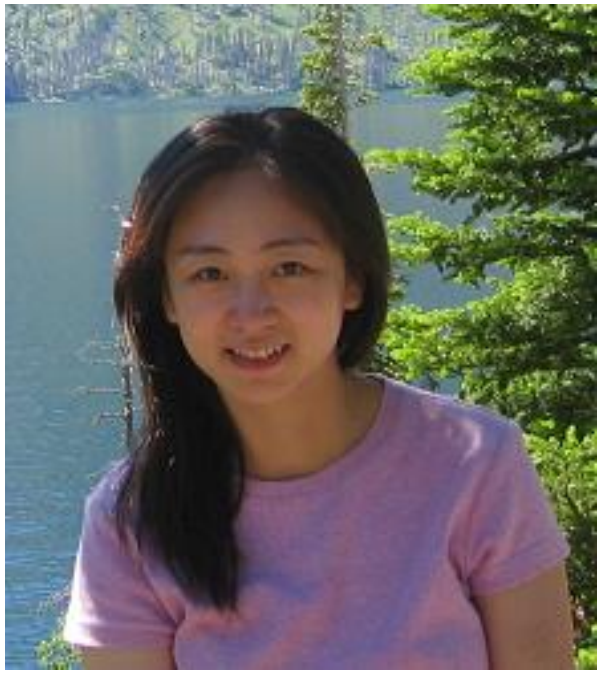
Data Mining

Ying Liu, Prof., Ph.D

School of Computer Science and Technology
University of Chinese Academy of Sciences
The Key Lab of Big Data Mining and Knowledge Management

Welcome

- Ying Liu
  - Computer Engineering, Ph.D, Northwestern University, USA
  - Research interests
    - Data Mining
    - Artificial Intelligence
    - High Performance Computing
    - Big Data
  - Email: yingliu@ucas.ac.cn

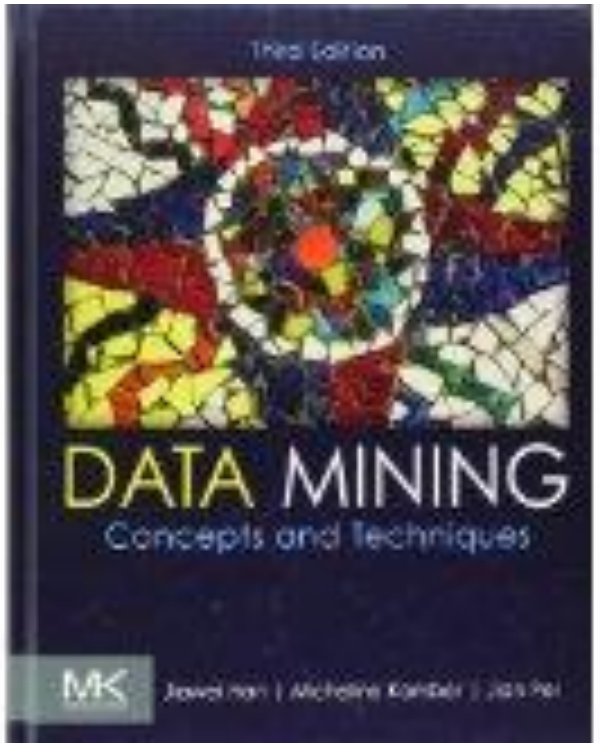


Useful Information

- Teaching Assistants
  - Jiaxu Leng
  - Tianlin Zhang
  - Yihui Ren
- Class: Monday & Wednesday 8:30 - 10:10, 教 1-101
- Website: http://sep.ucas.ac.cn

Textbook and References

- Textbook
  - Data Mining, Concepts and Techniques. Jiawei Han and Micheline Kamber, Morgan Kaufmann, 2011 (Third Edition)



- References
  - Research papers. To be announced in class.

Prerequisites

- Data Structure
- Algorithm
- Database
- Programming: C/C++ (preferred), Python, Java

A Mini Survey

- How many people were major in computer science?
- How many people took machine learning courses before?
- How many people took statistics courses before?
- How many people took database courses before?

Grading Scheme

- Assignments (30%)
  - 2 homework assignments
- Course Project (30%)
  - Group project (4 students/group)
  - Solve a real problem: propose an algorithm/approach and implement it
- Final Exam (40%)
  - In class, closed book

About the Project

- Option 1:
  - 2019 CCF大数据与计算智能大赛 (https://www.datafountain.cn/competitions)
  - Choose a topic from the following topics
  - Read through some related research papers and fully understand them
  - Develop and Implement the method
  - To be evaluated by the ranking or feedback from the contest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赛题详情(Competition
https://www.datafountain.cn/competitions/352
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竞赛
AI指北
数据集
我要办赛
人工智能教学实验室
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注册
CCF BDCI
乘用车细分市场
销量预测
乘用车细分市场销量预测
主办方： 中国计算机学会 & 深瞳云涂
预测回归
数据挖掘
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队伍 / 人数
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开赛
初赛 08.17 ~ 10.25
复赛 10.30 ~ 11.11
决赛
11.23 ~ 11.24
赛制规则
数据与评测
排行榜
参赛队伍
赛题讨论
常见问题
报名参赛
大赛介绍
赛题名称
大赛介绍
CCF大数据与计算智能大赛（CCF Computing Intelligence Contest，简称CCF BDCI）是由中国计算机学会大数据专家委员会于2013年创办的
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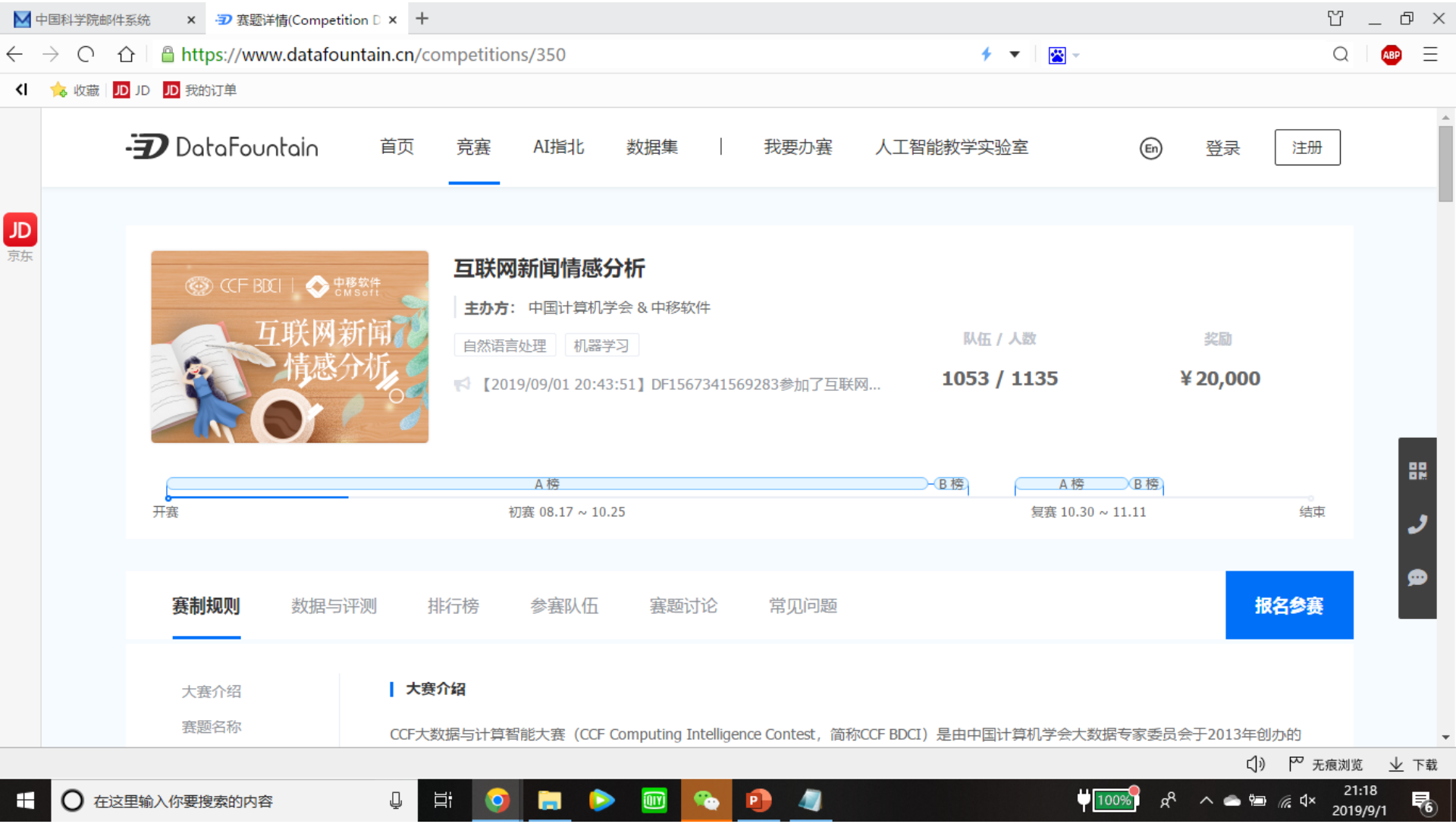
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AI指北
数据集
我要办赛
人工智能教学实验室
登录
注册
互联网新闻情感分析
主办方： 中国计算机学会 & 中移软件
自然语言处理
机器学习
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队伍 / 人数
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开赛
初赛 08.17 ~ 10.25
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结束
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2019
智慧气象服务创新大赛
"神气"大数据算法与应用赛 2TH
科技创新 气象惠民
算法组：卫星云图+地面观测云图预测辐照量
主办方： 中国气象服务协会 & 中国气象网
图像识别
【2019/09/01 21:07:32】胡搞瞎搞参加了算法组：卫星云图...
队伍 / 人数
29 / 31
奖金
￥70,000
A 榜
B 榜
A榜结束
开赛
初赛 08.30 ~ 10.30
决赛
11.12
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赛制规则
数据与评测
排行榜
参赛队伍
神气大数据
常见问题
报名参赛
大赛背景
大赛主题
赛程赛制
赛题任务
大赛奖项
大赛背景
第二届智慧气象服务创新大赛——2019"神气"大数据算法与应用赛是由中国气象局指导、中国气象服务协会主办、中国天气网承办的气象领域高规格赛事。通过气象大数据与行业数据的融合，激发高校、科研院所、社会各行业等对气象数据应用的想象力和创新力，促进产学研一体化发展，推动气象数据共享、开放和科研成果的转化与应用，打造气象服务创新平台，推动气象大数据价值链的形成和产业生态发展，提升气象部门的社会影响力，助力气象服务现代化发展。
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About the Project

