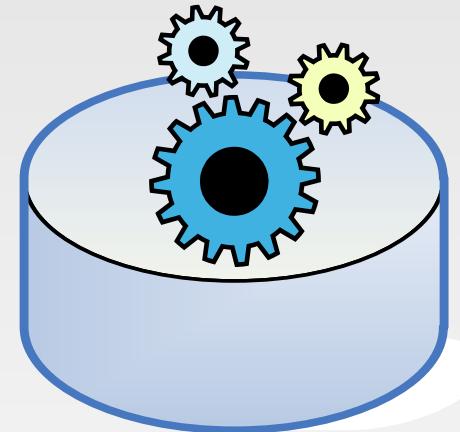
information from available data

❑ Extraction is automatic

- ❑ performed by appropriate algorithms

❑ Extracted information is represented by means of abstract models

- ❑ denoted as *pattern*



# Example: profiling

- ❑ Consumer behavior in e-commerce sites

- ❑ Selected products, requested information, ...



- ❑ Search engines and portals



- ❑ Query keywords, searched topics and objects

- ❑ Social network data

- ❑ Profiles (Facebook, Instagram, ...)



- ❑ Dynamic data: posts on blogs, FB, tweets



- ❑ Maps and georeferenced data

- ❑ Localization, interesting locations for users



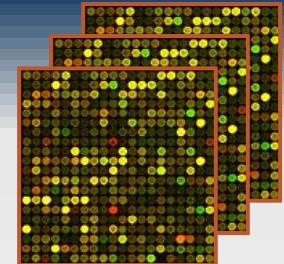
Google Maps

# Example: profiling

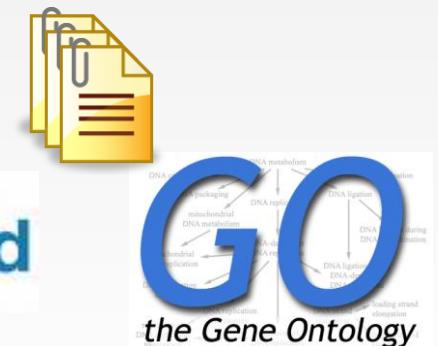
- ❑ User/service profiling
  - ❑ Recommendation systems, advertisements
- ❑ Market basket analysis
  - ❑ Correlated objects for cross selling
    - ❑ User registration, fidelity cards
- ❑ Context-aware data analysis
  - ❑ Integration of different dimensions
    - ❑ E.g., location, time of the day, user interest
- ❑ Text mining
  - ❑ Brand reputation, sentiment analysis, topic trends

# Example: biological data

- ❑ Microarray
  - ❑ expression level of genes in a cellular tissue
  - ❑ various types (mRNA, DNA)
- ❑ Patient clinical records
  - ❑ personal and demographic data
  - ❑ exam results
- ❑ Textual data in public collections
  - ❑ heterogeneous formats, different objectives
  - ❑ scientific literature (PUBMed)
  - ❑ ontologies (Gene Ontology)



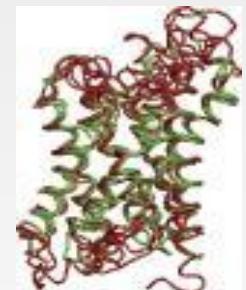
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IMAGE:74	ISG20    in	-1.02	-2.34	1.44	0.57	-0.13	0.12	0.34	-0.51
IMAGE:76	TNFSF13	-0.52	-4.06	-0.29	0.71	1.03	-0.67	0.22	-0.09
IMAGE:36	LOC93343	-0.25	-4.08	0.06	0.13	0.08	0.06	-0.08	-0.05
IMAGE:23	ITGA4    in	-1.375	-1.605	0.155	-0.015	0.035	-0.035	0.505	-0.865



# Biological analysis objectives

## □ Clinical analysis

- detecting the causes of a pathology
  - monitoring the effect of a therapy
- ⇒ diagnosis improvement and definition of new specific therapies

