Data Mining: Introduction

Lecture Notes for Chapter 1

Introduction to Data Mining, 2nd Edition by
Tan, Steinbach, Karpatne, Kumar

Large-scale Data is Everywhere!

- There has been enormous data growth in both commercial and scientific databases due to advances in data generation and collection technologies
- 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.

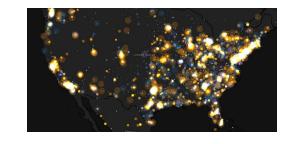




E-Commerce



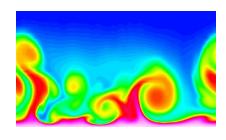
Traffic Patterns



Social Networking: Twitter



Sensor Networks



Computational Simulations

Why Data Mining? Commercial Viewpoint

- Lots of data is being collected and warehoused
 - Web data
 - Yahoo 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 for an edge (e.g. in Customer Relationship Management)



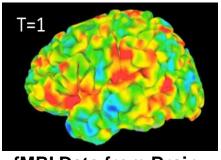






Why Data Mining? Scientific Viewpoint

- Data collected and stored at enormous speeds
 - remote sensors on a satellite
 - NASA EOSDIS archives over petabytes of earth science data / year

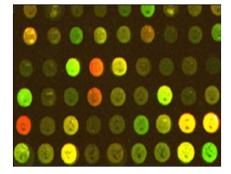


fMRI Data from Brain

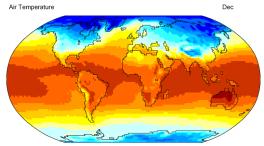


Sky Survey Data

- telescopes scanning the skies
 - Sky survey data
- High-throughput biological data
- scientific simulations
 - terabytes of data generated in a few hours
- Data mining helps scientists
 - in automated analysis of massive datasets
 - In hypothesis formation







Surface Temperature of Earth

Motivating Challenges

Scalability

- High Dimensionality
- Heterogeneous and Complex Data

Data Ownership and Distribution

Non-traditional Analysis

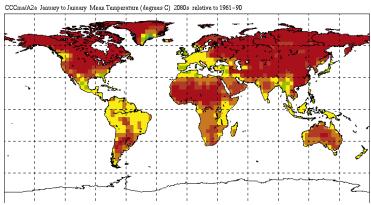
Great Opportunities to Solve Society's Major Problems



Improving health care and reducing costs



Finding alternative/ green energy sources



Predicting the impact of climate change



Reducing hunger and poverty by increasing agriculture production

Skills and Competencies

DATA COLLECTION

Access & Gather Appropriate Educational Data

DATA ETHICS

Ensure Clear Ethical Policies & Codes of Practices that Govern the Use of Educational Data

