DATA MINING INTRODUCTION

What is data mining?

Applications and techniques

“

Data is the new oil"

Clive Humby

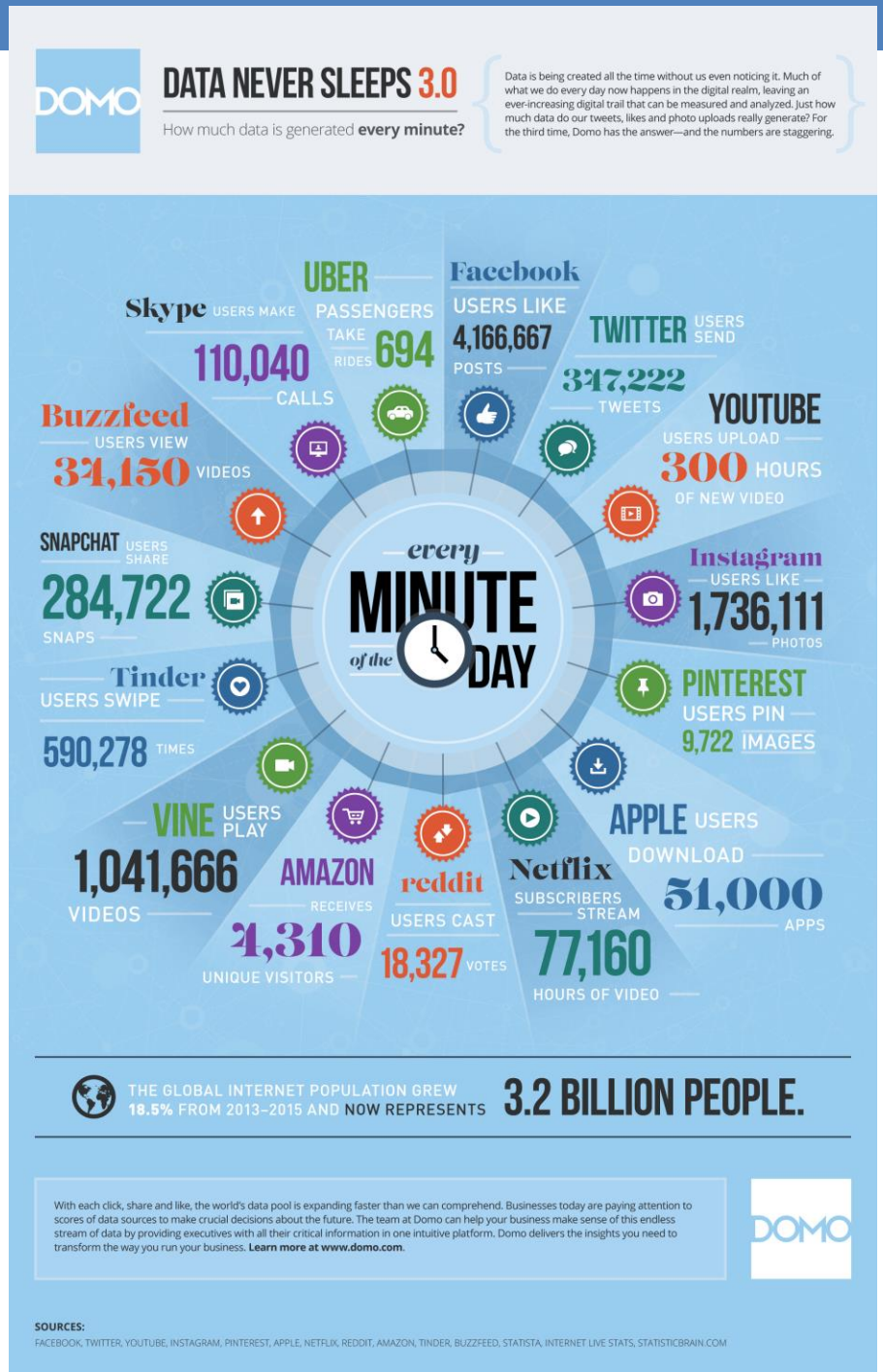
"Data is the new oil. It's valuable, but if unrefined it cannot really be used. It has to be changed into gas, plastic, chemicals, etc to create a valuable entity that drives profitable activity; so must data be broken down, analyzed for it to have value."

Data Mining

- In simple terms:

There is a lot of data

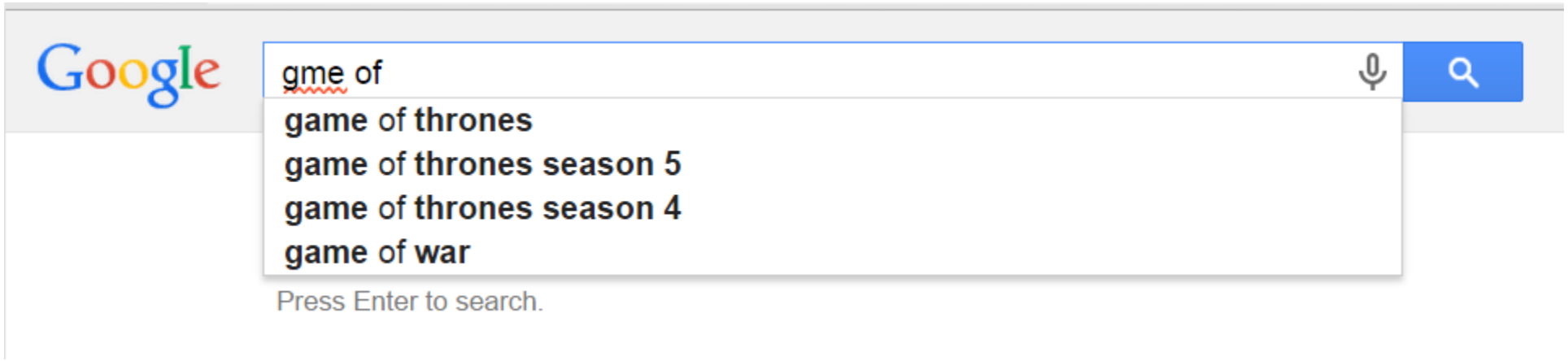
- Every human, physical, or machine activity generates data.
  - Transaction data in stores, credit cards
  - Scientific measurements
  - DNA sequences, gene coexpression
  - Health records, brain images, daily measurements
  - The Web, Wikipedia, Facebook posts, Tweets, Online Reviews
  - Queries to Google, Clicks, Browsing behavior, Ads
  - Facebook likes and comments, Twitter retweets
  - The Web graph, Facebook friends, Twitter followers
  - Movement data, Trajectories,
  - Mobile use, telephone calls
  - Wearable devices
  - Machine and workflow monitoring
- Everybody collects data!

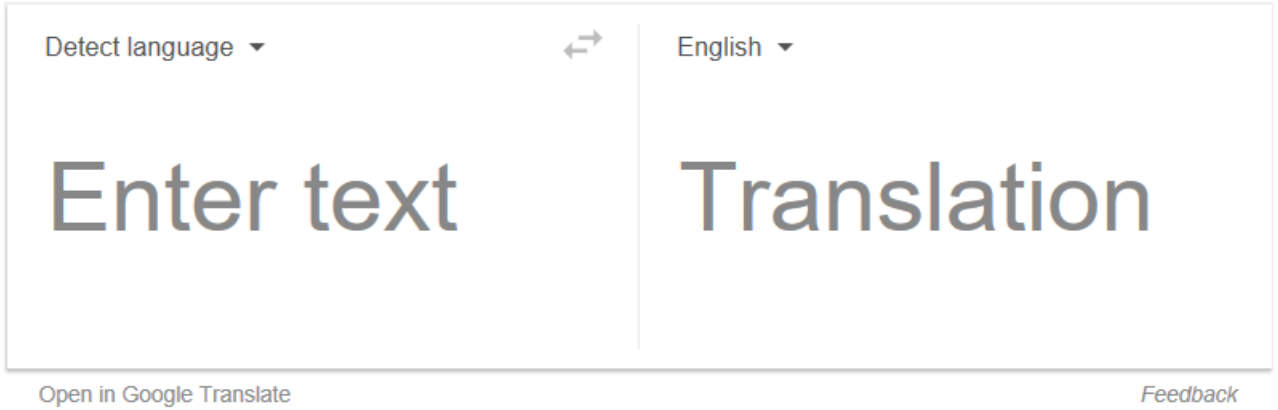


The data is complex and interconnected

- Multiple types of data: database tables, text, time series, images, videos, graphs, etc
- Spatial and temporal aspect
- 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, status updates in FB, images though cameras, queries to search engines