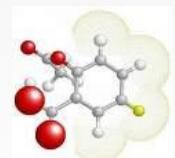


## □ Bio-discovery

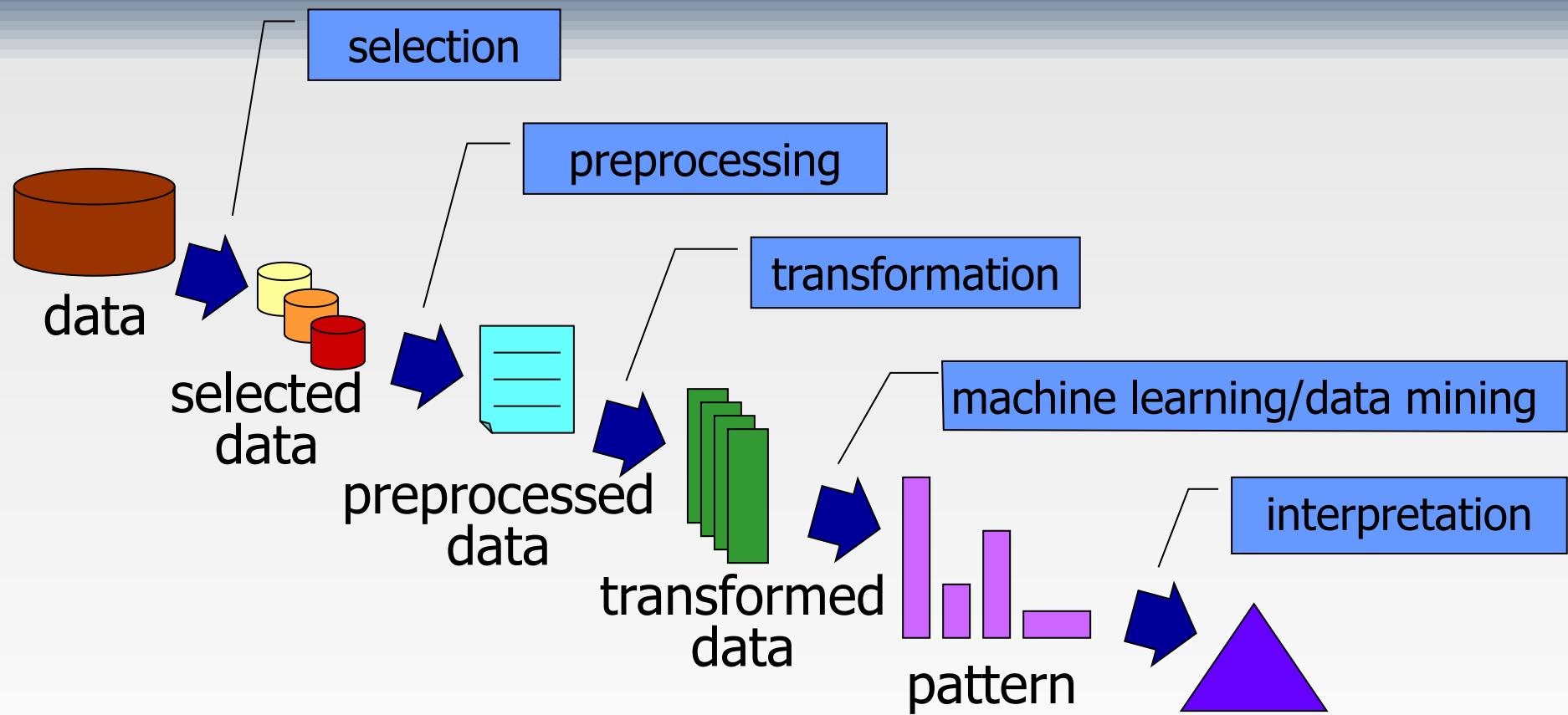
- gene network discovery
- analysis of multifactorial genetic pathologies