- Option 2:
  - Contest in class
  - Assigned a topic (to be announced)
  - Read through some related research papers and fully understand them
  - Develop and Implement the method
  - To be evaluated by the ranking in class

How to Do a Good Project?

- Start early
  - It takes time to understand and think
- Discuss with me
  - Maybe I can give some suggestions or ideas
- Implement concretely
- Think creatively

Why Take This Course ?

- Data mining is hot
  - Solve many interesting problems in real applications, e.g. business management, WWW, science exploration
  - Turn raw data into knowledge
  - Promising in research of many disciplines
  - Data miners' job market: many well-paid positions

➢*Data Mining is very useful*!

Syllabus (Tentative)

- Introduction
- Data warehouse
- Data pre-processing
- Classification
- Association rules
- Clustering
- Applications
- Big data mining

Objectives of This Course

- Introduce the motivation of data mining
- Outline principles, major algorithms
- Introduce applications
- Introduce advanced topics
- Enhance independent research capability

Policies

- Students are expected to attend all classes
- No late homework will be accepted
- All work must be efforts of your own (individual assignment) or of your approved team (group assignment)

No Plagiarism!

What Motivated Data Mining?

- The explosive growth of data
  - Data collection and data availability
    - Computer hardware & software develop dramatically
    - The amount of data collected and stored doubles/triples per year vs. CPU speed increases 15% per year (till 2003)
- Many types of databases
  - Object-oriented, spatial, temporal, time-series, text, multimedia, Web

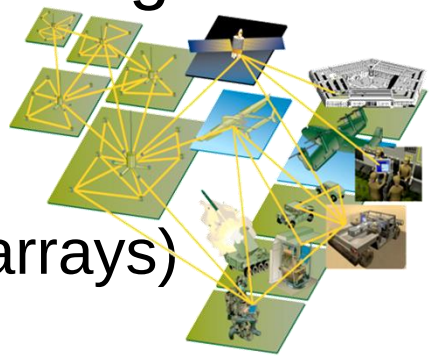
What Motivated Data Mining – Business World

- Tremendous of data being collected and stored
  - E-commerce
  - Transactions
  - Stocks
  - Credit card transactions

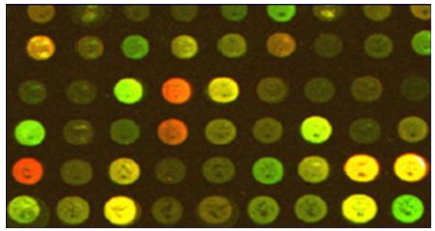
- Strong competitive pressure to extract and use the knowledge hidden in the data to provide customized CRM

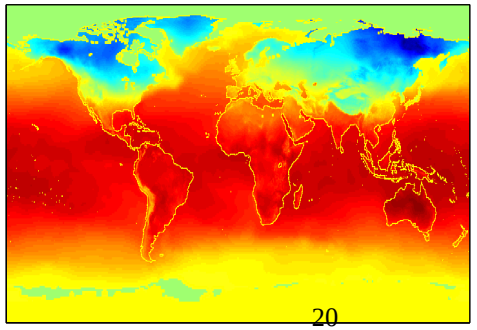
What Motivated Data Mining – Scientific World

- Tremendous of data being collected and stored
  - Remote sensing
  - Bioinformatics (Microarrays)
  - Scientific simulation



- Scientists need strong data analysis to assist research, such as classification, segmentation, etc.





What Motivated Data Mining?

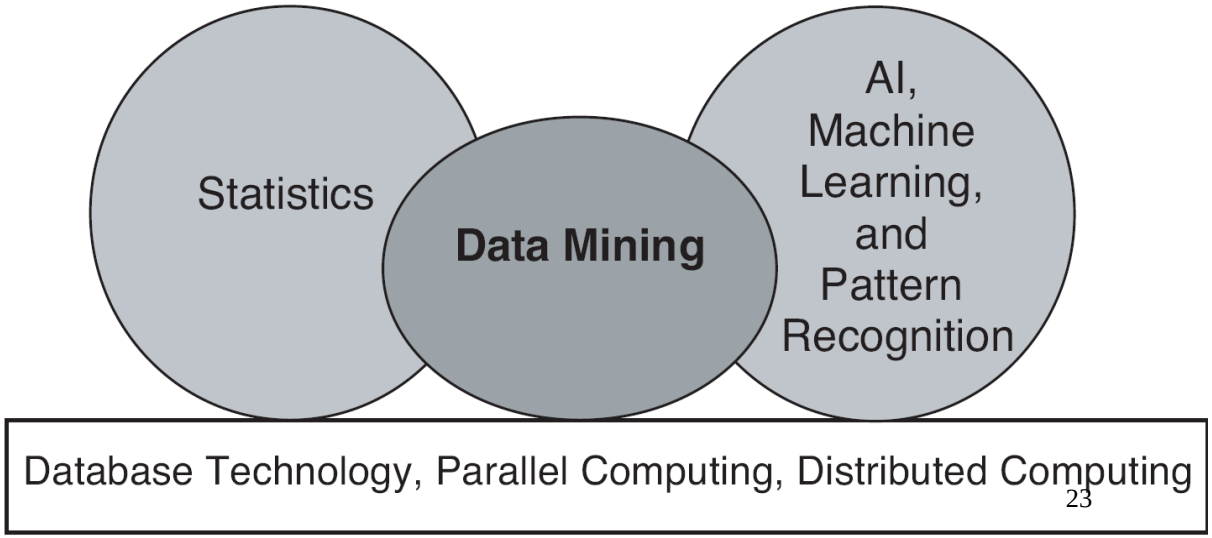
- We are drowning in data, but starving for knowledge!
  - Data rich, knowledge poor
  - Decision makers, domain experts have biases or errors
- Automated analysis of massive data sets

What is Data Mining?

- Data mining — Discover valid, novel, useful, and understandable patterns in massive datasets

What is Data Mining?

