Data Mining: Introduction

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Introduction to Data Mining, 2nd Edition
Chapter 1

What is Data Mining?

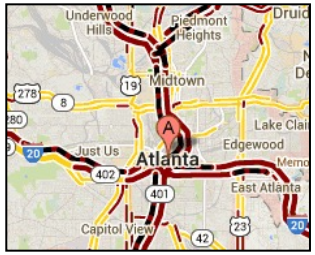
It is the use of **efficient** techniques for the analysis of **very large collections of data** and the **extraction** of useful and possibly unexpected patterns in data (hidden knowledge).

Large-scale Data is Everywhere!

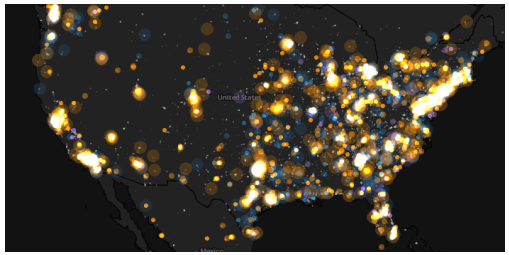
- **Enormous data growth in both commercial and scientific databases**
  - due to advances in data generation and collection technologies
- **New mantra**
  - Gather whatever data you can whenever and wherever possible
- **Expectations**
  - Gathered data will have value either for the purpose collected or for a purpose not envisioned.

Cyber Security

E-Commerce

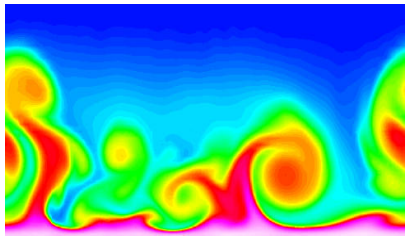


Traffic Patterns



Social Networking: Twitter

Sensor Networks



Computational Simulations

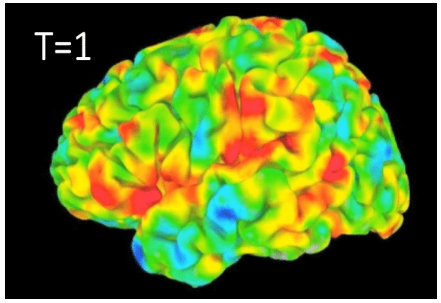
Why Data Mining? Commercial Viewpoint

- **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

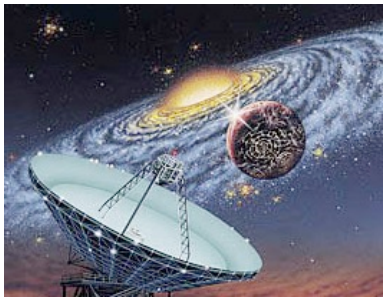
- **Computers have become cheaper and more powerful**
- **Competitive Pressure is Strong**
  - Provide better, customized services for an edge (e.g. in Customer Relationship Management)

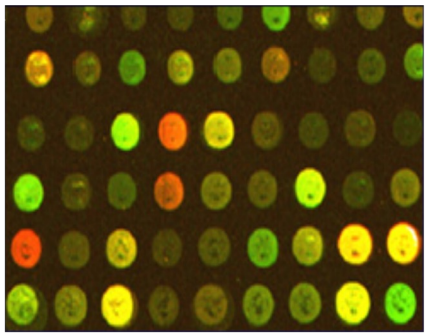
Why Data Mining? Scientific Viewpoint

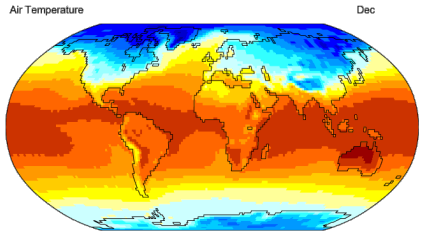
- **Data collected and stored at enormous speeds**
  - remote sensors on a satellite
    - NASA EOSDIS archives over petabytes of earth science data / year
  - telescopes scanning the skies
    - Sky survey data
  - High-throughput biological data
  - scientific simulations
    - terabytes of data generated in a few hours
- **Data mining helps scientists**
  - in automated analysis of massive datasets
  - In hypothesis formation