## □ Pharmacogenomics

- lab design of new drugs for genic therapies



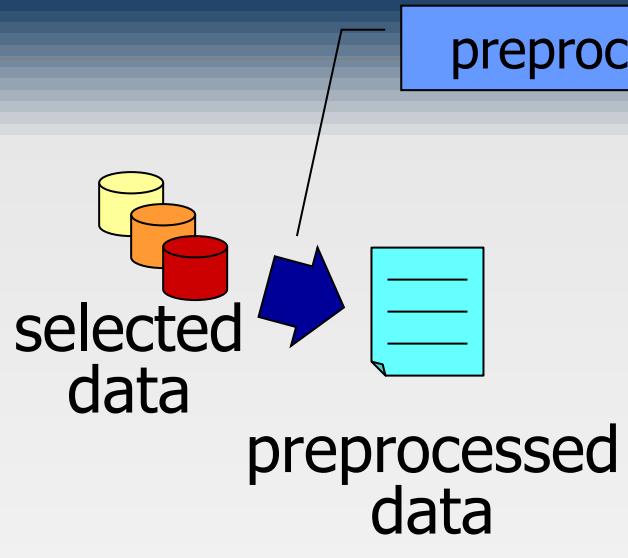
# Knowledge Discovery Process



KDD = Knowledge Discovery from Data

knowledge

# Preprocessing



## data cleaning

- reduces the effect of noise
- identifies or removes outliers
- solves inconsistencies

## data integration

- reconciles data extracted from different sources
- integrates metadata
- identifies and solves data value conflicts
- manages redundancy

Real world data is “dirty”

Without good quality data, no good quality pattern

# A word from practitioners

- ❑ At least 80-90% of their work involves not machine learning, but
  - ❑ Working with experts to understand the domain, assumptions, questions
  - ❑ Trying to catalog and make sense of the data sources
  - ❑ Wrangling, extracting, and integrating the data
  - ❑ Cleaning the wrangled data

# Association rules

## ❑ Objective

- ❑ extraction of frequent correlations or pattern from a transactional database

Tickets at a supermarket counter

TID	Items
1	Bread, Coke, Milk
2	Beer, Bread
3	Beer, Coke, Diapers, Milk
4	Beer, Bread, Diapers, Milk
5	Coke, Diapers, Milk
...	...



## ■ Association rule

$\text{diapers} \Rightarrow \text{beer}$

- 2% of transactions contains both items
- 30% of transactions containing diapers also contain beer

# Association rules



## Frequently Bought Together



Price For All Three: £9.00

Add all three to Basket

Show availability and delivery details

- This item: Paperback Oxford English Dictionary by Oxford Dictionaries Paperback £3.00
- Oxford Paperback Thesaurus by Oxford Dictionaries Paperback £3.00
- Oxford Essential French Dictionary by Oxford Dictionaries Paperback £3.00