DATA APPLICATION

Use Educational
Data Analysis
Results to Make
Decisions to Revise
Instruction



DATA MANAGEMENT

Organize, Clean, Curate & Preserve Educational Data

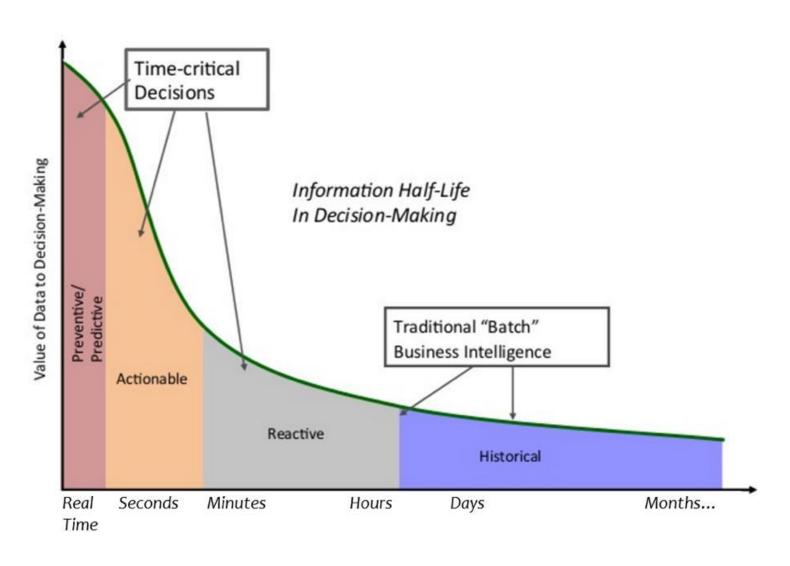
DATA ANALYSIS

Apply Educational Data Modelling & Presentation Methods

DATA COMPREHENSION & INTERPRETATION

Understand what the Educational Data Represent & Mean

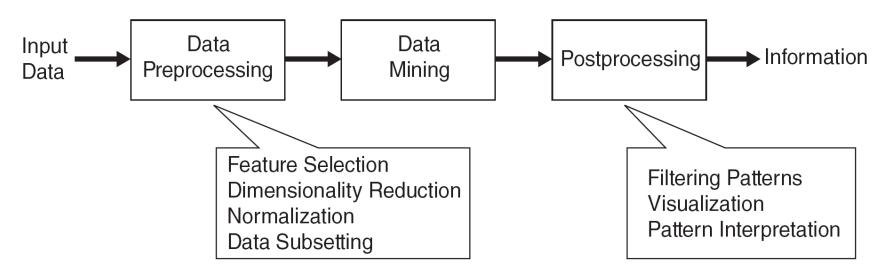
The diminishing value of data



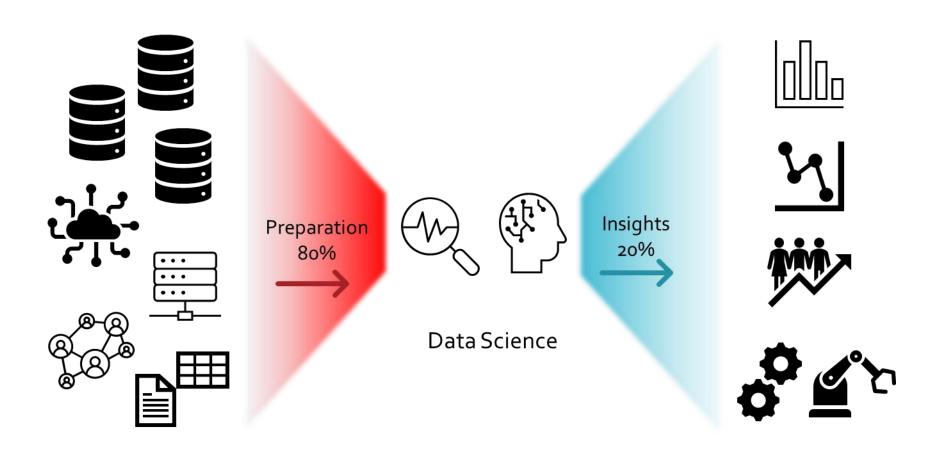
What is Data Mining?

Many Definitions

- Non-trivial extraction of implicit, previously unknown and potentially useful information from data
- Exploration & analysis, by automatic or semi-automatic means, of large quantities of data in order to discover meaningful patterns



The 80/20 data science dilemma



Tasks of data preparation

- Discovery
- Accessing
- Interpreting
- Collecting
- Organising

- Validating
- Cleaning
- Modelling
- Enriching
- Storing

Why is this such a problem?

- Consistency of access (formats, connections, velocity)
- Accessibility to data
- Effort to process and move data
- Subject matter expertise
- Reliability/Validity of data
- Communication/Knowledge Sharing/Retention difficult over time
- Time consuming

What is (not) Data Mining?

What is not Data Mining?

- Look up phone number in phone directory
- Query a Web search engine for information about "Amazon"

What is Data Mining?

- Certain names are more prevalent in certain US locations (O'Brien, O'Rourke, O'Reilly... in Boston area)
- Group together similar documents returned by search engine according to their context (e.g., Amazon rainforest, Amazon.com)

Origins of Data Mining

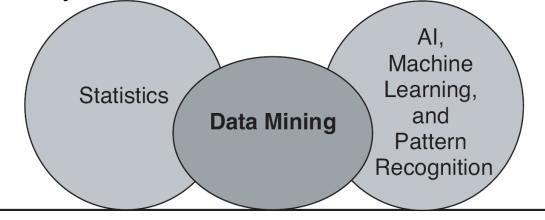
 Draws ideas from machine learning/AI, pattern recognition, statistics, and database systems