fMRI Data from Brain


Sky Survey Data


Gene Expression Data

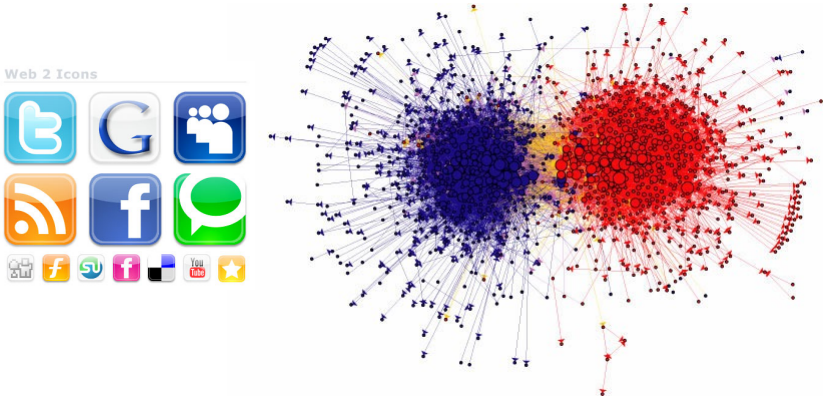


Surface Temperature of Earth

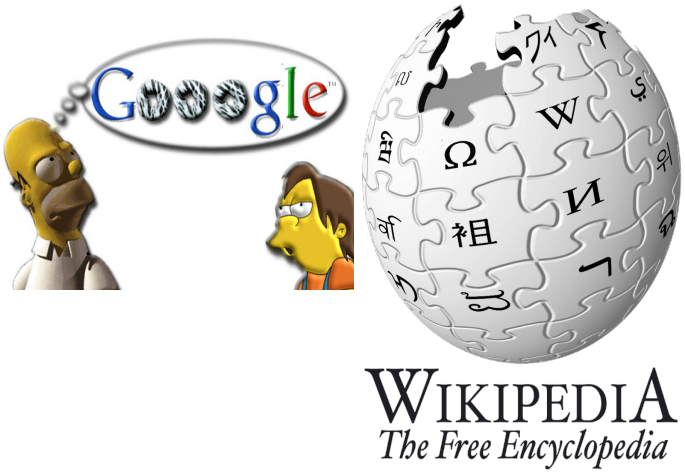
Big data proxies of social life

