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 World Cup.
Data creates value

James Harden defence

Players are not only much more likely to shoot when guarded by James Harden ...

... but when they do shoot, their shots are more efficient.
Putting it all together: The LinkedIn Data Mining Pipeline

Data Pipeline
- feature extraction
- feature transformation
- user modeling

Model Fitting Pipeline (Hadoop)
- offline modeling fitting (cold-start model)
- nearline modeling fitting (warm-start model)
  - daily/weekly
  - minutes/hourly

Online Serving System
- multi-pass rankers
- candidates generation
- real-time feedback
- online A/B test
- model evaluation
Data Mining Example

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

- Social network contacts
- Interaction with contacts: messages, likes, replies, shares
- Posts, content of posts
- Interactions with feed: Clicks, Likes, Comments, 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 post, 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

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

- What conclusion can we draw?
Exploiting similarities

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

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

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

• What if we were missing this entry?

• 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?
  - Ad click prediction
  - Ad clickthrough prediction
  - Like prediction
  - Predict if a post is offensive
  - Predict if a photo contains nudity
  - 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
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
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 if 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
Game of Thrones Show Summary and Episode Schedule
www.pogdesign.co.uk/cat/Game-of-Thrones-summary

Game of Thrones. Seven noble families fight for control of the mythical land of Westeros. Political and sexual intrigue abound. The primary families are the Stark, ...

Will Bibi’s Doomsday Speech Matter? - The Daily Beast
www.thedailybeast.com/.../bibi-israel-in-deadly-game-of-thrones-with-ir...
2 days ago - "In this deadly game of thrones, there's no place for America or for Israel, no peace for Christians, Jews or Muslims who don't share the Islamist ...

Is 'Winds of Winter' finished? 'Game of Thrones' Nikolaj ... www.zap2it.com/.../is_winds_of_winter_finished_game_of_thrones_nik...
6 hours ago - Nikolaj Coster-Waldau of Game of Thrones Is "Game of Thrones" fans' impatient wait for George R.R. Martin's next book, "The Winds of Winter," ...

Sand Snakes or Snow Snakes? Not Everyone Is Happy With ... www.styleite.com/.../sand-snakes-or-snow-snakes-new-game-of-thrones-...
2 days ago - Game of Thrones is getting a trio of badass new female characters next season. Obera (Keisha Castle-Hughes), Tyene (Rosabell Laurenti ...

OMG, The 'Game Of Thrones' Sand Snakes Look Amazing
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 that 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

Data Mining

- Database Technology
- Statistics
- Machine Learning
- Visualization
- Pattern Recognition
- Algorithms
- Other Disciplines
Data Mining: Confluence of Multiple Disciplines

- Database Technology
- Statistics
- Machine Learning
- Pattern Recognition
- Algorithms
- Visualization
- Other Disciplines
Data Mining: Confluence of Multiple Disciplines

- Database Technology
- Statistics
- Machine Learning
- Visualization
- Pattern Recognition
- Algorithms
- Distributed Computing
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
• Is AI a threat?
The Skills of a Data Miner – Data Scientist

It is a hard job
But also a rewarding one

"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