Traditional techniques may be unsuitable due to data that is

Large-scale

High dimensional

- Heterogeneous
- Complex
- Distributed



Database Technology, Parallel Computing, Distributed Computing

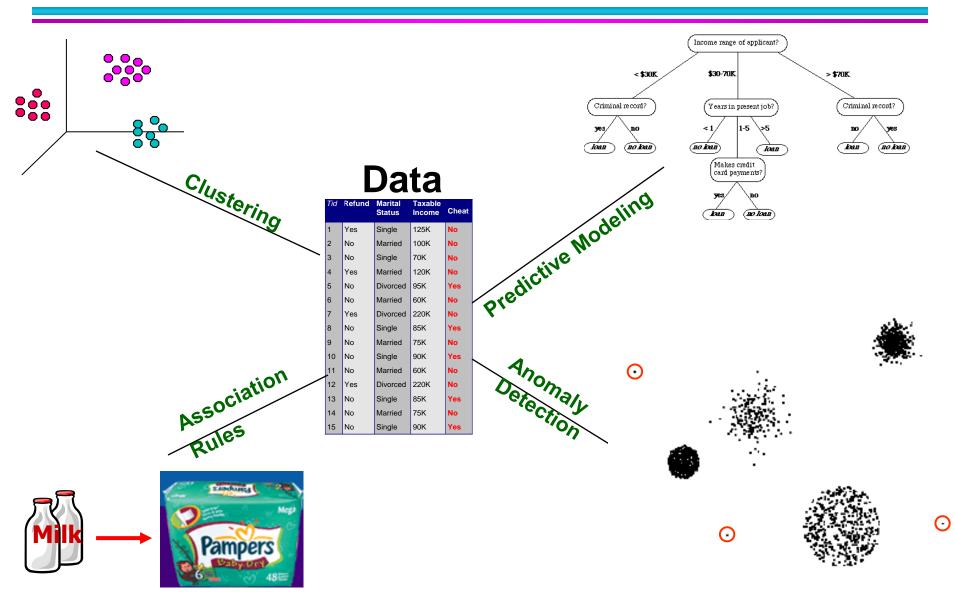
A key component of the emerging field of data science and datadriven discovery

Data Mining Tasks

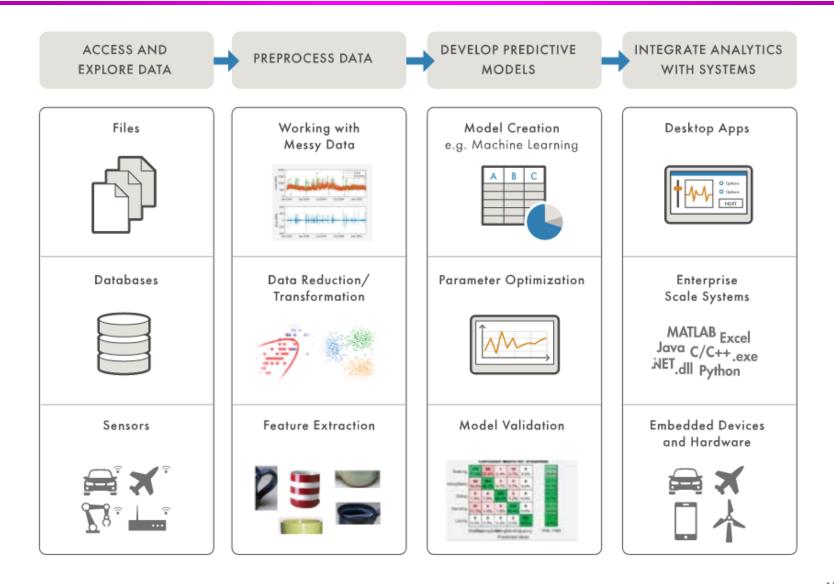
- Prediction Methods
 - Use some variables to predict unknown or future values of other variables.

- Description Methods
 - Find human-interpretable patterns that describe the data.

Data Mining Tasks ...