Shopping patterns & lyfestyle

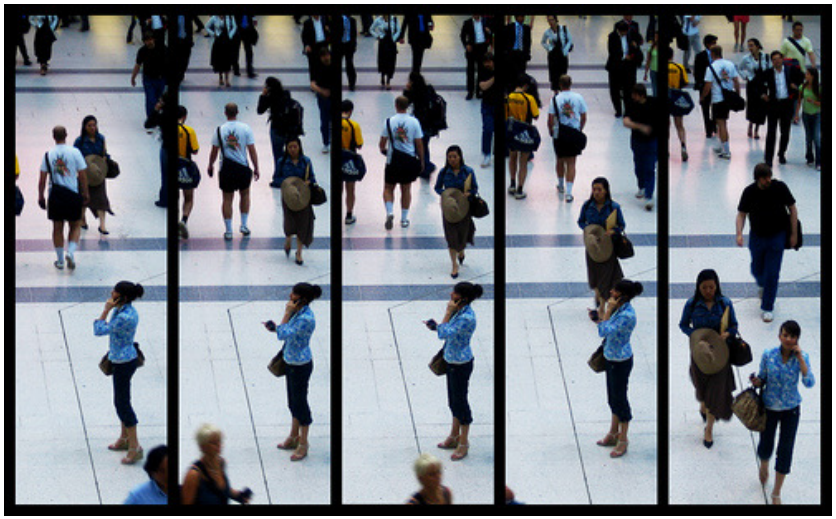
RELATIONSHIPS & SOCIAL TIES

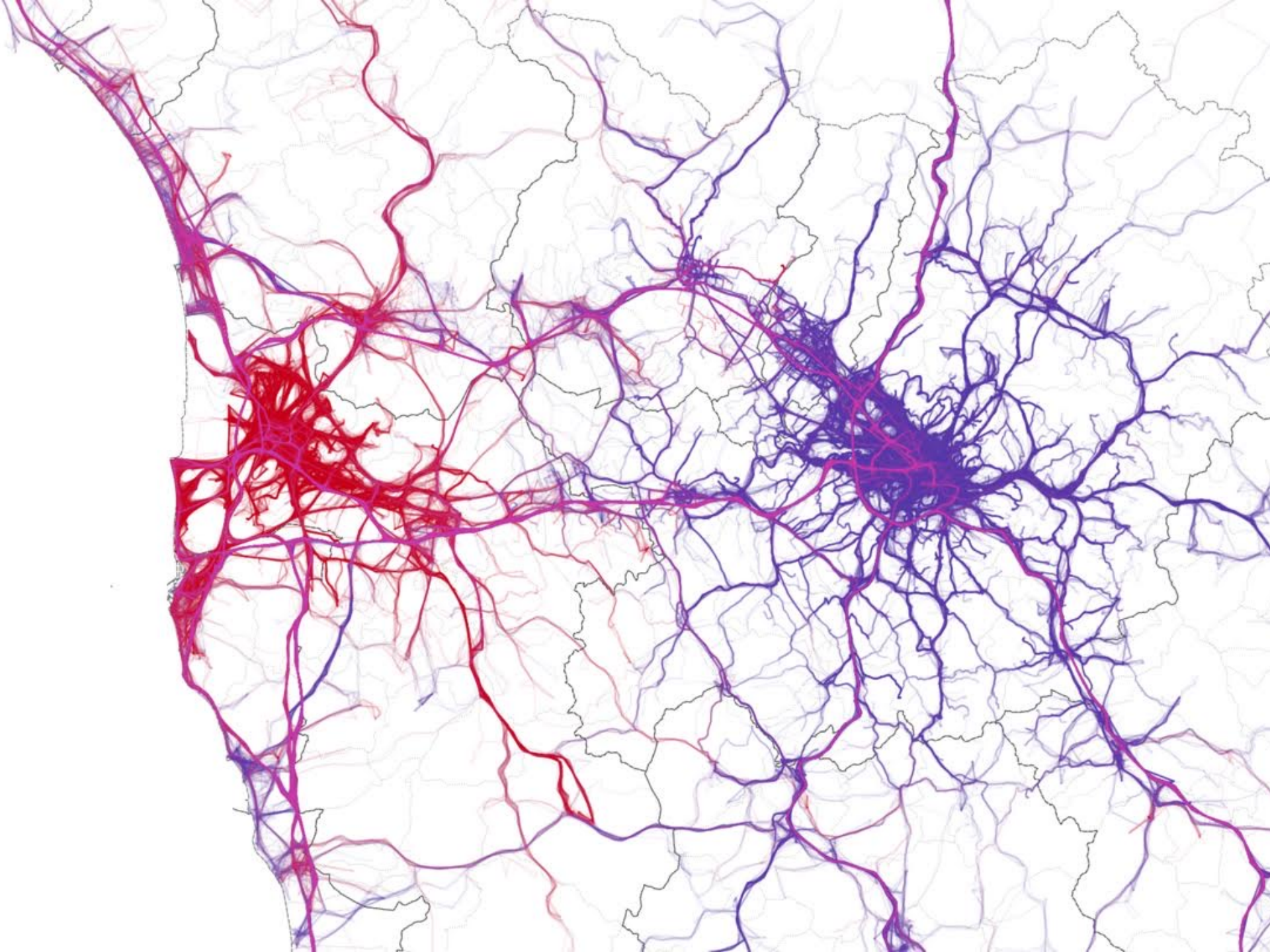


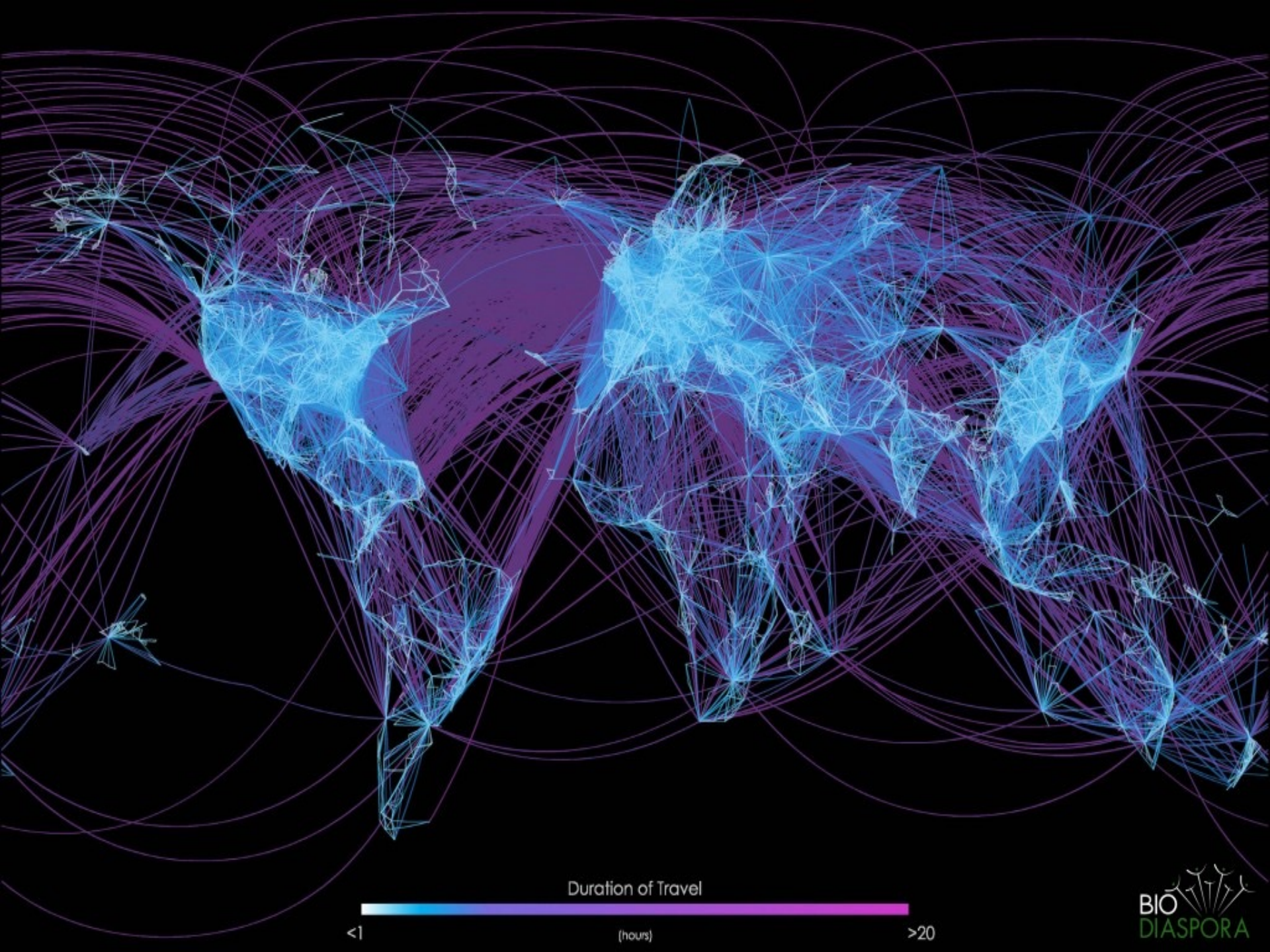