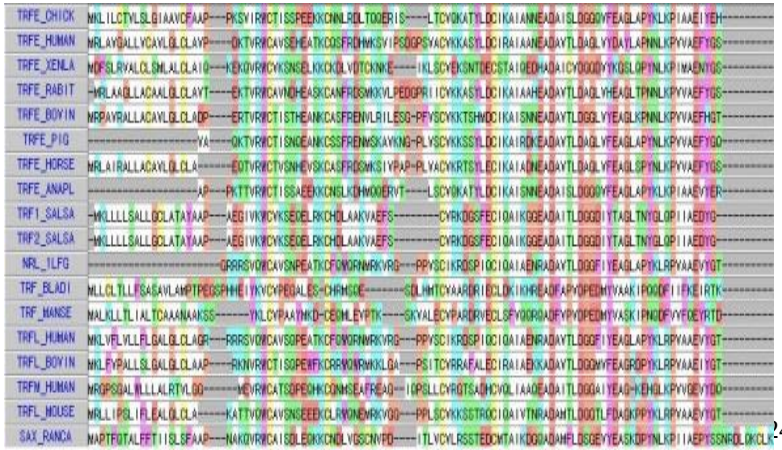
- Cross Disciplines
  - Databases
  - Machine learning: decision tree, Bayesian classifier, etc.
  - Statistics: regression, etc.
  - Neural networks
  - Parallel/Distributed computing



Why Not Traditional Data Analysis?

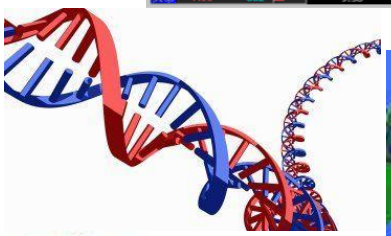
- Tremendous amount of data
  - Algorithms must be highly scalable to handle such as tera-bytes of data

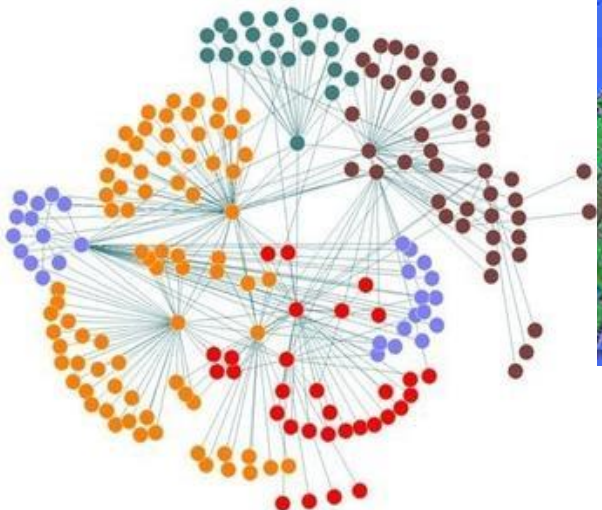
- High-dimensionality of data
  - DNA sequences may have tens of thousands of dimensions

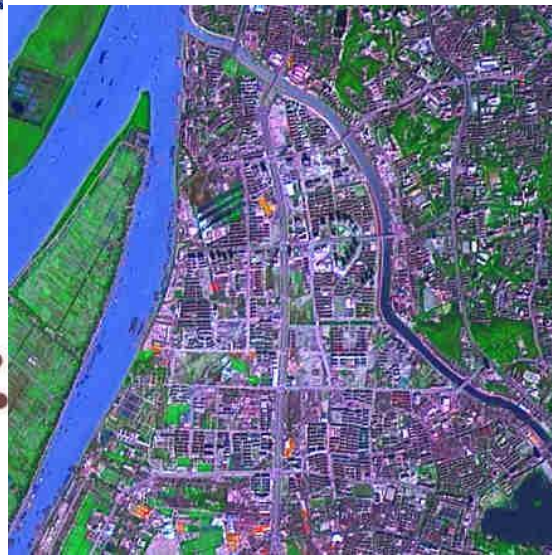


Why Not Traditional Data Analysis?

- High complexity of data
  - Data streams and sensor data
  - Time-series data, sequence data
  - Graphs, social networks
  - Spatial, multimedia, text and Web data
- New and sophisticated applications







Why Not Traditional Data Analysis?

- Database
  - Storage-oriented
  - Provide simple queries
- Data warehouse
  - Subject-oriented
  - A multidimensional view of data
  - Operations to access summarized data
- Statistical algorithms
  - Based on many hypothesis
  - Find patterns in small number of samples

Data mining

Discover knowledge from data in databases

Advanced data analysis tools

Less hypothesis

Find patterns in large number of samples

Abnormal patterns

Characteristics of Data Mining

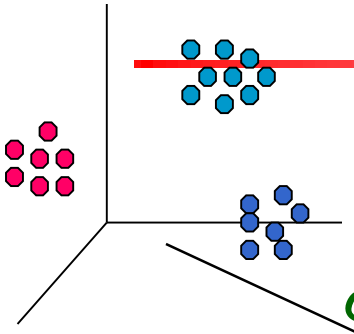
- Massive dataset
- Automatically searching for interesting patterns from historical data
- Fast
- Scalable
- Update easily
- Practical
- Decision support

Exercises

1. Could you present an application of data mining in business domain?

2. Could you present an application of data mining in scientific domain?

What Kinds of Tasks

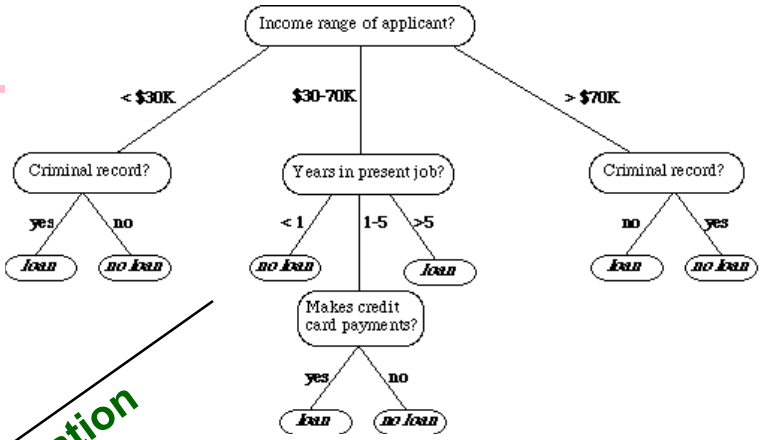


Clustering

Data

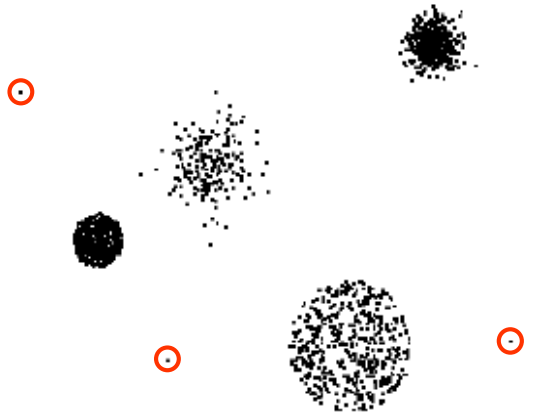
Tid	Refund	Marital Status	Taxable Income	Cheat
1	Yes	Single	125K	No
2	No	Married	100K	No
3	No	Single	70K	No
4	Yes	Married	120K	No
5	No	Divorced	95K	Yes
6	No	Married	60K	No
7	Yes	Divorced	220K	No
8	No	Single	85K	Yes
9	No	Married	75K	No
10	No	Single	90K	Yes
11	No	Married	60K	No
12	Yes	Divorced	220K	No
13	No	Single	85K	Yes
14	No	Married	75K	No
15	No	Single	90K	Yes

Classification



Association Rules

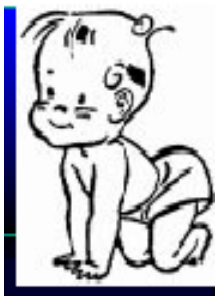
Anomaly Detection



Association Rules Mining

- Detect sets of attributes or items that frequently co-occur in many database records and rules among them

On Thursdays, during 4-11pm customers often purchase diapers and beers together!