Predictive analytics workflow



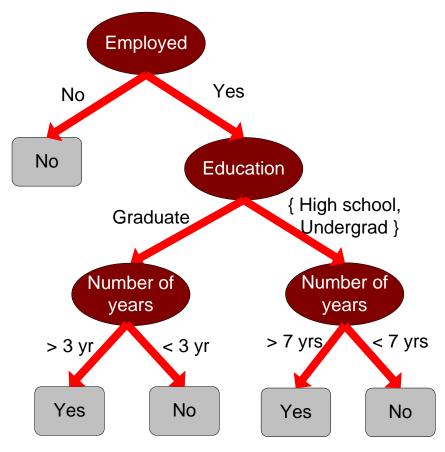
Predictive Modeling: Classification

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

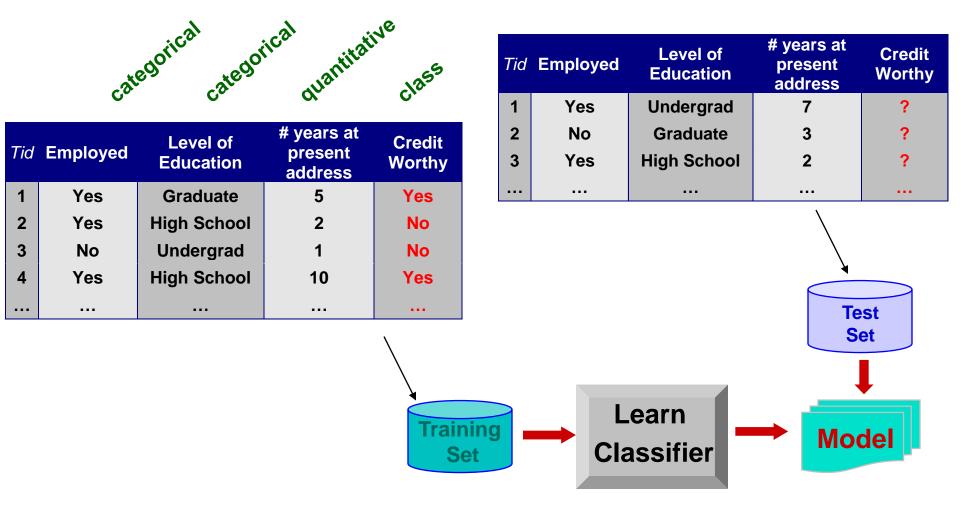
Model for predicting credit worthiness

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
	•••		•••	•••



Classification Example



Examples of Classification Task

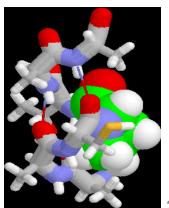
- Classifying credit card transactions as legitimate or fraudulent
- Classifying land covers (water bodies, urban areas, forests, etc.) using satellite data



- Identifying intruders in the cyberspace
- Predicting tumor cells as benign or malignant
- Classifying secondary structures of protein as alpha-helix, beta-sheet, or random coil







Classification: Application 1

Fraud Detection

 Goal: Predict fraudulent cases in credit card transactions.

- 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, etc
- 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.

Classification: Application 2

- Churn prediction for telephone customers
 - Goal: To predict whether a customer is likely to be lost to a competitor.

- Use detailed record of transactions with each of the past and present customers, to find attributes.
 - How often the customer calls, where he calls, what timeof-the day he calls most, his financial status, marital status, etc.
- Label the customers as loyal or disloyal.
- Find a model for loyalty.

Classification: Application 3

Disaster Response Social Media Messages Classification

- Goal: Automatically identify social media messages that are most urgent and require immediate attention.
 - "I'm trapped in my home and need to be rescued"
 - "I have a boat and can help with evacuations"

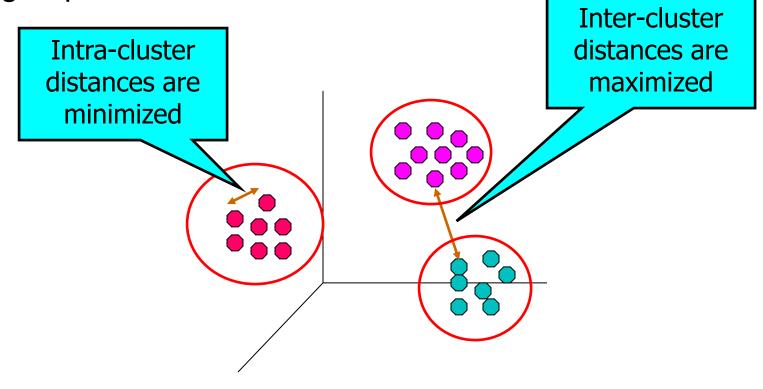
- Ponce-López, V., Spataru, C. Social media data analysis framework for disaster response. *Discov Artif Intell* 2, 10 (2022). https://doi.org/10.1007/s44163-022-00026-4
- Asif, A., Khatoon, S., Hasan, M.M. et al. Automatic analysis of social media images to identify disaster type and infer appropriate emergency response. J Big Data 8, 83 (2021). https://doi.org/10.1186/s40537-021-00471-5
- Zou, Z., Gan, H., Huang, Q., Cai, T., & Cao, K. (2021). Disaster Image Classification by Fusing Multimodal Social Media Data. ISPRS International Journal of Geo-Information, 10(10), 636.
 MDPI AG. Retrieved from http://dx.doi.org/10.3390/ijgi10100636