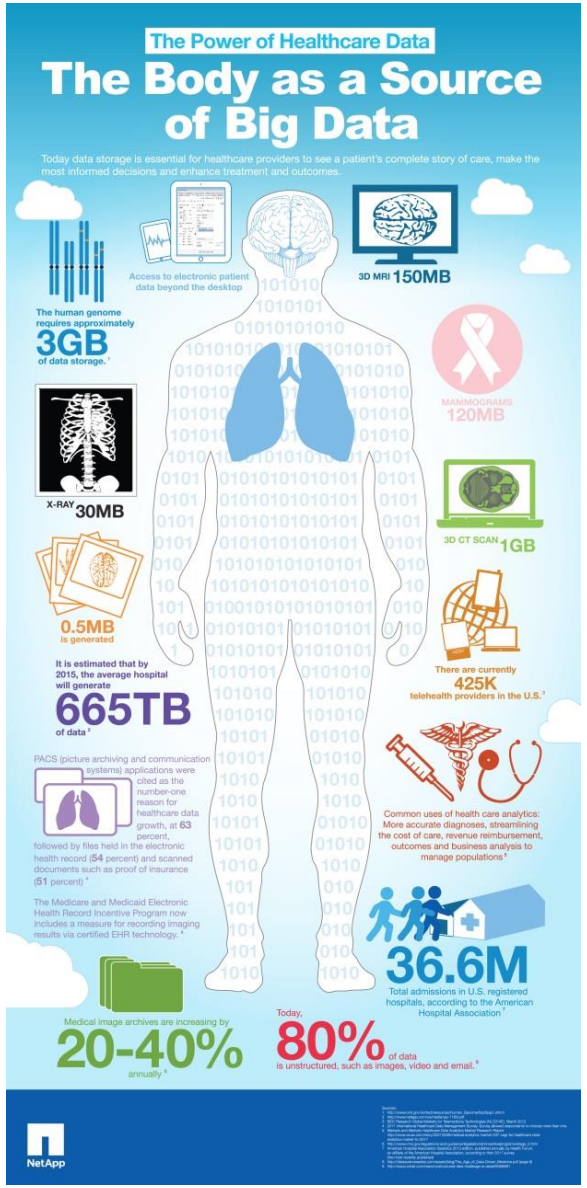
Data creates value





Natural language understanding is driven by data

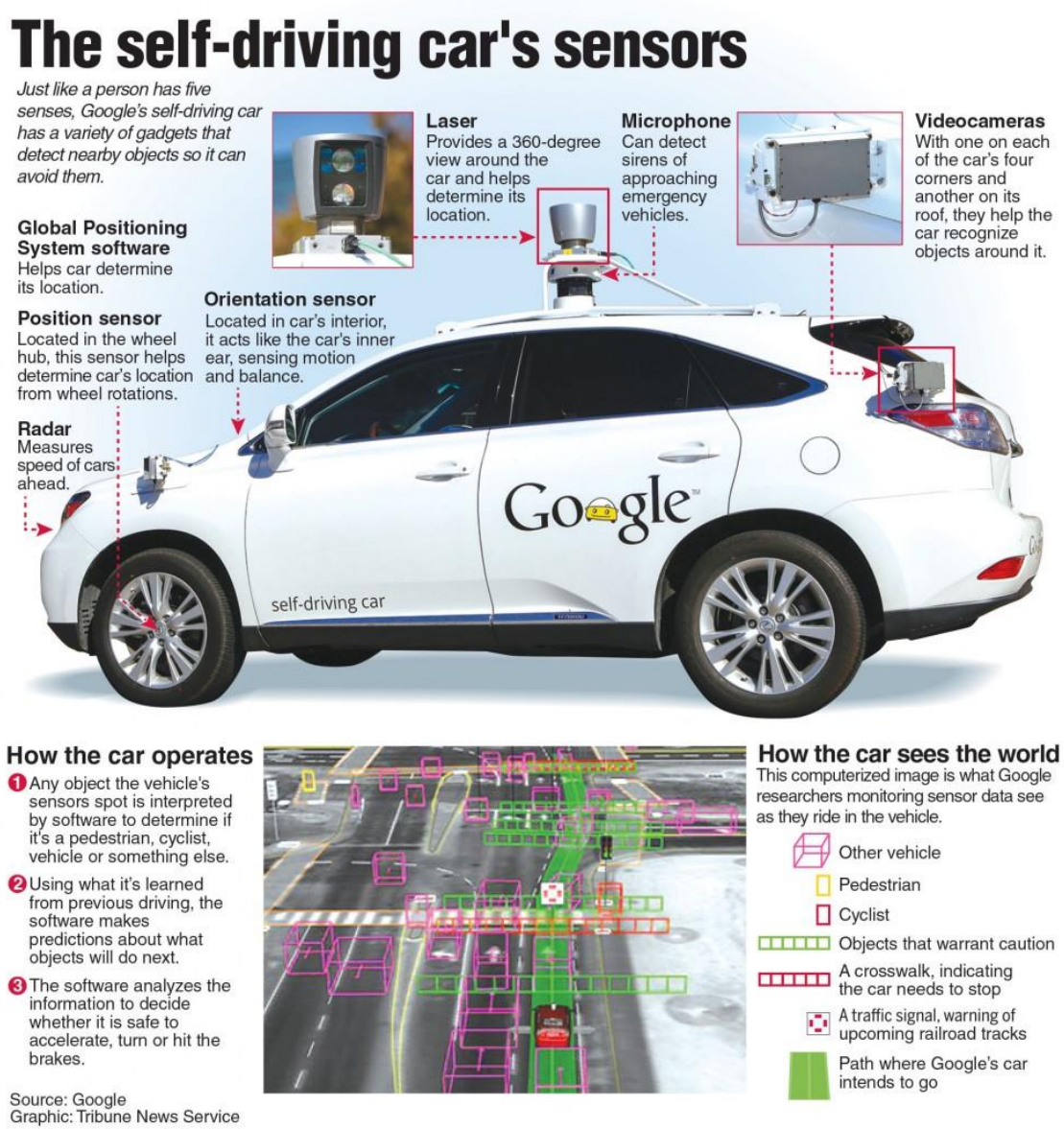
Data creates value



Precision/Personalized medicine:
Find the best treatment for patients using their genotype and all data that are related to them

Also: understanding drug side-effects through google queries

Data creates value



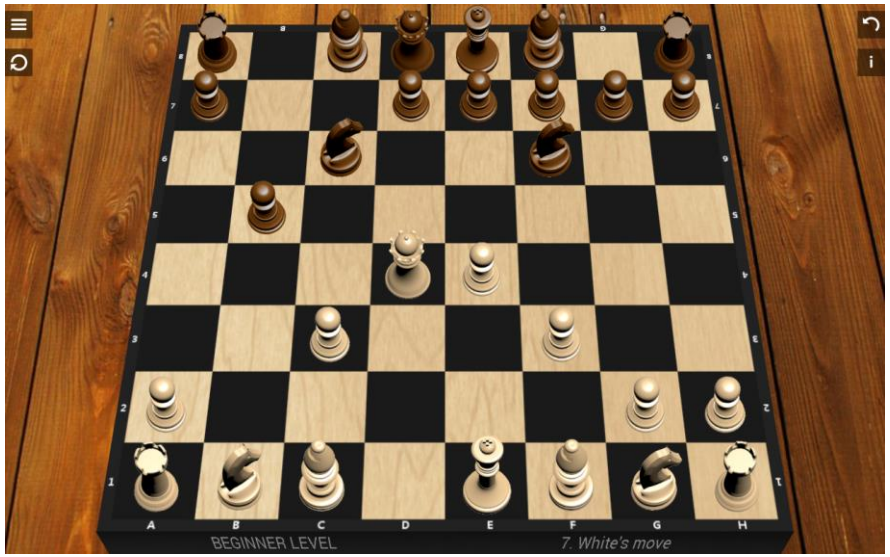
Self-Driving Cars:

Car is the next computer. A future of smart cars that can drive themselves and learn from data

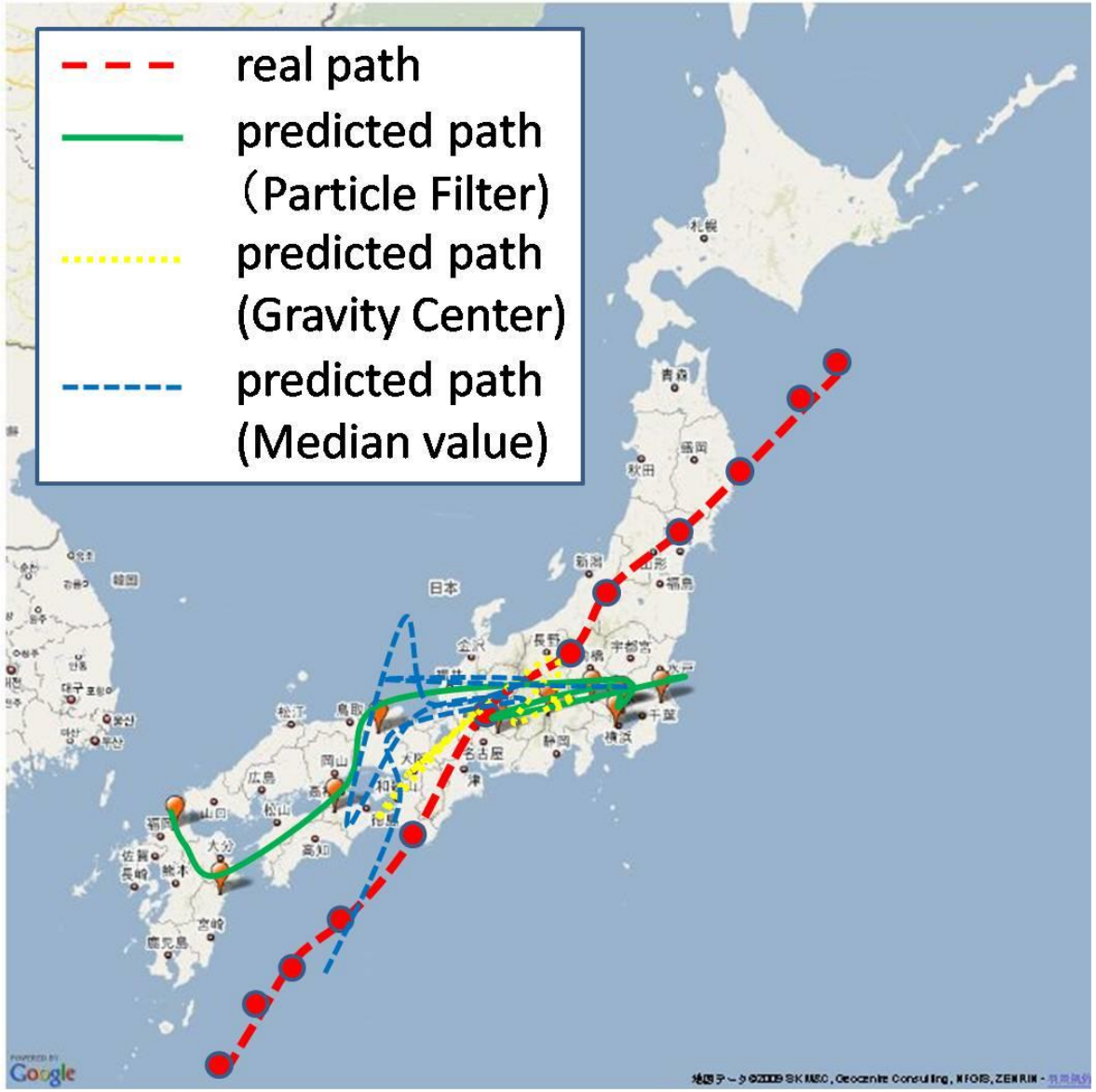
Also: smart cities – urban computing

Data creates value

Computers learn to play games by observing data



Data creates value



Use of data for crisis management

Data creates value

- All major soccer and basketball teams use data mining to make decisions.

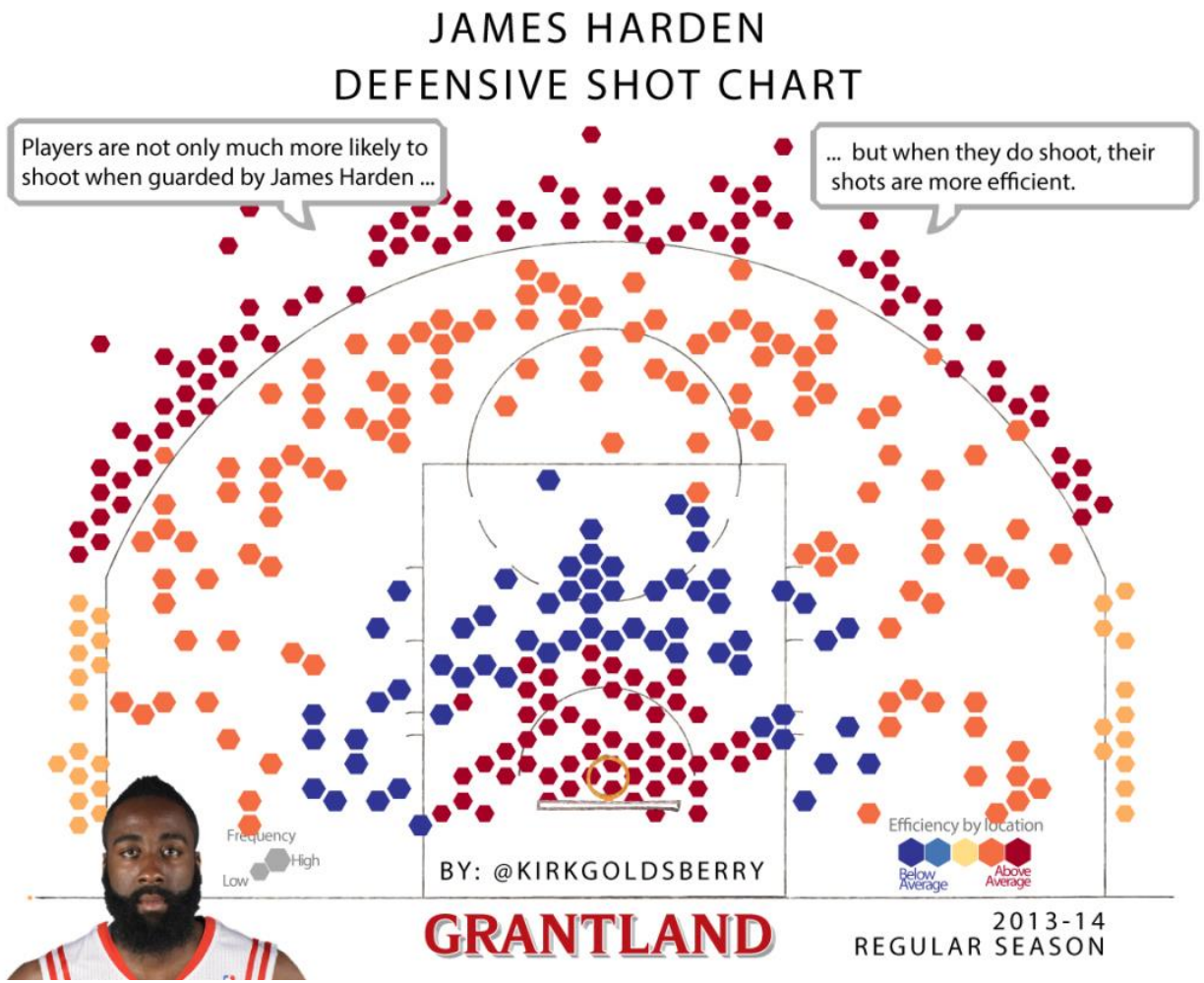
The national team of Germany had a special software for the analysis of video.

They concluded that the possession time per player should be reduced.