Ex. 1: Production Recommendation

- Where does the data come from?
  - supermarket transactions, membership cards, discount coupons
- Discover individual products, or groups of products that tend to occur together in transactions
- Determine recommendations and cross-sell and up-sell opportunities
- Improve the efficiency of a promotional campaign

Classification

- Build a model of classes on training dataset, and then, assign a new record to one of several predefined classes

	categorical	categorical	continuous	class
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
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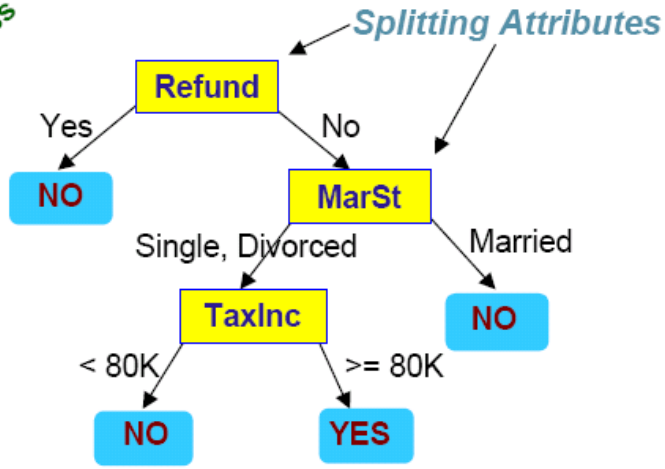
9	No	Married	75K	No
10	No	Single	90K	Yes

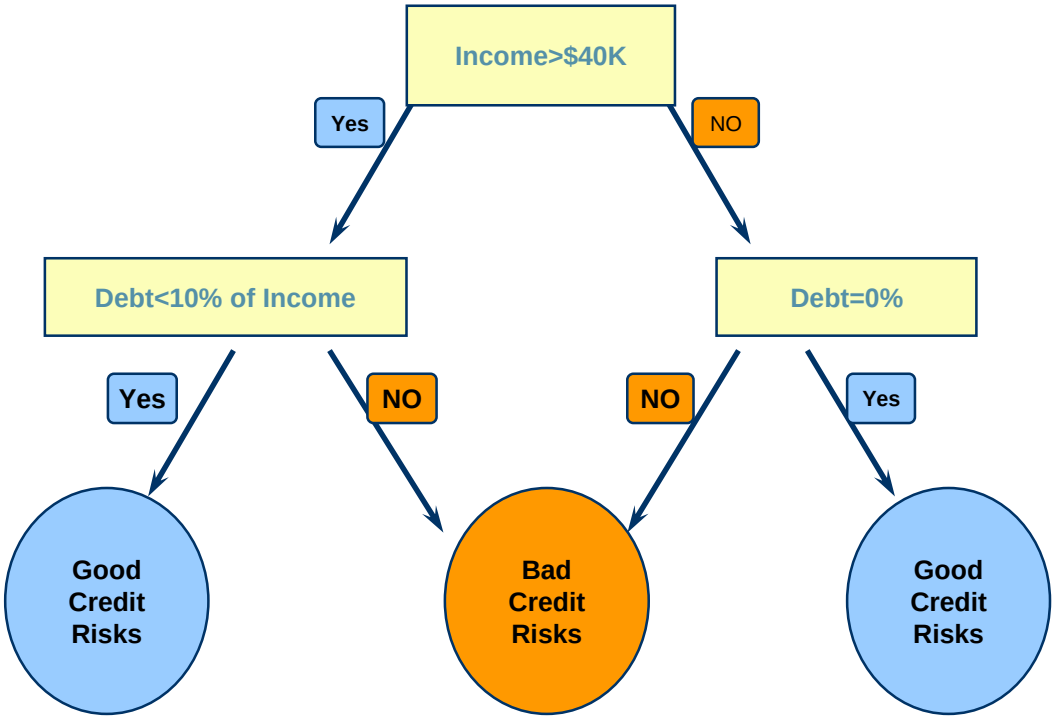


The splitting attribute at a node is determined based on the Gini index.

- Decision Tree

rule 1： if (Refund='no') and (MarSt = 'Single, Divorced') and (TaxInc >= 80K) then "Cheat"

Ex.2 Credit Scoring



- Decision Tree

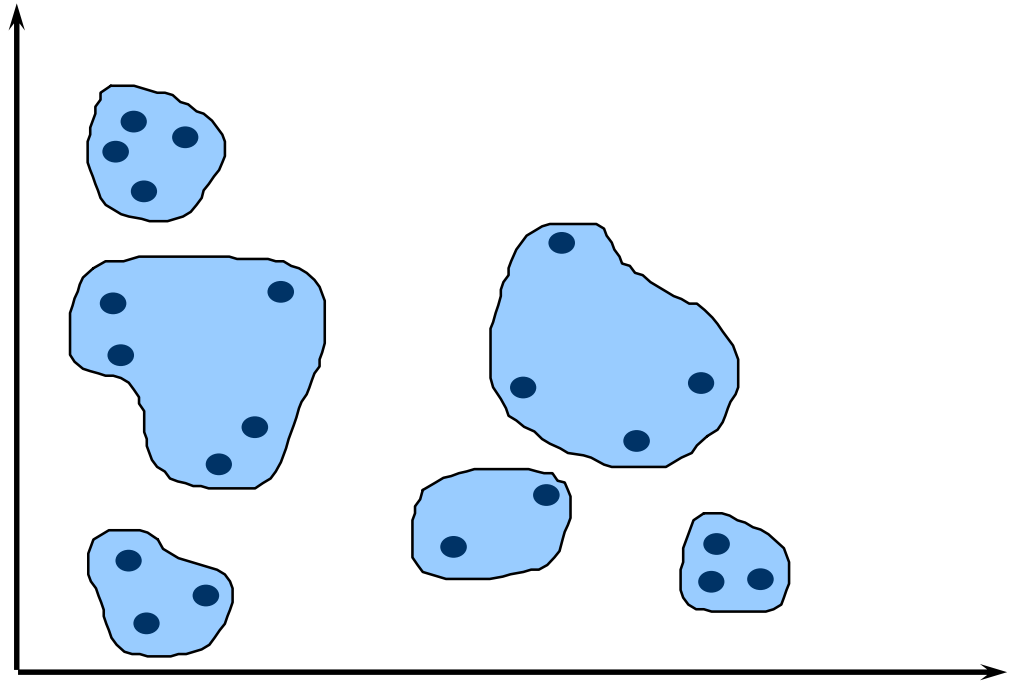
rule 1： if (Income<=$40k) and (Debt=0) then "good"
rule 2: if (Income>$40K) and (Debt<10% of Income) then "good"

Ex.2 Credit Scoring

- Where does the data come from?
  - Credit card transactions, credit card payments, loan payments, demographic data
- Predict the probability to bankrupt or charge-off
- Reduce the credit risk to the banks
- Increase the profitability of the banks

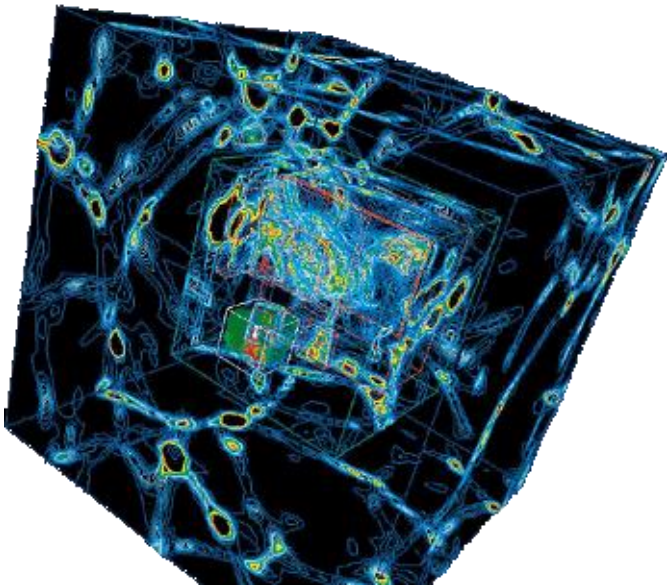
Clustering

- Partition the dataset into groups such that elements in a group have lower inter-group similarity and higher intra-group similarity



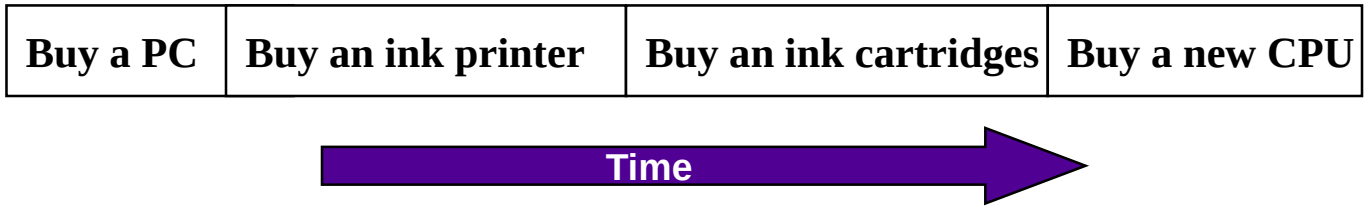
Ex.3 Scientific Simulation

- Cosmological simulation
  - Simulate the formation of the galaxy
  - Enormous particles at each evolution stage, beyond the capability of human being to analyze