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.
- Extensively studied in statistics, neural network fields.
- Examples:
 - Predicting sales amounts of new product based on advetising 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



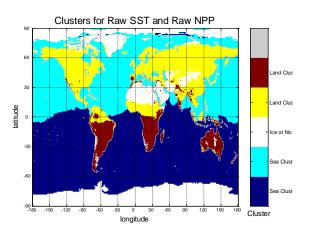
Applications of Cluster Analysis

Understanding

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

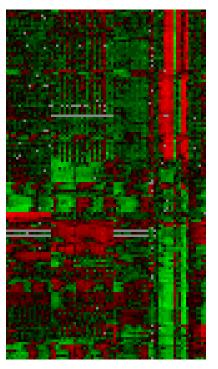
Summarization

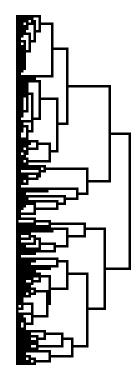
Reduce the size of large data sets



Use of K-means to partition Sea Surface Temperature (SST) and Net Primary Production (NPP) into clusters that reflect the Northern and Southern Hemispheres.

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Courtesy: Michael Eisen



Clustering: Application 1

Market Segmentation:

 Goal: subdivide a market into distinct subsets of customers where any subset may conceivably be selected as a market target to be reached with a distinct marketing mix.

- 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 it to cluster.

Enron email dataset



Association Rule Discovery: Definition

- 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}
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Association Analysis: Applications

Market-basket analysis

 Rules are used for sales promotion, shelf management, and inventory management

Telecommunication alarm diagnosis

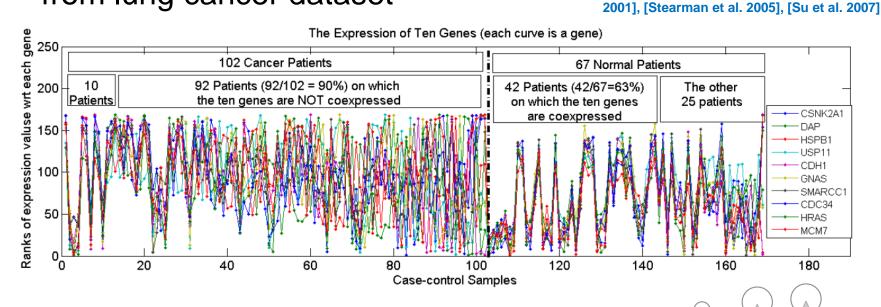
 Rules are used to find combination of alarms that occur together frequently in the same time period

Medical Informatics

 Rules are used to find combination of patient symptoms and test results associated with certain diseases

Association Analysis: Applications

An Example Subspace Differential Coexpression Pattern
 from lung cancer dataset
 Three lung cancer datasets [Bhattacharjee et al 2007]

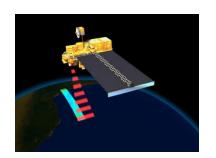


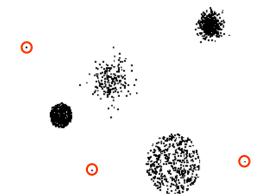
Enriched with the TNF/NFB signaling pathway which is well-known to be related to lung cancer P-value: 1.4*10⁻⁵ (6/10 overlap with the pathway)

[Fang et al PSB 2010]

Deviation/Anomaly/Change Detection

- Detect significant deviations from normal behavior
- Applications:
 - Credit Card Fraud Detection
 - Network Intrusion
 Detection
 - Identify anomalous behavior from sensor networks for monitoring and surveillance.
 - Detecting changes in the global forest cover.







Summary

- Data Science is <u>Transdisciplinary</u>
 - New application areas
 - Advancing data science
 - Building coalitions