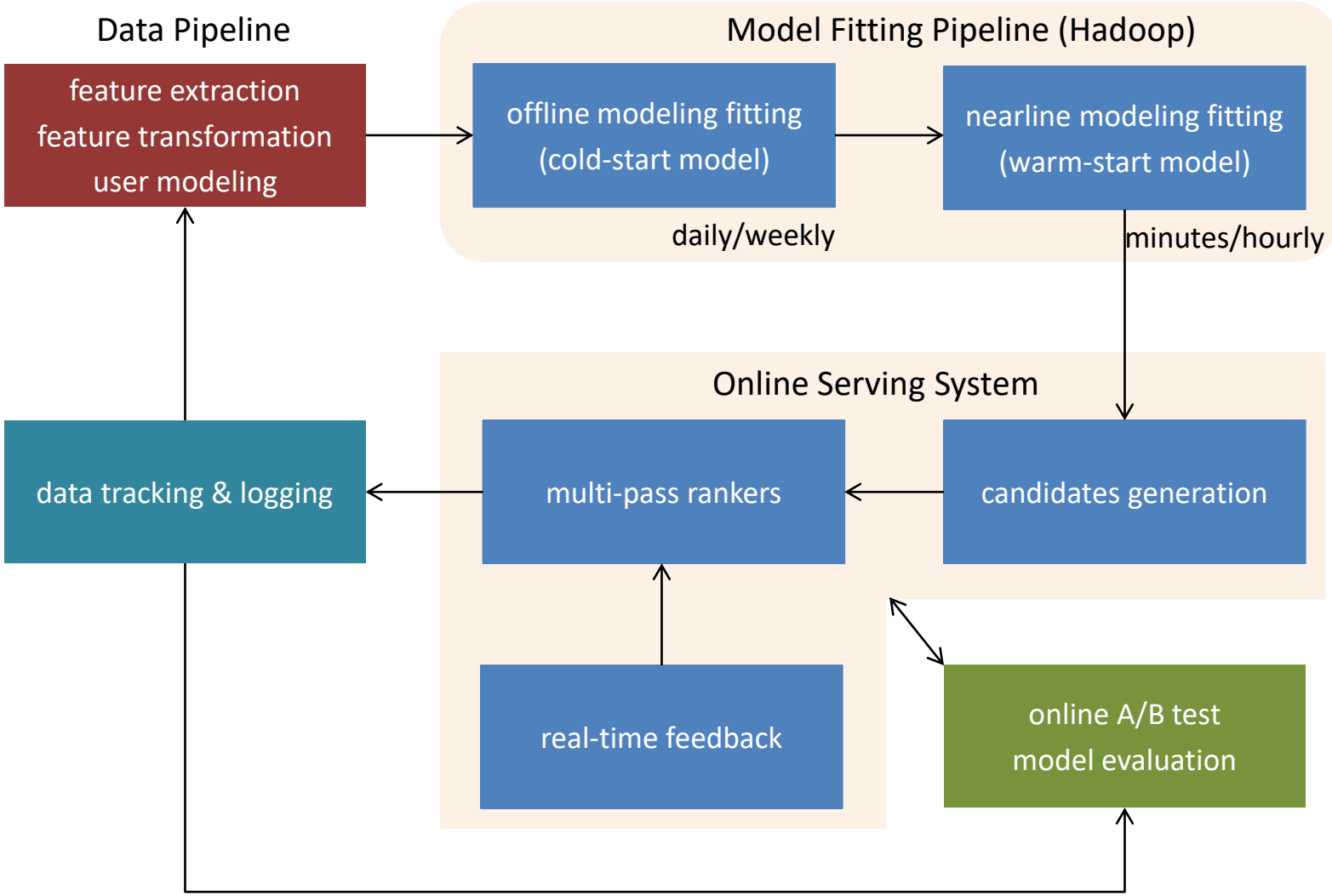
Germany won the 2014 word cup

Data creates value

James Harden defence



Putting it all together: The Data Mining Pipeline (LinkedIn)



Data Mining Example

- Suppose that you were creating the Greek Facebook.
- What kind of data would you collect and store?

Posts, content of posts

Social network contacts

Interactions with feed: Clicks, Likes, Comments, Shares

Interaction with contacts: messages, likes, replies, shares

Photos

Videos uploaded videos consumed

Demographics: Age, City, etc

Ads seen, ads clicked

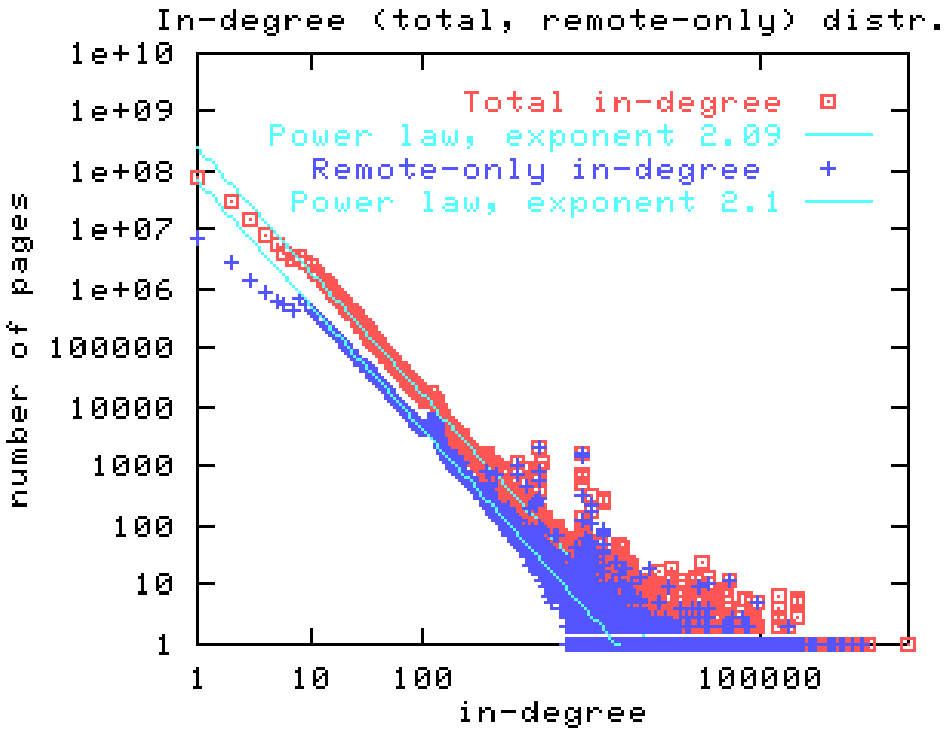
Products bought

and many more!

What would you do with this data?

Exploratory Analysis

- Make measurements to understand what the data looks like
- Example: Posts
  - How often do users posts, how many posts per user, when do they post, is there a correlation between number of posts and number of friends, etc
- This is one of the first steps when collecting data.
  - Metrics: Deciding what to measure is important
- The example of the Web graph



Exploiting similarities

- Consider the following data for six users:
  - Number of times they have clicked on posts from these pages

	NBA	ESPN	Sports.com	MSNBC	NY Times	Wall Street	Politico
A	100	50	73	10	1	1	4
B	500	200	400	20	10	4	1
C	80	100	60	1	3	1	1
D	4	2	1	12	90	100	80
E	9	3	4	9	100	80	70
F	3	4	5	30	300	200	500

- What conclusion can we draw?