Sequence Mining

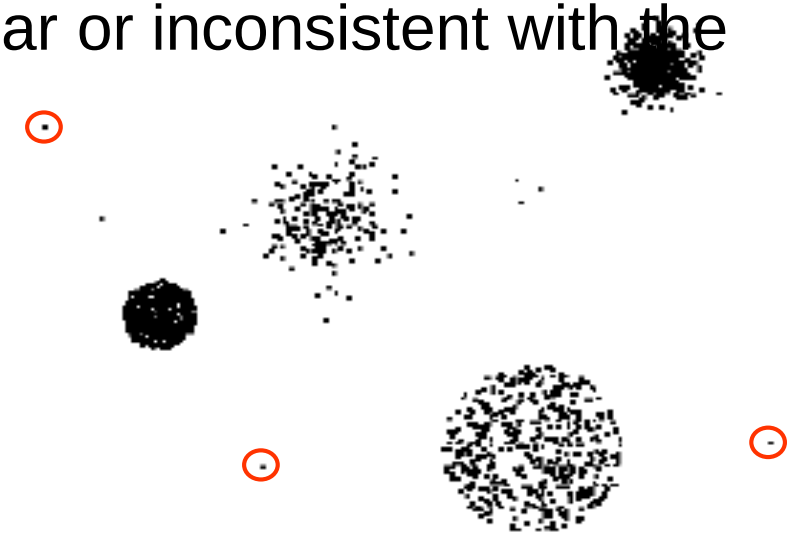
- Given a set of sequences, find the complete set of frequent subsequences



Marketing stragegy: recommend a new CPU for the customer 9 months after his first purchase

Anomaly Detection

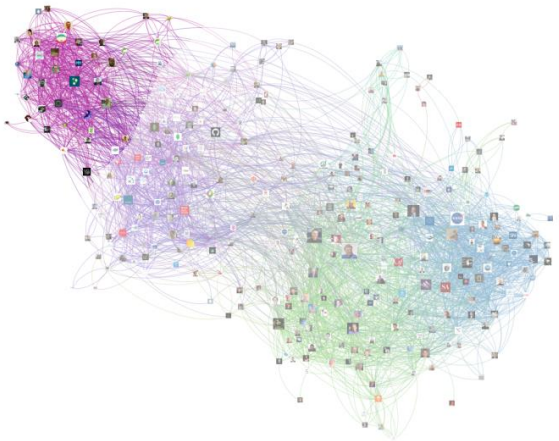
- What are anomalies?
  - The set of objects are considerably dissimilar from the remaining of the data
- Given a set of *n* objects, and *k,* the number of expected anomalies, find the top *k* objects that are considerably dissimilar or inconsistent with the remaining data



Anomalies may be valuable!

Social Analysis

- Social media mining
  - Detect communities
  - Communities evolution



Recommender systems

- Recommend products that would be interesting to individuals
  - Build a function, $f : U \times I \rightarrow \mathbb{R}$, for user set U and item set I

Product

amazon

JD.COM 京东

天猫 TMALL.COM

Movie

爱奇艺 iQIYI

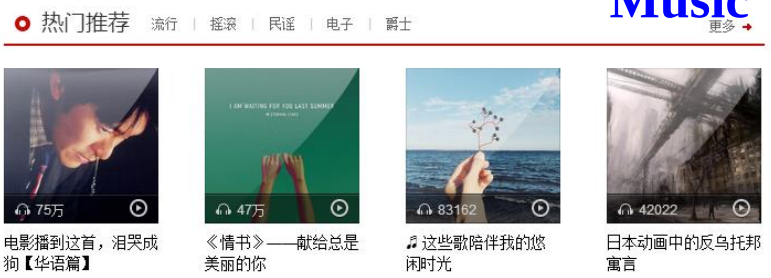
优酷 YOUKU

腾讯视频 V.QQ.COM

Music

QQ音乐

网易云音乐



Exercises

1. Can you describe other possible kind of knowledge that needs to be discovered by data mining methods but not been mentioned in class yet?

On What Kinds of Data?

- Database-oriented data sets and applications
  - Relational database, data warehouse, transactional database
- Advanced database applications
  - Data streams
  - Spatial data
  - Text database
  - Multimedia data
  - Time-series
  - Bio-medical data
  - Network traffic data

Relational Databases

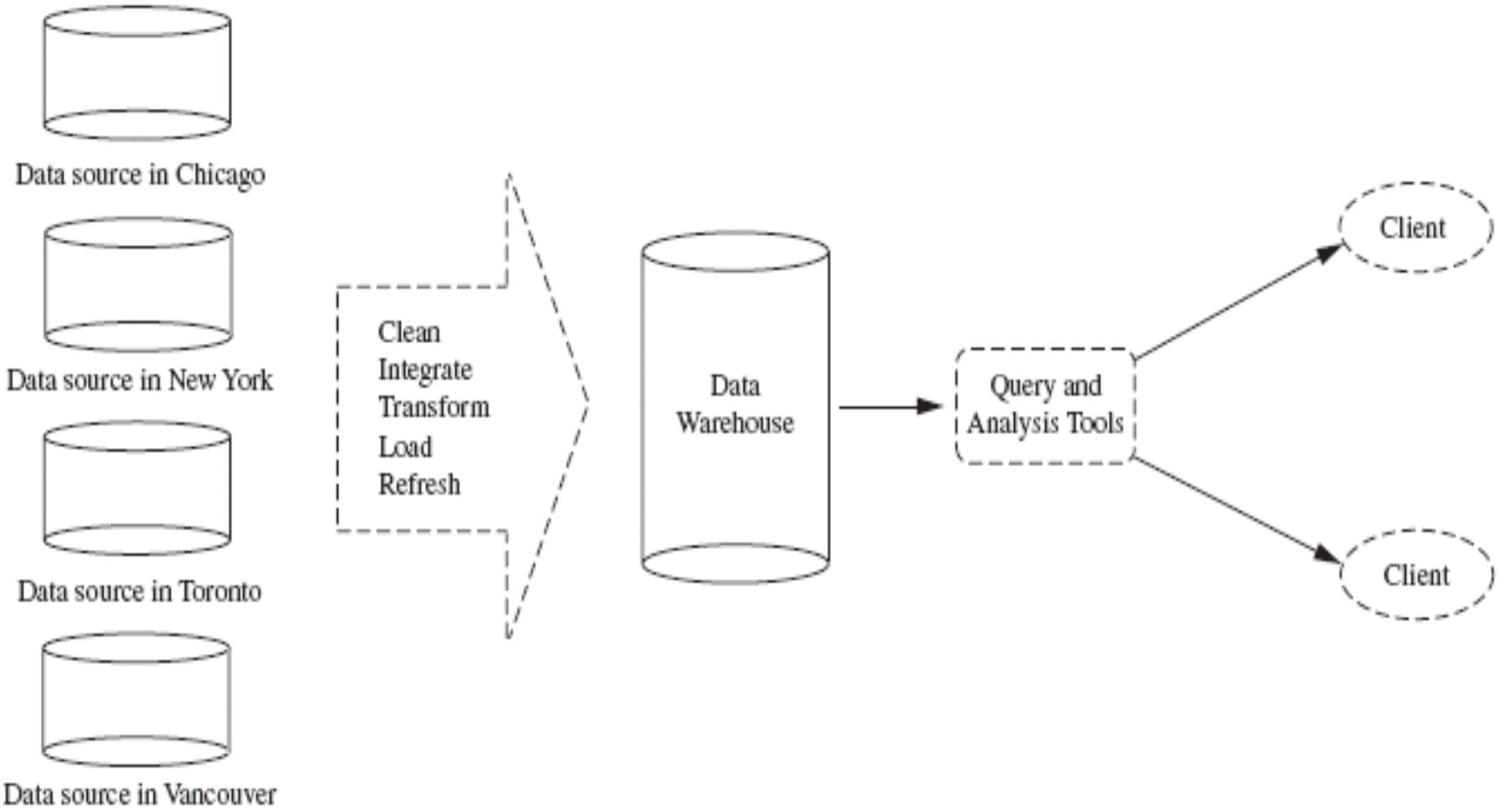
- Structured data
  - Table – records – attributes
  - Accessed by queries, SQL
- Online transactional processing (OLTP)
  - Insert a student “Ying Liu” into class “Introduction to Data Mining”, fall 2014

Name	Time	Course	score	Room
Ying Liu	Fall 2014	Introduction to Data Mining	90	002
Tom	Fall 2014	Math	85	001
Merlisa	Spring 2014	Compiler	70	001
George	Fall 2014	Graphics	92	001