## Jobs You May Be Interested In

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### Senior Data Analyst Job

Thomson Reuters - Bangalore, KA



### Data Scientist/ Senior Data Scientist

HeadHonchos.com - Bangalore - IN



### Hiring Computer Scientist (Java) for...

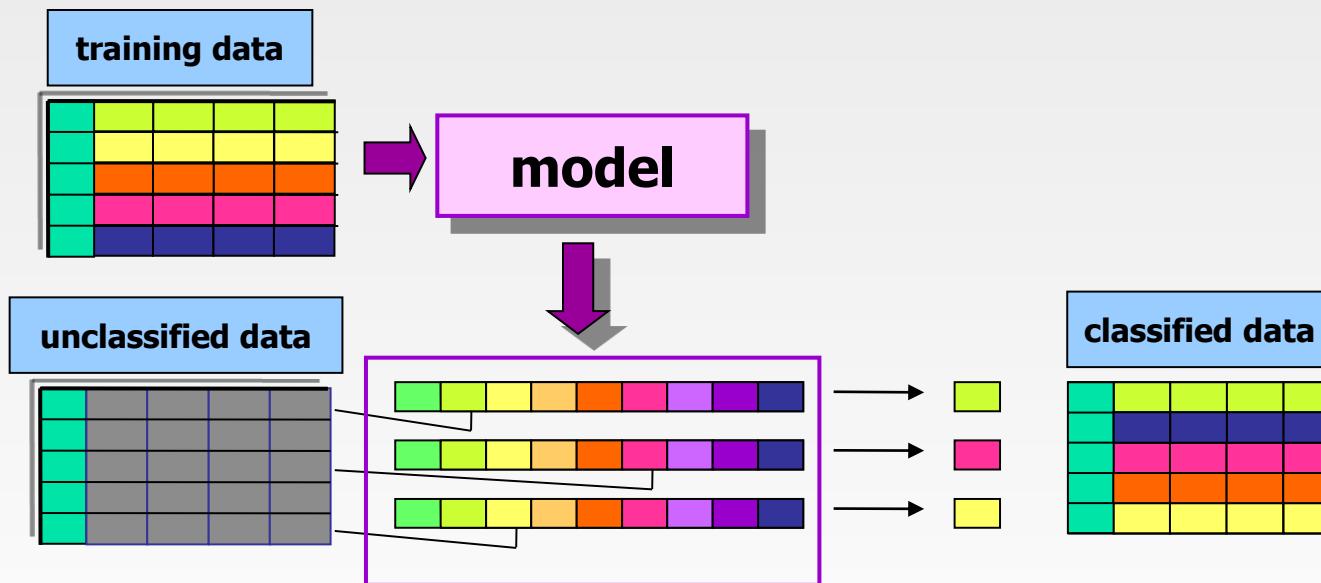
Adobe - Noida



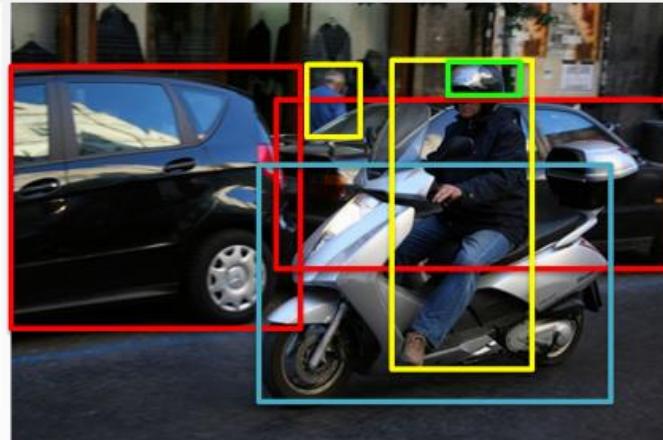
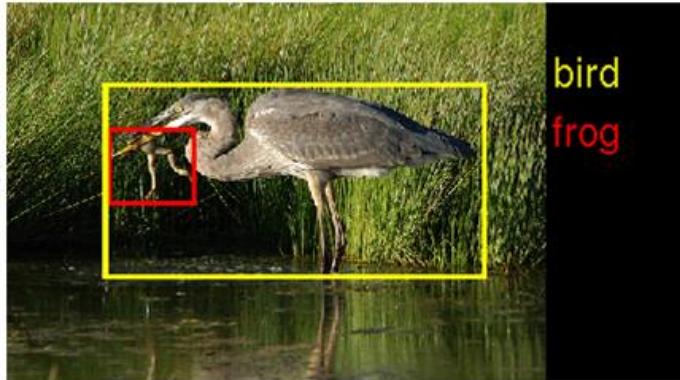
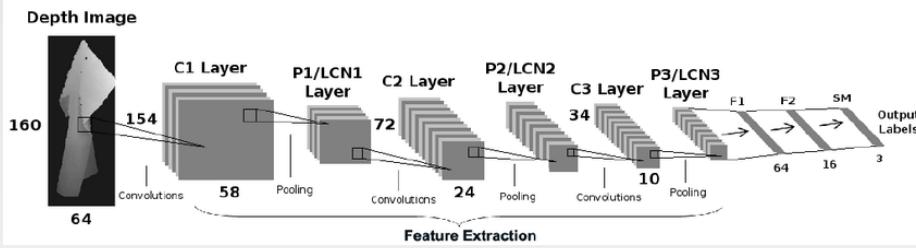
# Classification

## ❑ Objectives

- ❑ prediction of a class label
- ❑ definition of an interpretable model of a given phenomenon