DESIRES, OPINIONS, SENTIMENTS



MOVEMENTS



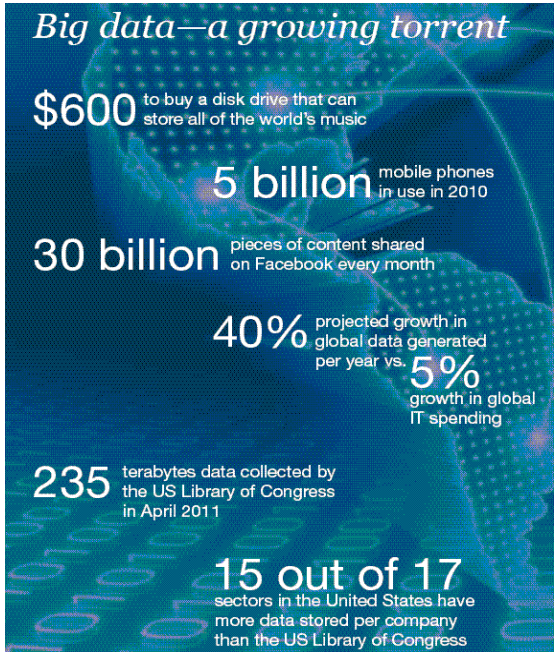


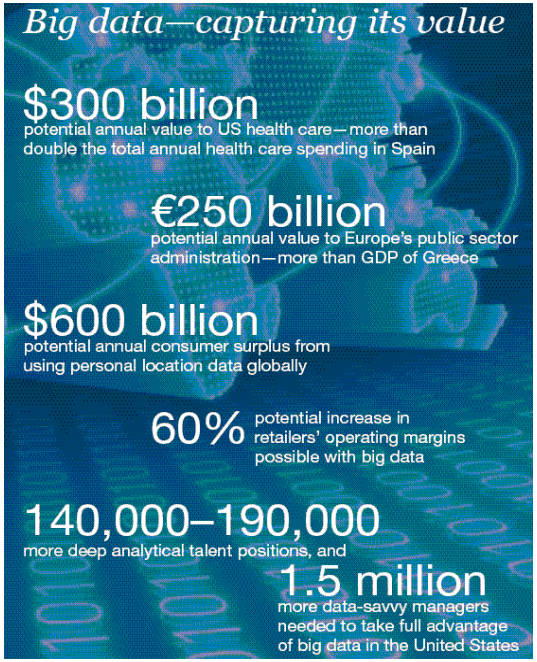

Duration of Travel
<1
(hours)
>20
BIO
DIASPORA

Great opportunities to improve productivity in all walks of life

McKinsey Global Institute

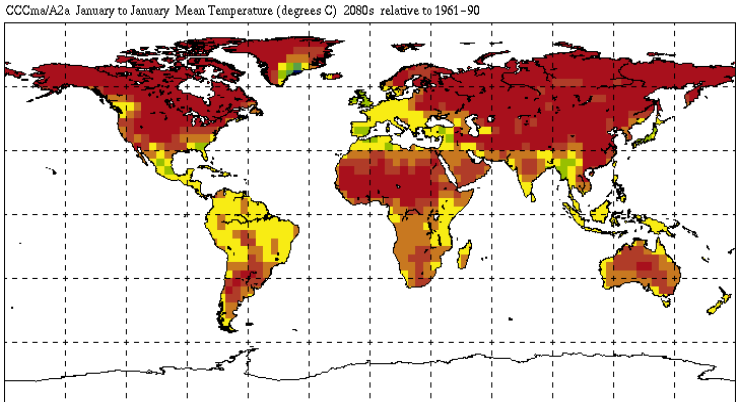
Big data: The next frontier for innovation, competition, and productivity