Data Warehouses

- A subject-oriented, integrated, cleaned collection of data in support of management's decision making process
- Data from multiple databases
- Consistency checking in data warehouses
- Data warehouses can answer OLAP queries efficiently
  - Online analytical processing (OLAP)
  - Find the average class score of "Ying Liu" in the last 3 years, grouped by semesters
- Many patterns are summarization of data
  - Roll-up, drill-down

Data Warehouses



Transactional Databases

- $I=\{x_1, \ldots, x_n\}$ is the set of items
- An itemset is a subset of I
- A transaction is a tuple (tid, X)
  - Transaction ID tid
  - Itemset X
- A transactional database is a set of transactions

Tid	Itemset
T100	Milk, bread, beer, diaper
T200	Beer, cook, fish, potato, orange, apple
…	…

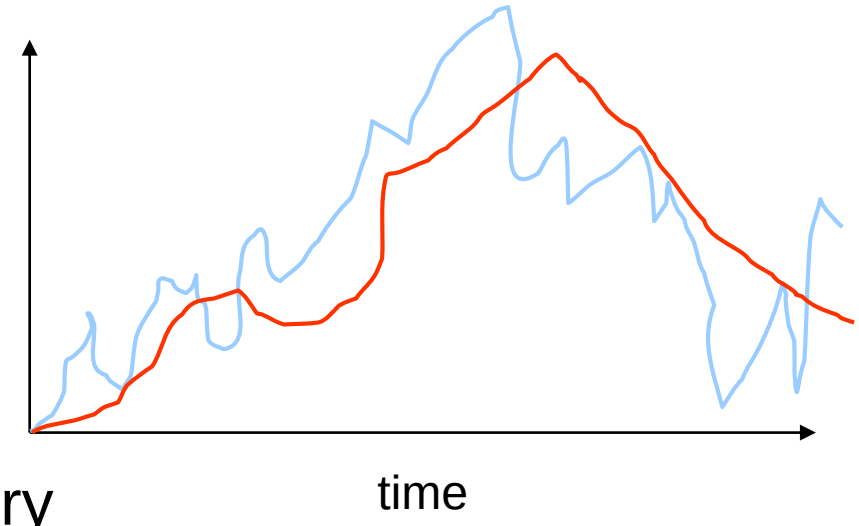
Spatial Data

- Spatial information
  - Geographic databases (map)
  - VLSI chip design databases
  - Satellite/remote sensing image databases
  - Medical image database
- Spatial patterns
  - Find characteristics of homes near a given location
  - Change in trend of metropolitan poverty rates based on distances from major highways

编号	中心	正右方	右上方	面积
1	居民地	绿地	水体	100
2	绿地	水体	水体	50
3	水体	居民地	居民地	600
4	水体	绿地	绿地	54
…	…	…	…	…

Time Series

- A sequence of values that change over time
  - Sequences of stock price at every 5 minutes
  - Daily temperature
  - Power supply
  - Electrocardiogram
- Typical operations
  - Similarity search
  - Trend analysis
  - Periodic pattern discovery



Text Databases & Multimedia Databases

- HTML web documents
- XML documents
- Digital libraries
- Annotated multimedia databases
  - Image, audio and video data
  - Typical operations
    - Similarity-based pattern matching
    - Deep learning

Data Streams

- Data in the form of continuous arrival in multiple, rapid, time-varying, possibly unpredictable and unbounded streams
  - Dynamically changing patterns, high volume, infinite, quick response, no re-scan
- Many applications
  - Stock exchange, network monitoring, telecommunications data management, web application, sensor networks, etc.

Biomedical Data

- Bio-sequences
  - DNA: very long sequences of nucleotides
  - Similarity search
  - Identify sequential patterns that play roles in various diseases
  - Association analysis: co-occurring gene sequences

World-Wide Web

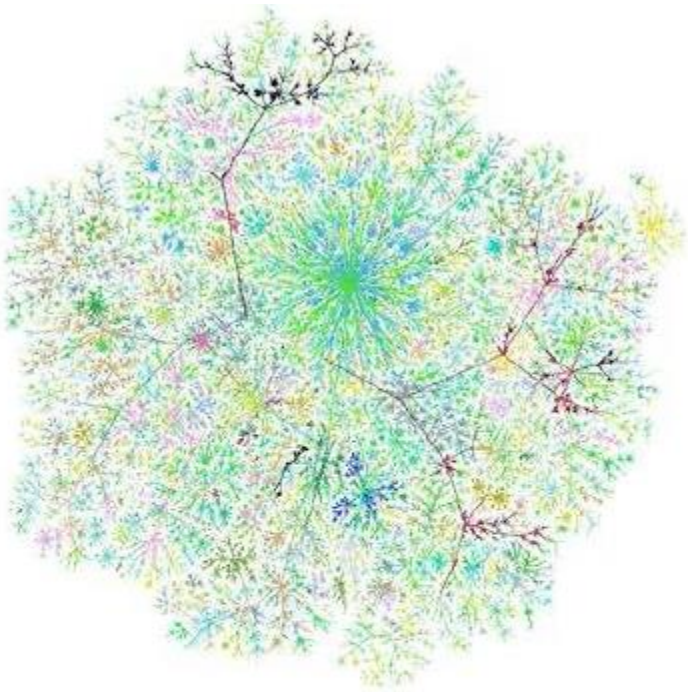
- The WWW is huge, widely distributed, global information service center for
  - Information services: news, advertisements, consumer information, financial management, education, government, e-commerce, etc.
  - Hyper-link information
  - Access and usage information
- WWW provides rich sources for data mining
- Challenges
  - Too huge for effective data warehousing and data mining
  - Too complex and heterogeneous: no standards and structure

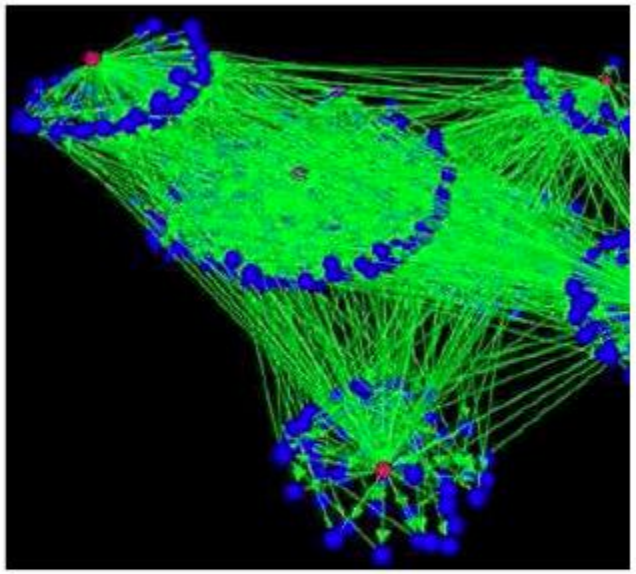
World-Wide Web

- Web Usage: Logs and IP package header streams
  - Mine Weblog records to discover user accessing patterns of Web pages
- Web Content
  - Extract knowledge from a Web documents, automatic categorization
- Web Structure
  - Identifying interesting graph patterns among different Web pages