Exploiting similarities

- Two types of users and two types of pages
  - Sports and politics

	NBA	ESPN	Sports.com	MSNBC	NY Times	Wall Street	Politico
A	100	50	73	10	1	1	4
B	500	200	400	20	10	4	1
C	80	100	60	1	3	1	1
D	4	2	1	12	90	100	80
E	9	3	4	9	100	80	70
F	3	4	5	30	300	200	500

- Questions:
  - How do we compute similarity?
  - How do we group similar users? Clustering

Exploiting similarities

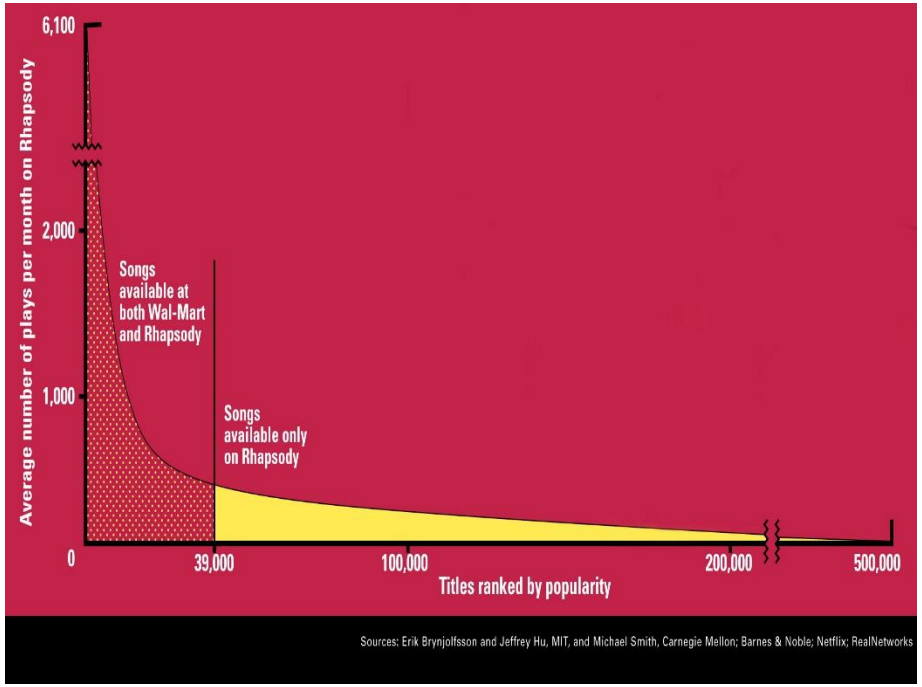
- What if we were missing this entry?

	NBA	ESPN	Sports.com	MSNBC	NY Times	Wall Street	Politico
A	100	50	73	10	1	1	4
B	500	200	400	20	10	4	1
C	80	100	???	1	3	1	1
D	4	2	1	12	90	100	80
E	9	3	4	9	100	80	70
F	3	4	5	30	300	200	500

- Can we fill this value?
- Similar users like items similarly: Recommendation systems

Amazon Recommendations

- “People who have bought this also bought…”



- A huge breakthrough for amazon
  - Took advantage of the long tail
- A big breakthrough for data mining in general

Making predictions

- Filling the missing value can also be viewed as a prediction task
- Types of prediction tasks:
  - Predicting a real value (e.g. number of clicks): Regression
  - Predicting a YES/NO value (e.g., will the user click?): Binary classification
  - Predicting over multiple classes (e.g., what is the topic of a post): Classification
- Can you think of prediction/classification tasks for your social network?

Predict if a post is offensive

Ad click prediction

Like prediction

Predict if a photo contains nudity

Ad clickthrough prediction

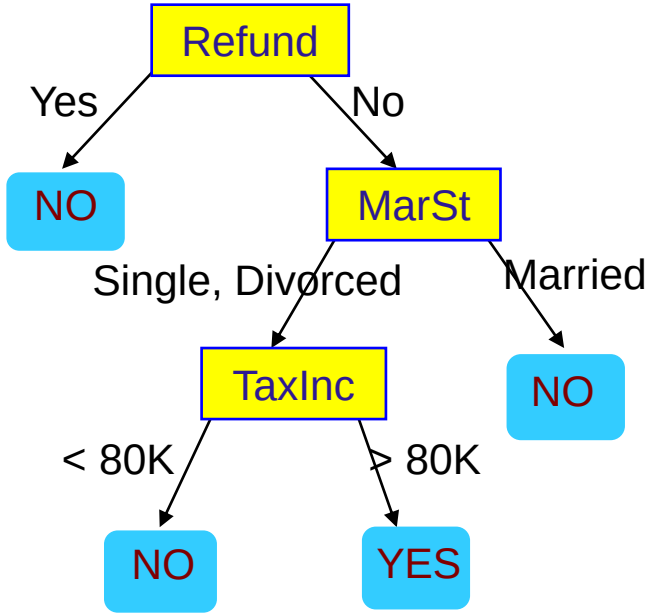
Predict if a user will like a post over another: Learning to rank

Classification

- Classification process:
  - Find features that describe an entity.
  - Use examples of the classes you want to predict.
  - Learn a model (function) that predicts

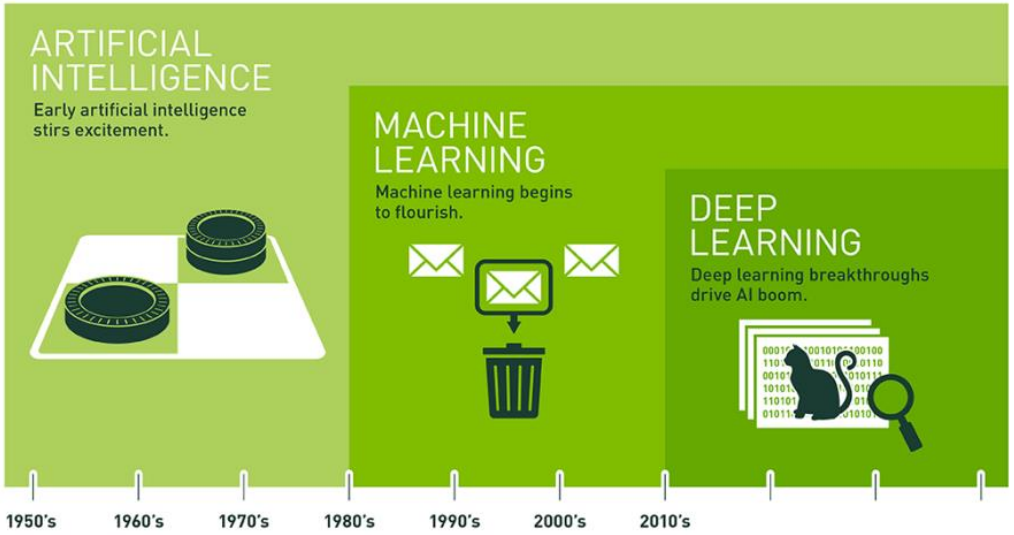
- Classification is the engine behind the AI revolution
  - Used in all systems that make decisions
  - Became very powerful with Deep Learning
  - Huge applications in vision

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



Deep learning

- Machine learning systems that use neural networks with multiple layers and are trained on very large quantities of data
  - Able to learn complex representations and powerful models.
  - Applications in recommendations, network analysis, text analysis, image recognition, car driving, playing games…
  - Require less feature engineering



Since an early flush of optimism in the 1950s, smaller subsets of artificial intelligence – first machine learning, then deep learning, a subset of machine learning – have created ever larger disruptions.

Generative AI

- Machine learning tools that generate realistic text or images
  - ChatGPT
  - DALL·E 2, Midjourney

- Trained on massive amounts of data to predict missing words, or the next frame in a video

The social graph

- Your Greek Facebook also has a social graph. What can you do with this data?

Who is important and influential in the graph?

What is the shortest path between two nodes?