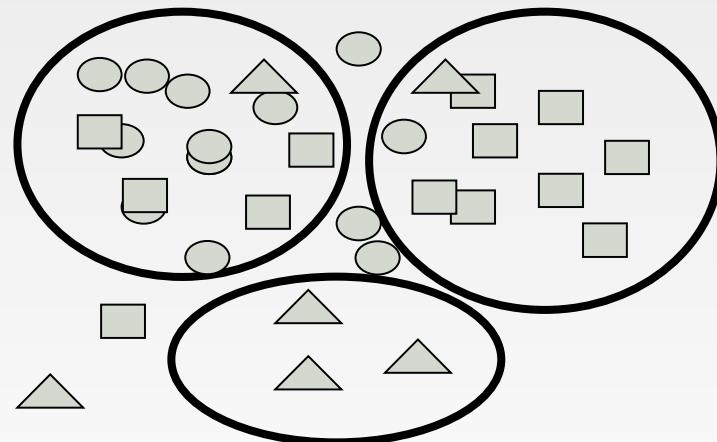


# Classification



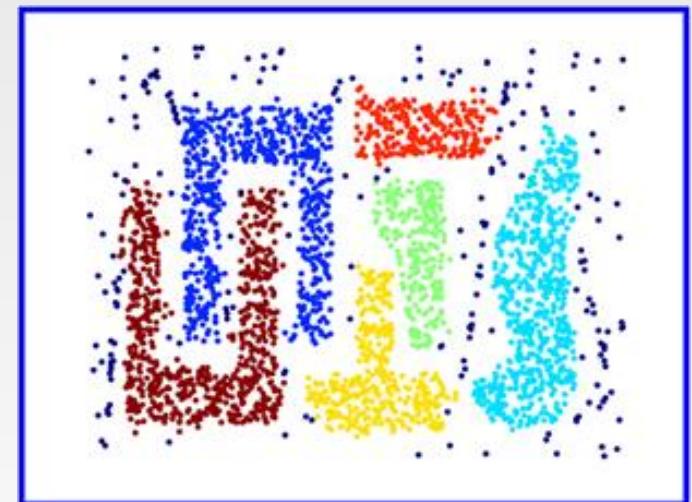
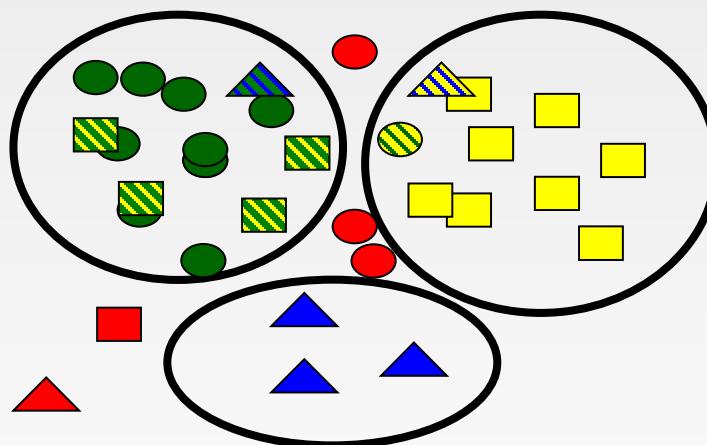
# Clustering

- ❑ Objectives
  - ❑ detecting groups of similar data objects
  - ❑ identifying exceptions and outliers

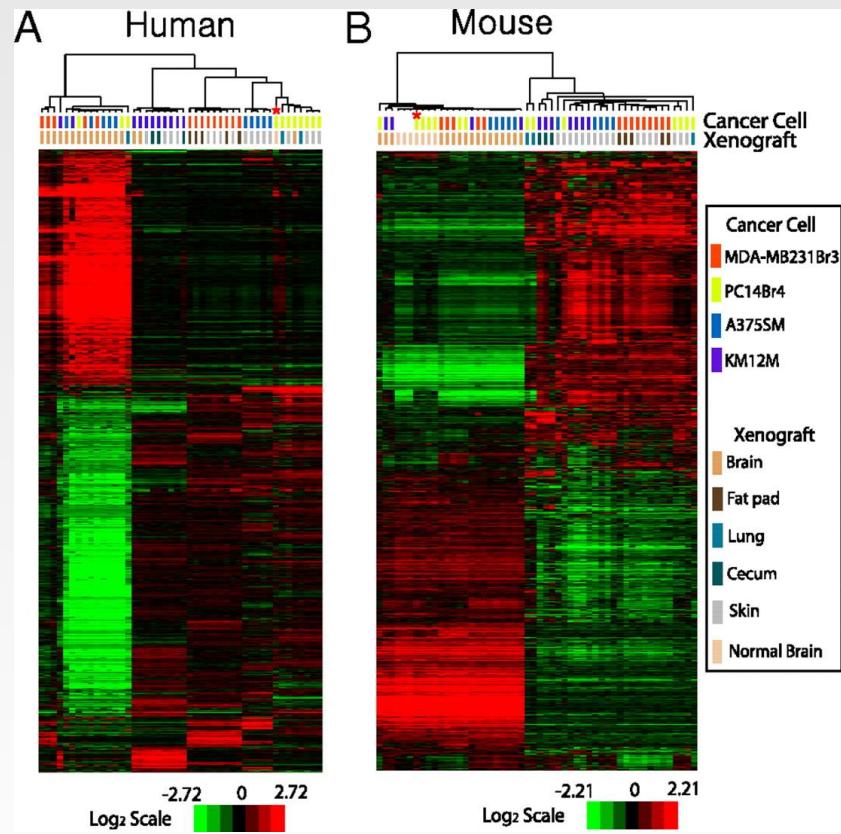
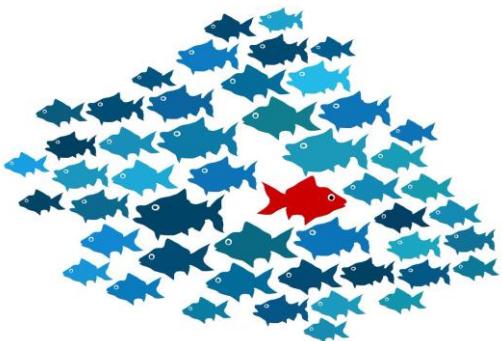