Graph

- Internet graph

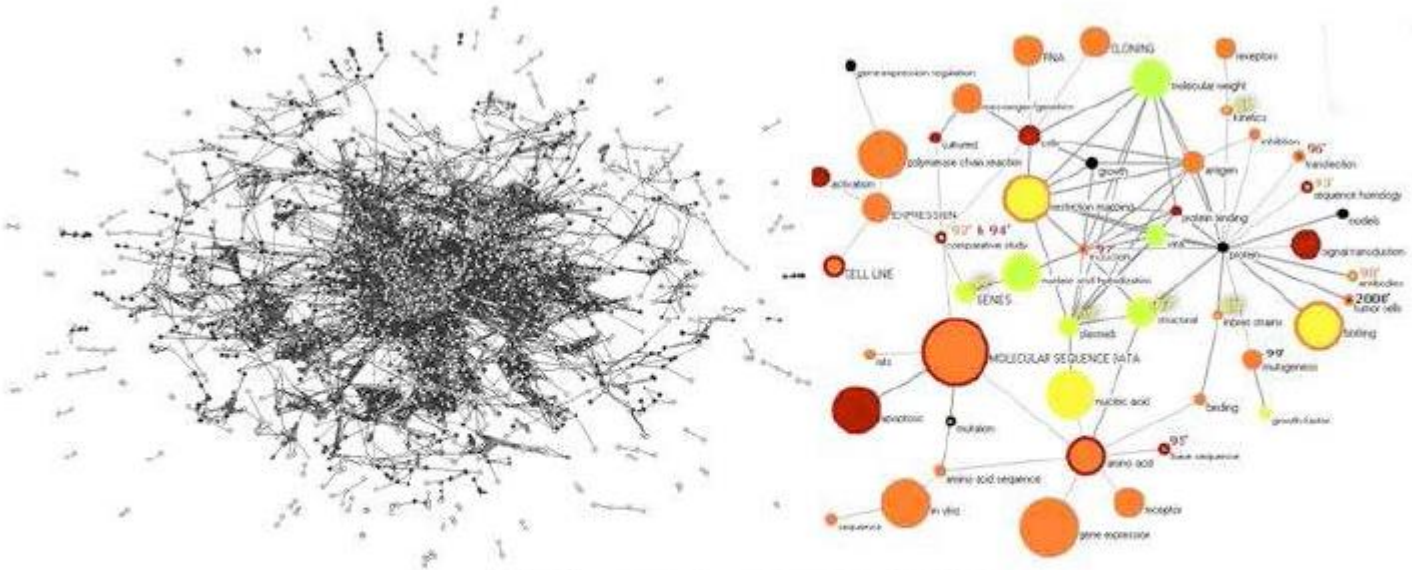




The images are downloaded from
http://www.maths.bris.ac.uk/~maarw/graphs/graph.html
and http://www.netdimes.org/new/?q=node/17

Graph

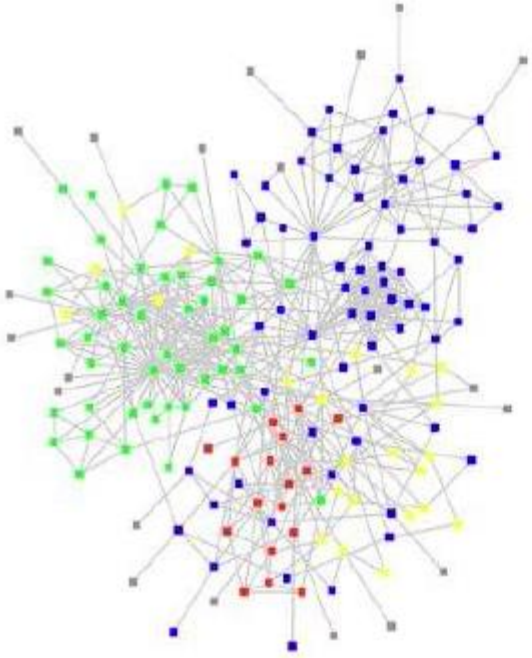
- Citation graph



The images are downloaded from
http://www.emeraldinsight.com/fig/2780600403005.png
and www.bordalierinstitute.com/target1.html

Graph

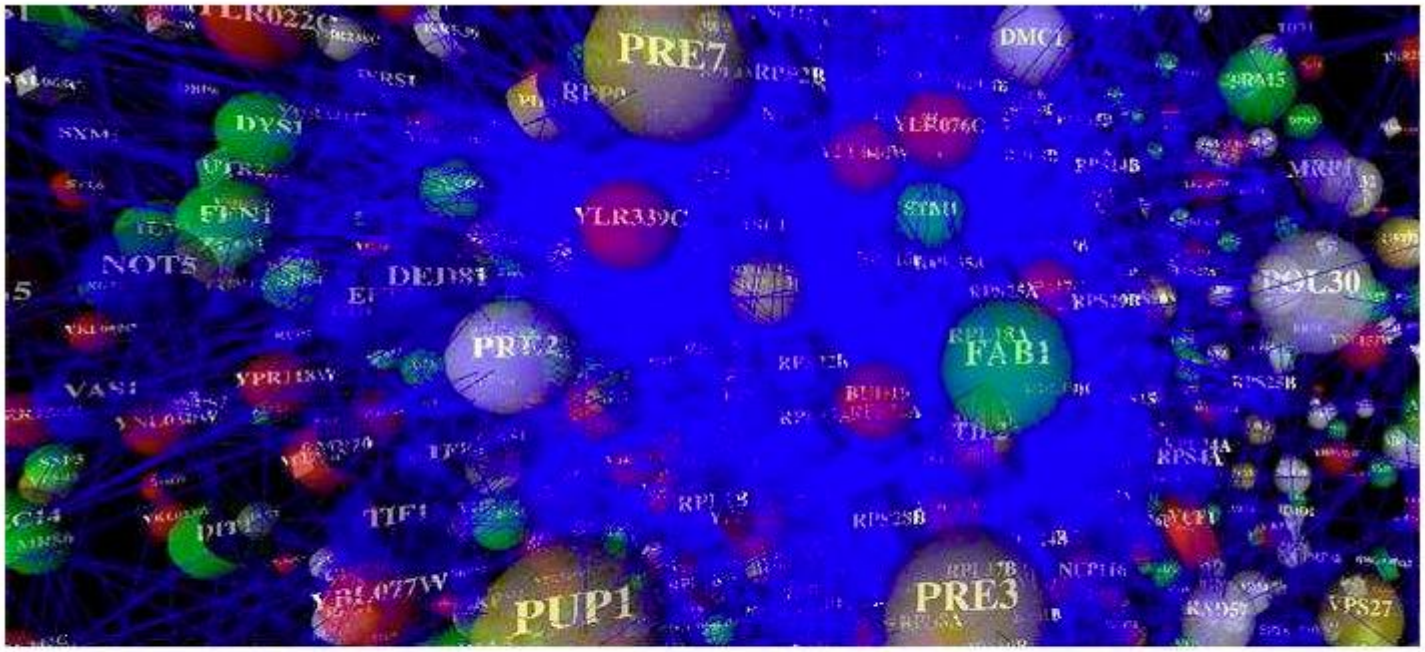
- Friendship graph



The images are downloaded from
http://www.thenetworkthinker.com/
and http://myweb20list.com/blog/2008/03/23/
new-amazing-facebook-photo-mapper/my-facebook-friend-graph/