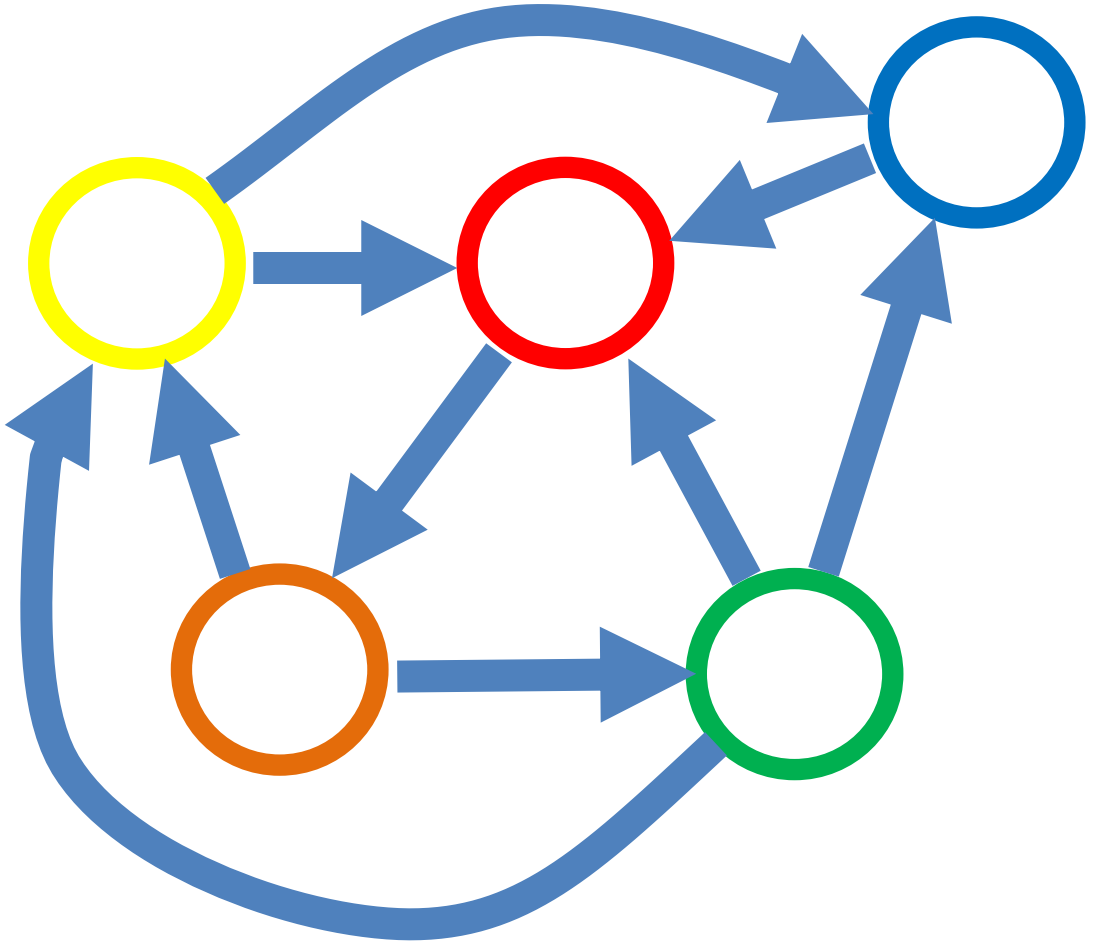
How does information spread in the network?

What becomes viral?

Will two users become friends in the future?

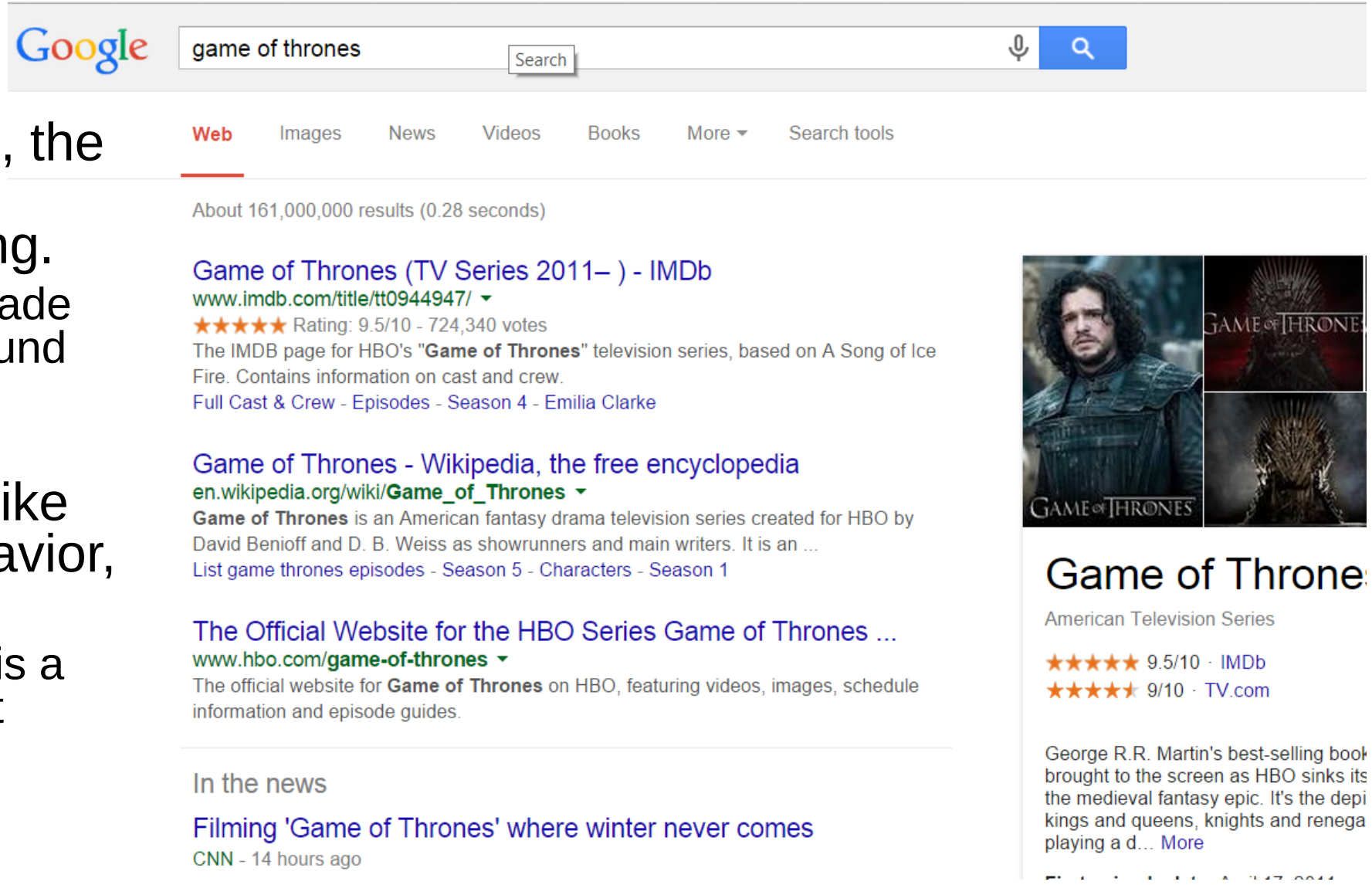
Node importance

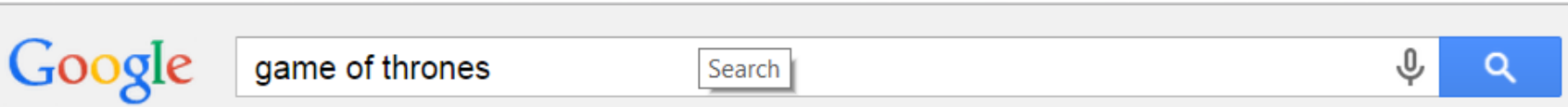
- What is the most important node in this graph?
- The PageRank algorithm: A node is important is it is pointed to by other important nodes



The Web as a graph

- When ranking pages, the authoritativeness is factored in the ranking.
  - This is the idea that made Google a success around 2000
- Today a lot more information is used, like clicks, browsing behavior, etc
  - Ranking of the pages is a very complex task that requires sophisticated techniques





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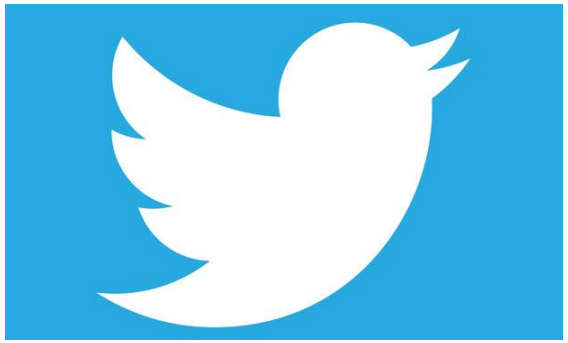
Friendship suggestions

- LinkedIn, Twitter, Facebook friendship suggestions
  - Useful for the users to discover their friends, but also useful for the network in order to grow, and increase engagement
    - LinkedIn success story



- Triadic closure principle: Links are created in a way that usually closes a triangle
  - If both Bob and Charlie know Alice, then they are likely to meet at some point.

What is Data Mining again?