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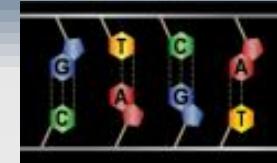
# Clustering



# Other data mining techniques

## □ Sequence mining

- ordering criteria on analyzed data are taken into account
- example: motif detection in proteins



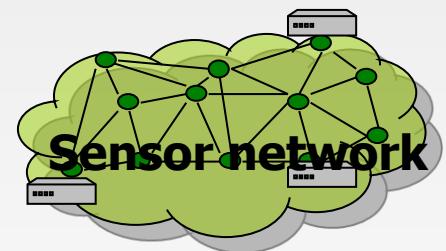
## □ Time series and geospatial data

- temporal and spatial information are considered
- example: sensor network data



## □ Regression

- prediction of a continuous value
- example: prediction of stock quotes



## □ Outlier detection

- example: intrusion detection in network traffic analysis



# The data science process

- ❑ What *question* are you answering?
- ❑ What is the right *scope* of the project?
- ❑ What *data* will you use?
- ❑ What *techniques* are you going to try?
- ❑ How will you *evaluate* your result?
- ❑ What *maintenance* will be required?

# The data science recipe

- ❑ Different ingredients needed
    - ❑ Data expert
      - ❑ Data processing, data structures
    - ❑ Data analyst
      - ❑ Data mining, statistics, machine learning
    - ❑ Visualization expert
      - ❑ Visual art design, storytelling skills
    - ❑ Domain expert
      - ❑ Provide understanding of the application domain
    - ❑ Business expert
      - ❑ Data driven decisions, new business models



**MODERN DATA SCIENTIST**

Data Scientist, the sexiest job of 21st century requires a mixture of multidisciplinary skills ranging from an intersection of mathematics, statistics, computer science, communication and business. Finding a data scientist is hard. Finding people who can do it well and data scientist is, especially hard. So here is a little cheat sheet on who the modern data scientist really is.

<b>MATH &amp; STATISTICS</b>	<b>PROGRAMMING &amp; DATABASE</b>
<ul style="list-style-type: none"> <li>★ Machine learning</li> <li>★ Statistical modeling</li> <li>★ Experiment design</li> <li>★ Bayesian inference</li> <li>★ Supervised learning: decision trees, random forests, logistic regression</li> <li>★ Unsupervised learning: clustering, dimensionality reduction</li> <li>★ Optimization: gradient descent and variants</li> </ul>	<ul style="list-style-type: none"> <li>★ Computer science fundamentals</li> <li>★ Scripting language e.g. Python</li> <li>★ Statistical computing package e.g. R</li> <li>★ Database SQL and NoSQL</li> <li>★ Relational algebra</li> <li>★ Parallel databases and parallel query processing</li> <li>★ MapReduce concepts</li> <li>★ Hadoop and Hive/Pig</li> <li>★ Custom reducers</li> <li>★ Experience with IaaS like AWS</li> </ul>
<b>DOMAIN KNOWLEDGE &amp; SOFT SKILLS</b>	<b>COMMUNICATION &amp; VISUALIZATION</b>
<ul style="list-style-type: none"> <li>★ Passionate about the business</li> <li>★ Curious about data</li> <li>★ Influence without authority</li> <li>★ Hacker mindset</li> <li>★ Problem solver</li> <li>★ Strategic, proactive, creative, innovative and collaborative</li> </ul>	<ul style="list-style-type: none"> <li>★ Able to engage with senior management</li> <li>★ Story telling skills</li> <li>★ Translate data-driven insights into decisions and actions</li> <li>★ Visual art of design</li> <li>★ R packages like ggplot or lattice</li> <li>★ Knowledge of any of visualization tools e.g. Flare, D3.js, Tableau</li> </ul>