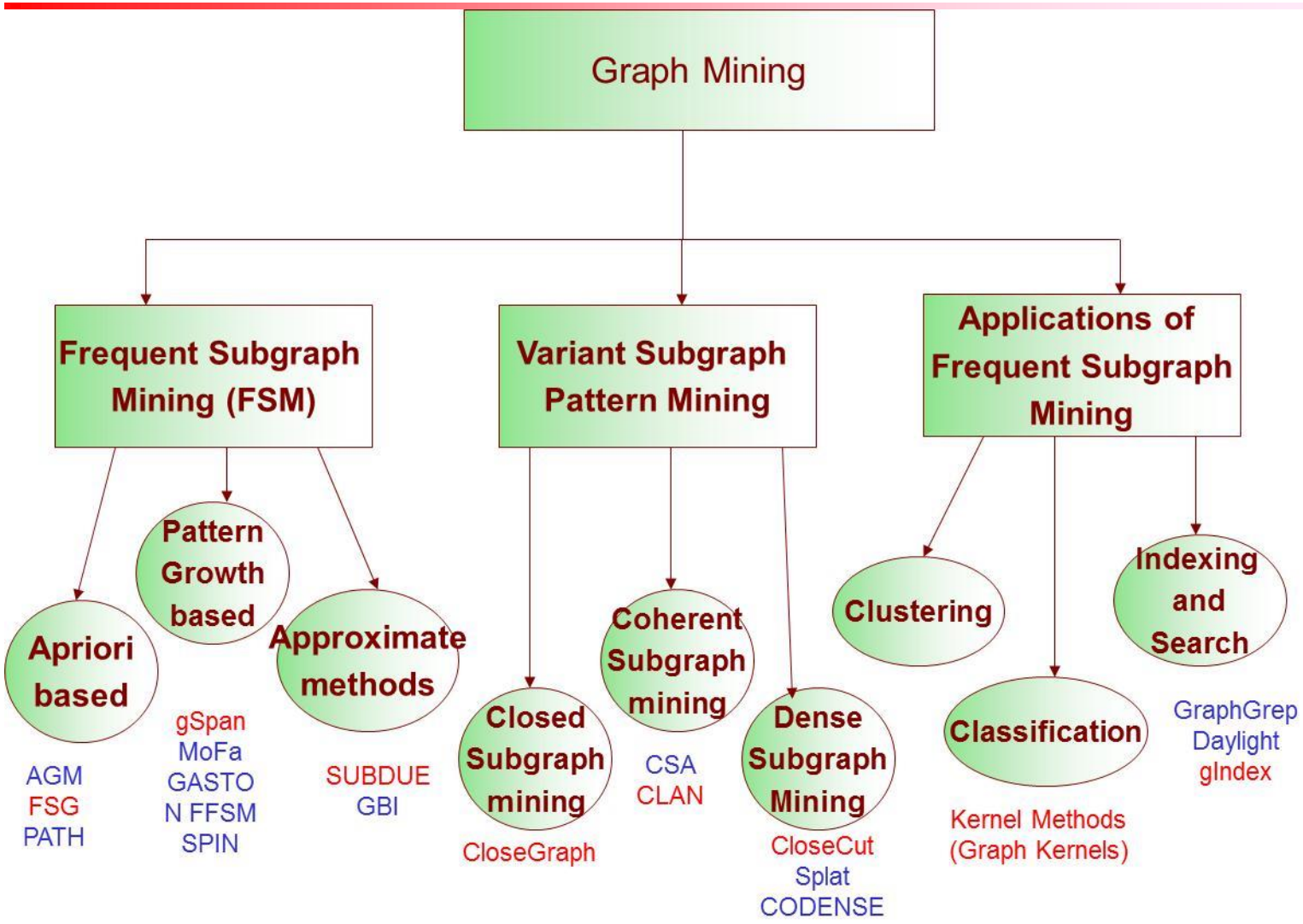
Graph

- Protein interaction graph



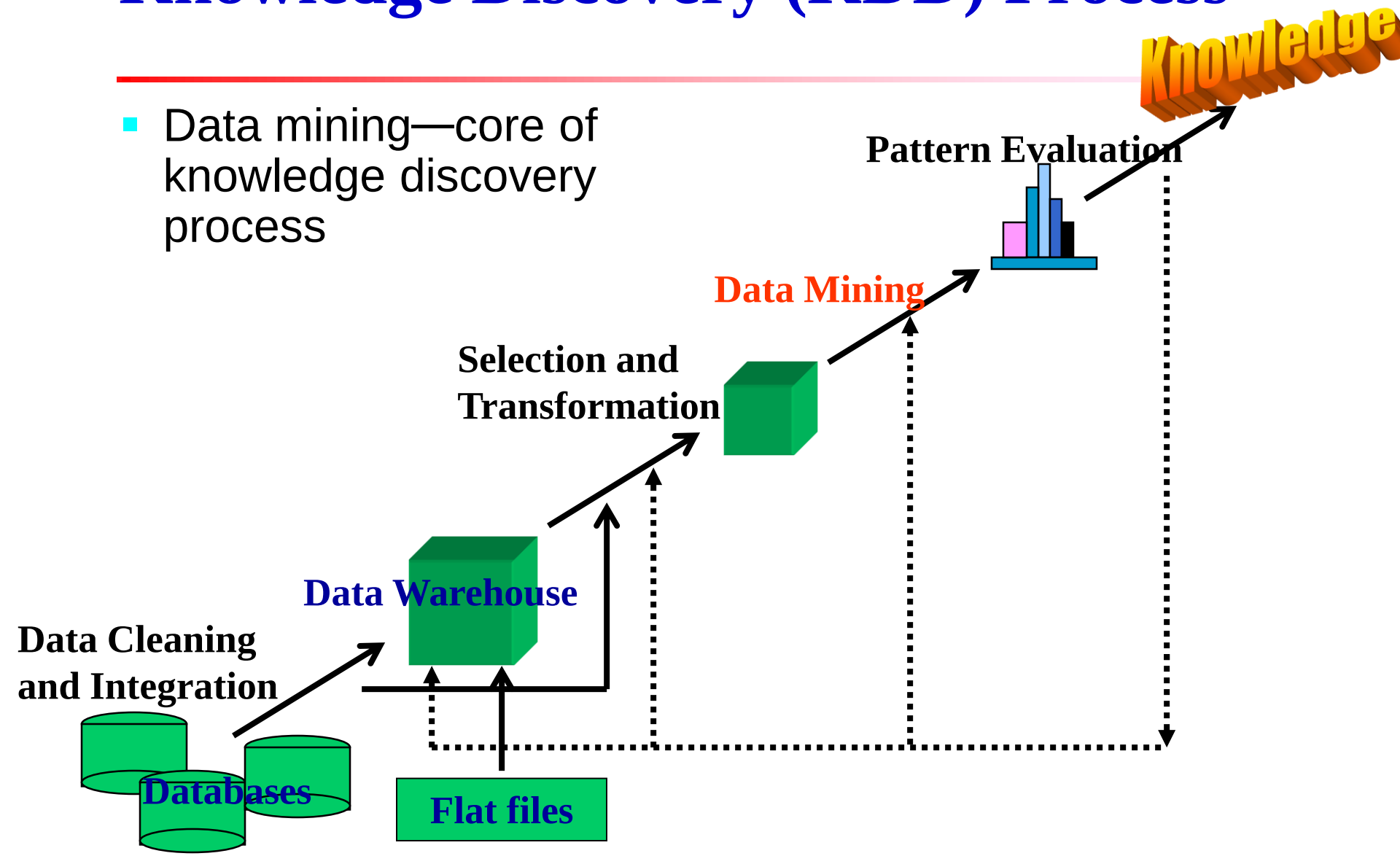
The images are downloaded from
http://bioinformatics.icmb.utexas.edu/lgl/Images/rsomZoom.jpg

Graph


Graph Mining
Frequent Subgraph Mining (FSM)
Variant Subgraph Pattern Mining
Applications of Frequent Subgraph Mining
Apriori based
Pattern Growth based
Approximate methods
Closed Subgraph mining
Coherent Subgraph mining
Dense Subgraph Mining
Clustering
Classification
Indexing and Search
AGM
FSG
PATH
gSpan
MoFa
GASTO
N FFSM
SPIN
SUBDUE
GBI
CloseGraph
CSA
CLAN
CloseCut
Splat
CODENSE
Kernel Methods
(Graph Kernels)
GraphGrep
Daylight
gIndex

Knowledge Discovery (KDD) Process

- Data mining—core of knowledge discovery process



Key Steps in KDD Process

- Learning the application domain
  - relevant prior knowledge and goals of application
- Creating a target data resource
- Data cleaning and preprocessing: (may take 60% of effort!)
- Data reduction and transformation
  - Find useful features, dimensionality/variable reduction, invariant representation
- Choosing the mining algorithm(s) to search for patterns of interest
- Pattern evaluation and knowledge presentation
  - visualization, transformation, removing redundant patterns, etc.
- Use of discovered knowledge

Are All the "Discovered" Patterns Interesting?

- Data mining may generate thousands of patterns: Not all of them are interesting
- Interestingness measures
  - A pattern is interesting if it is easily understood by humans, valid on new or test data with some degree of certainty, potentially useful, novel, or validates some hypothesis that a user seeks to confirm
- Objective vs. subjective interestingness measures
  - Objective: based on statistics and structures of patterns, e.g., support, confidence, etc.
  - Subjective: based on user's belief in the data, e.g., unexpectedness, novelty, actionability, etc.

Find All and Only Interesting Patterns?

- Find all the interesting patterns: Completeness
  - Can a data mining system find all the interesting patterns? Do we need to find all of the interesting patterns?
  - Heuristic vs. exhaustive search
- Search for only interesting patterns: An optimization problem — Challenging
  - Can a data mining system find only the interesting patterns?
  - Approaches
    - First generate all the patterns and then filter out the uninteresting ones
    - Guide and constrain the discovery process

Research Issues in Data Mining

- Mining methodology
  - Mining different kinds of knowledge from diverse data types, e.g., Web, graph, bio, stream, image, audio
  - Performance: efficiency, effectiveness, and scalability
  - Parallel, distributed and incremental mining methods
  - Handling noise and incomplete data
  - Pattern evaluation: the interestingness problem
  - Incorporation of background knowledge

Research Issues in Data Mining

- User interaction
  - Data mining query languages
  - Expression and visualization of data mining results
- Applications and social impacts
  - Domain-specific data mining
  - Protection of data security, integrity, and privacy

Important Resources

- Data mining conferences
  - ACM SIGKDD, IEEE ICDM, SIAM DM, PKDD, PAKDD
- Database conferences
  - ACM SIGMOD, VLDB, ACM PODS, IEEE ICDE, EDBT, ICDT
- Important journals
  - ACM Data Mining and Knowledge Discovery
  - IEEE Transactions on Knowledge and Data Engineering
  - Knowledge and Information Systems