- “Data mining is the analysis of (often large) observational data sets to find unsuspected relationships and to summarize the data in novel ways that are both understandable and useful to the data analyst” (Hand, Mannila, Smyth)

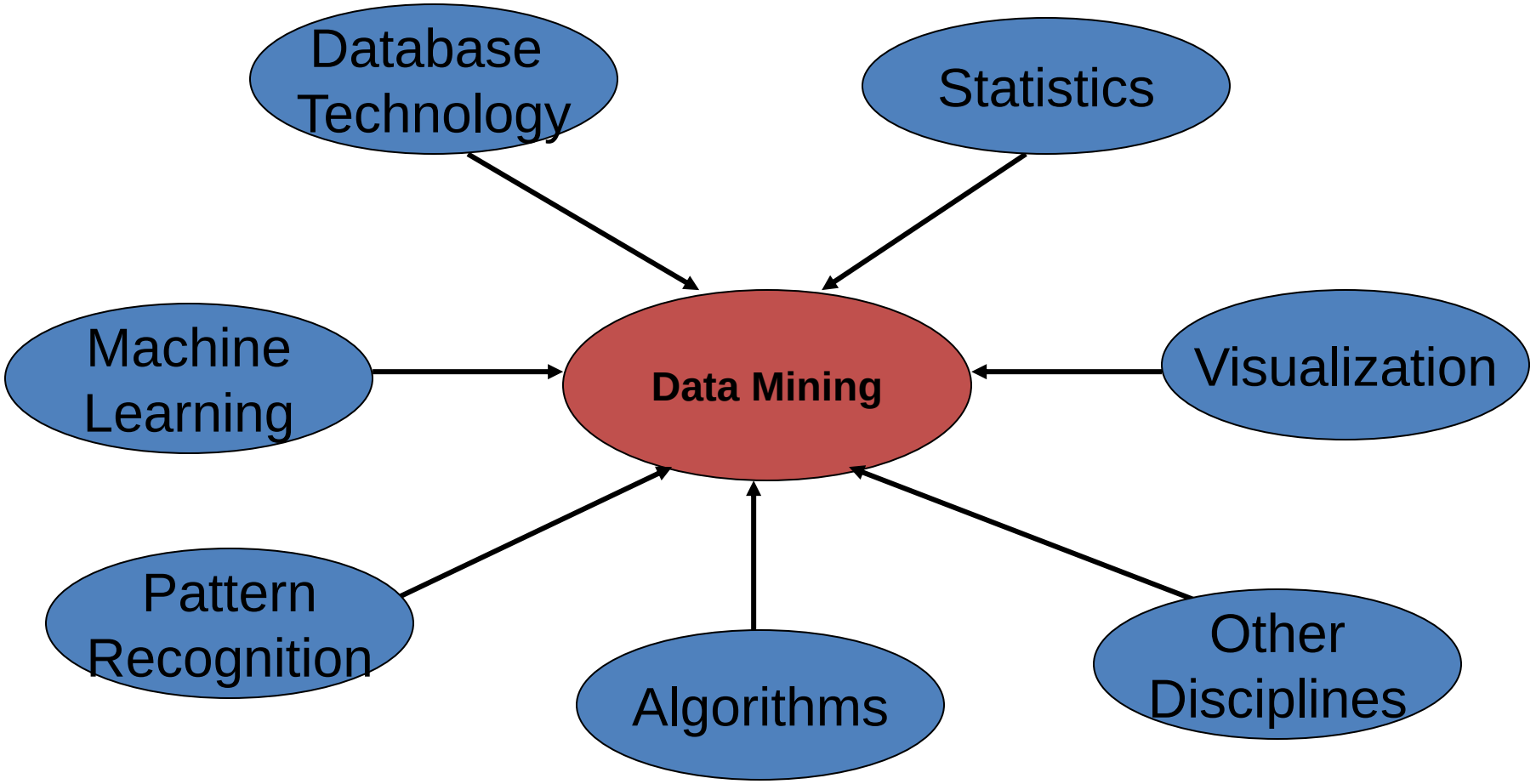
- “Data mining is the discovery of models for data” (Rajaraman, Ullman)
  - We can have the following types of models
    - Models that explain the data (e.g., a single function)
    - Models that predict the future data instances.
    - Models that summarize the data
    - Models the extract the most prominent features of the data.

- “Data Mining is the study of collecting, processing, analyzing, and gaining useful insights from data” – Charu Aggarwal

Why data mining?

- Scientific point of view
  - Scientists are at an unprecedented position where they can collect TB of information
    - Examples: Sensor data, astronomy data, social network data, gene data
  - We need the tools to analyze such data to get a better understanding of the world and advance science and help people
- Commercial point of view
  - Data has become the key competitive advantage of companies
    - Examples: Facebook, Google, Amazon
  - Being able to extract useful information out of the data is key for exploiting them commercially.
- Scale (in data size and feature dimension)
  - Why not use traditional analytic methods?
  - Enormity of data, curse of dimensionality
  - The amount and the complexity of data does not allow for manual processing of the data. We need automated techniques.

Data Mining: Confluence of Multiple Disciplines



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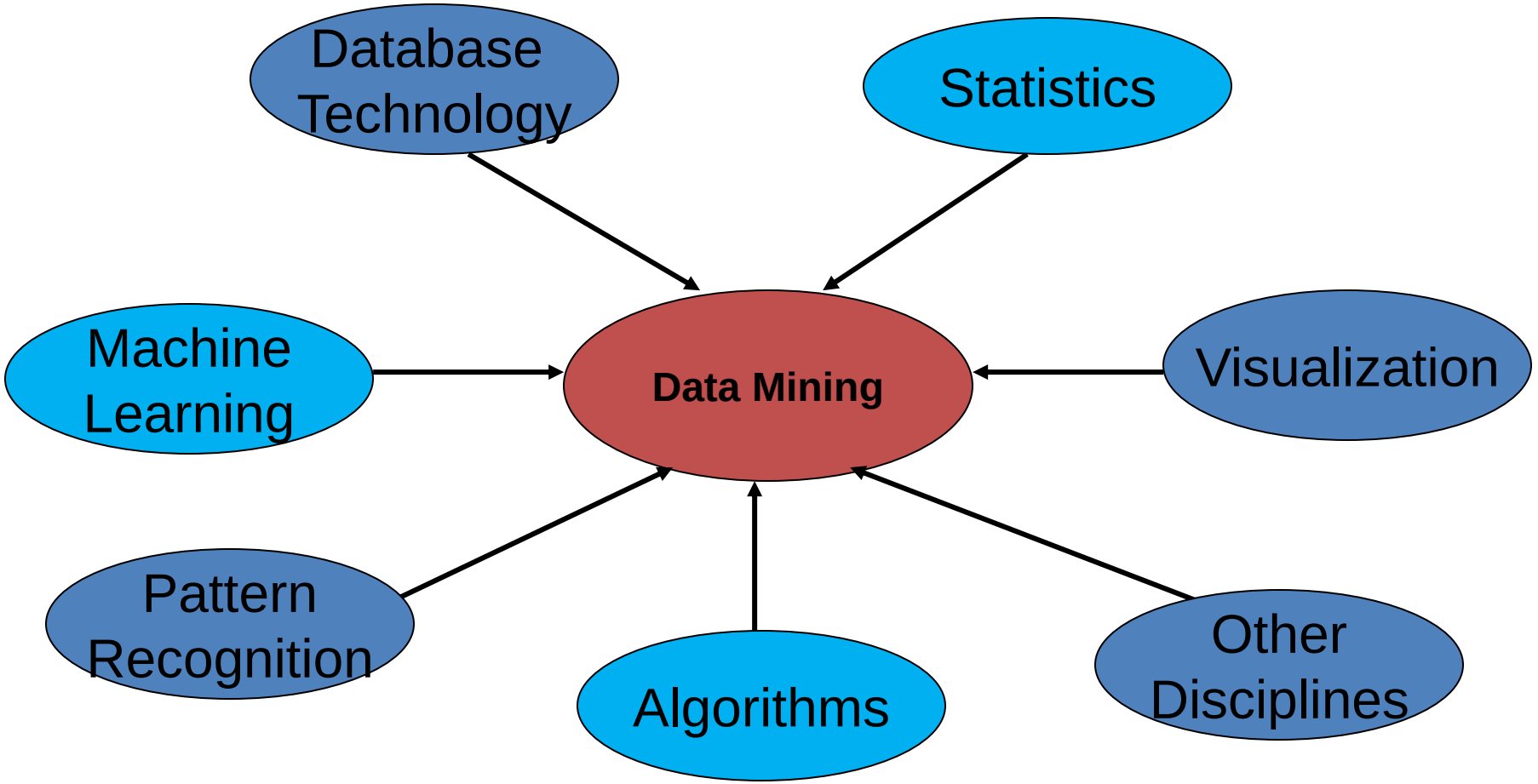