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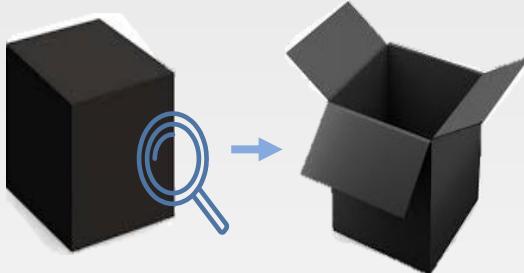
# Open issues

- ❑ Social impact of analysis is very important
- ❑ Interpretability and transparency of the analysis process
- ❑ Bias in algorithms and data
- ❑ Privacy preservation



# Interpretability in machine learning

*“The ability to explain or to present in understandable terms to a human”*



Open the black box



Trade-off Accuracy-Interpretability

- ❑ Model explanation: global understanding of how a model works
- ❑ Prediction explanation: local understanding of why a prediction is made
- ❑ Interpretable feature selection: incorporating interpretability-based criteria into the model design

# Interpretability

- ❑ Learned decision rule in pneumonia patients dataset from USA hospital  
*history of asthma → lower chance of dying from pneumonia*
- ❑ MD consider asthma as a serious risk factor for people who get pneumonia
- ❑ Analysis
  - ❑ asthmatics probably notice earlier the symptoms of pneumonia
  - ❑ a healthcare professional is going to provide earlier pneumonia diagnosis
  - ❑ as high-risk patients, they're going to get high-quality treatment sooner than other people
- ➡ asthmatics actually have almost half the chance of dying of non-asthmatics
- ❑ Using a neural network, this model issue would *never* have been uncovered

# Algorithmic and data bias

- ❑ Task: predict likelihood of an individual committing a future crime
    - ❑ Risk scores used by US criminal justice system
  - ❑ Scores computed from
    - ❑ Questions answered by the defendants
    - ❑ Information pulled by criminal records
  - ❑ Race was not among the questions
    - ❑ ... however other items may be correlated (e.g., poverty, joblessness)
  - ❑ Software product flagged black defendants as future criminals more frequently than white defendants
- ➡ Training data was biased by a larger black defendant population

# Privacy

**STRAVA LABS**

Projects Blog Developers Strava.com Careers

Global Heatmap

Heatmap Color

IRAQ

AFGHANISTAN

https://www.theguardian.com/world/2018/jan/28/fitness-tracking-app-gives-away-location-of-secret-us-army-bases

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## Fitness tracking app Strava gives away location of secret US army bases

Data about exercise routes shared online by soldiers can be used to pinpoint overseas facilities

Latest: Strava suggests military users 'opt out' of heatmap as row deepens

51 GMT

BBC Mark

News Sport Weather iPlayer TV Radio

## Strava released their global heatmap. 13 trillion GPS points from their users

Technology

### Fitness app Strava lights up staff at military bases

29 January 2018



The movements of soldiers within Bagram air base - the largest US military facility in Afghanistan

Security concerns have been raised after a fitness tracking firm showed the exercise routes of military personnel in bases around the world.

# Open issues

- ❑ Social impact of analysis is very important
  - ❑ Interpretability and transparency of the analysis process
  - ❑ Privacy preservation
- ❑ Many technical issues are not solved
  - ❑ Scalability to *huge* data volumes
  - ❑ Data dimensionality
  - ❑ Complex data structures, heterogeneous data formats
  - ❑ Data quality
  - ❑ Streaming data