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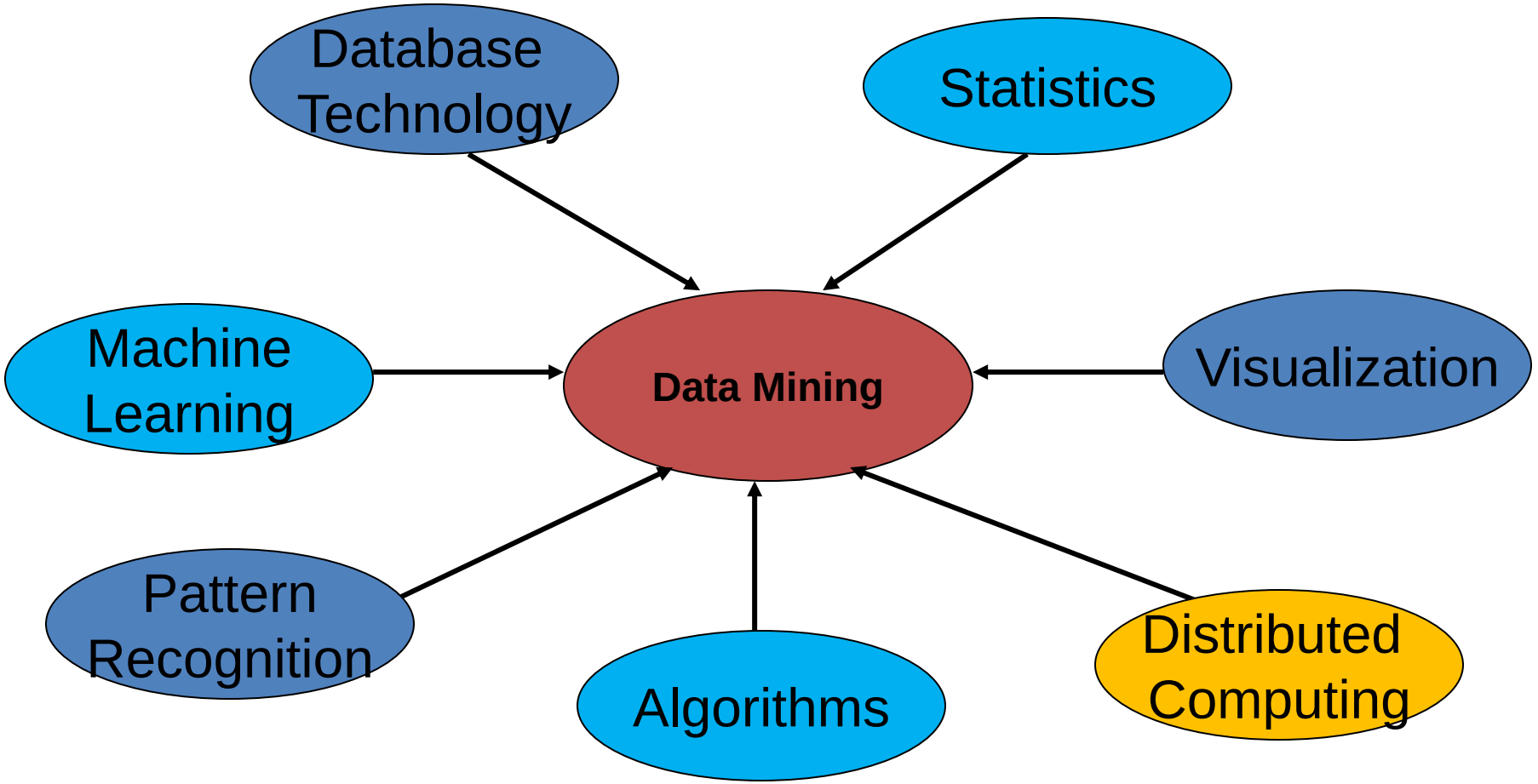


The buzz around data

- Data Science: Data is useful to understand a process and improve it. All organizations should have a data science team that analyses their data and proposes improvements
  - Focuses on more immediate applications and insights
- Big Data: Data appear everywhere. We should process it collectively and interconnect them. We need infrastructure (cloud computing, cloud storage) to do this
  - More systems oriented
- AI/Machine Learning/Deep Learning: These have been around for a while but now we have the data to learn more complex models that are significantly more powerful
  - More emphasis on scientific breakthroughs

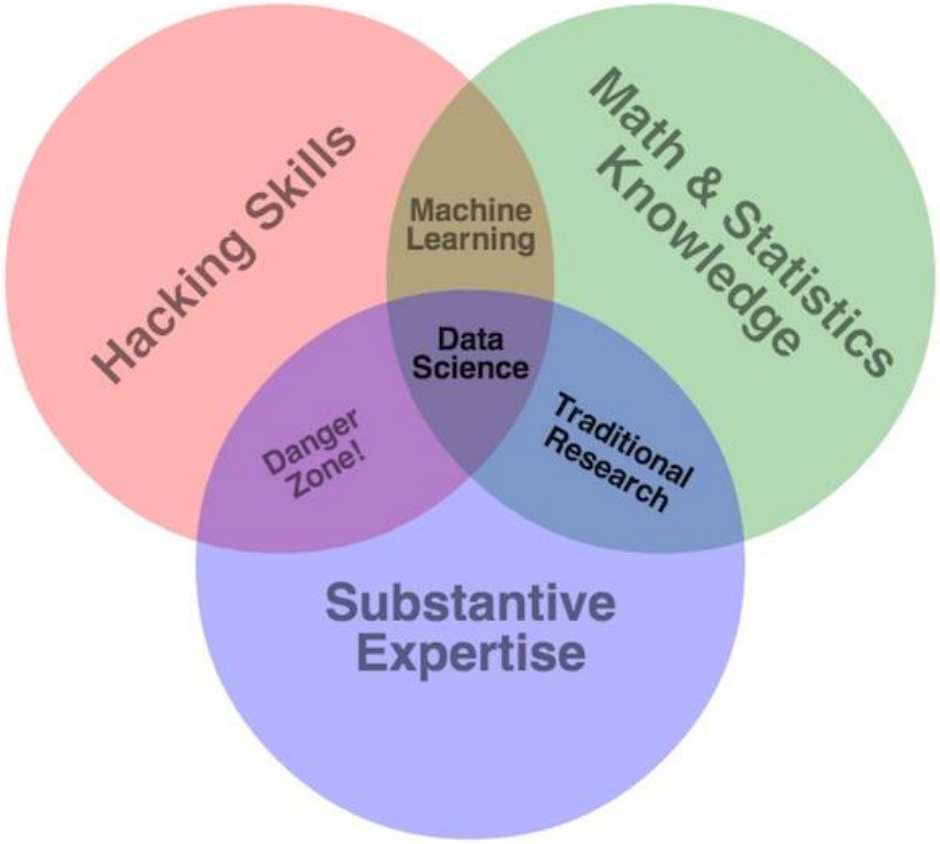
New era of data mining

- Boundaries are becoming less clear
  - Today data mining, machine learning, and AI are synonymous. It is assumed that the algorithms should scale. It is clear that statistical inference is used for building the models.
  - Data is the engine for AI
  - Data Mining touches everything related to data.

Which also has a dark side

- Are the algorithms making fair and correct decisions?
- Do algorithms create filter bubbles, echo chambers, and promote misinformation? Are they a threat to democracy?
- Surveillance capitalism
- Black box society
- Is AI a threat?

The Skills of a Data Miner – Data Scientist



It is a hard job

But also a rewarding one

Sexiest job but…

"The success of companies like Google, Facebook, Amazon, and Netflix, not to mention Wall Street firms and industries from manufacturing and retail to healthcare, is increasingly driven by better tools for extracting meaning from very large quantities of data. 'Data Scientist' is now the hottest job title in Silicon Valley." – Tim O'Reilly

Data Scientist: The Sexiest Job of the 21st Century

by Thomas H. Davenport and D.J. Patil

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