Great Opportunities to Solve Society's Major Problems

Improving health care and reducing costs

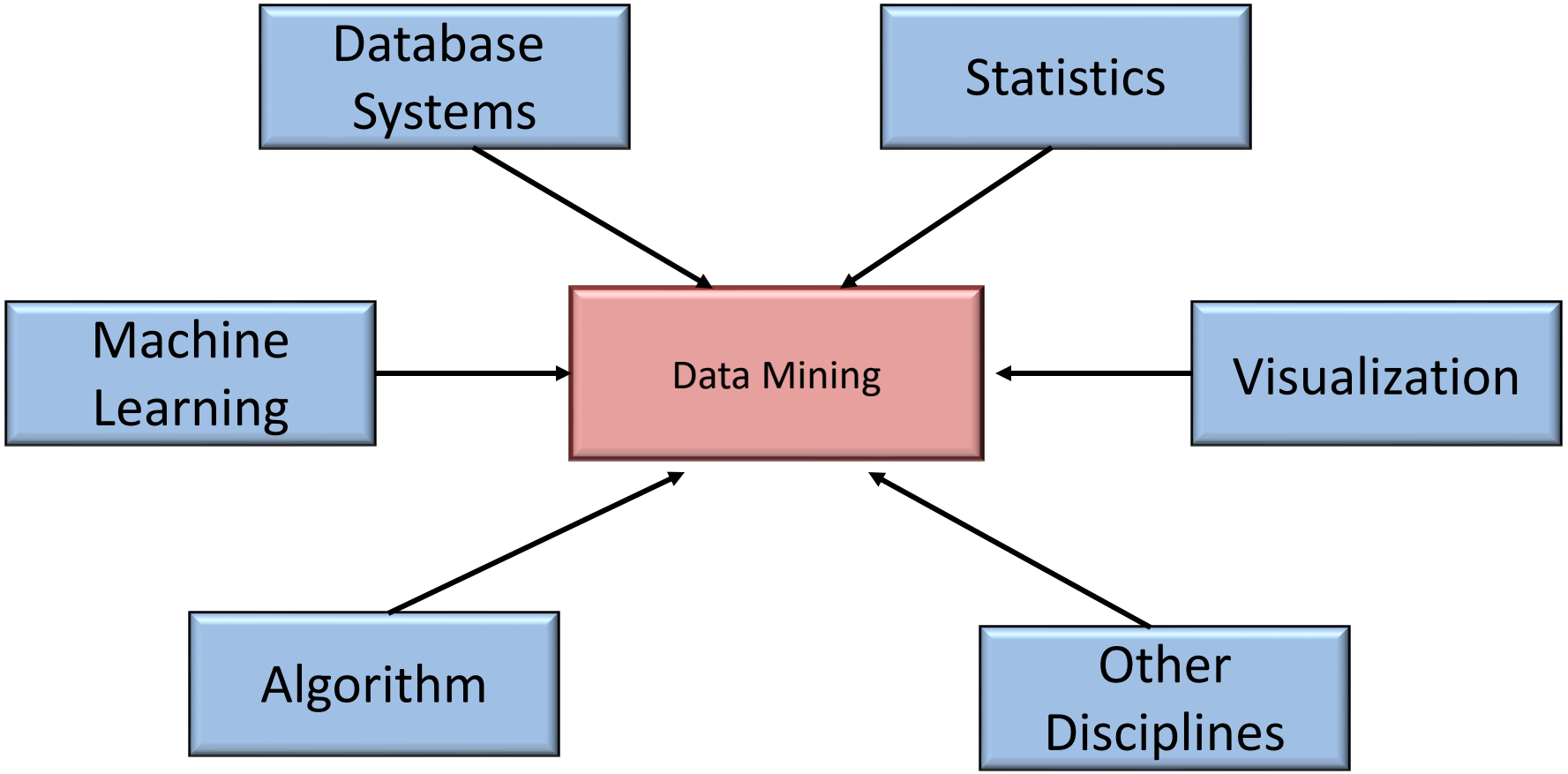


Predicting the impact of climate change

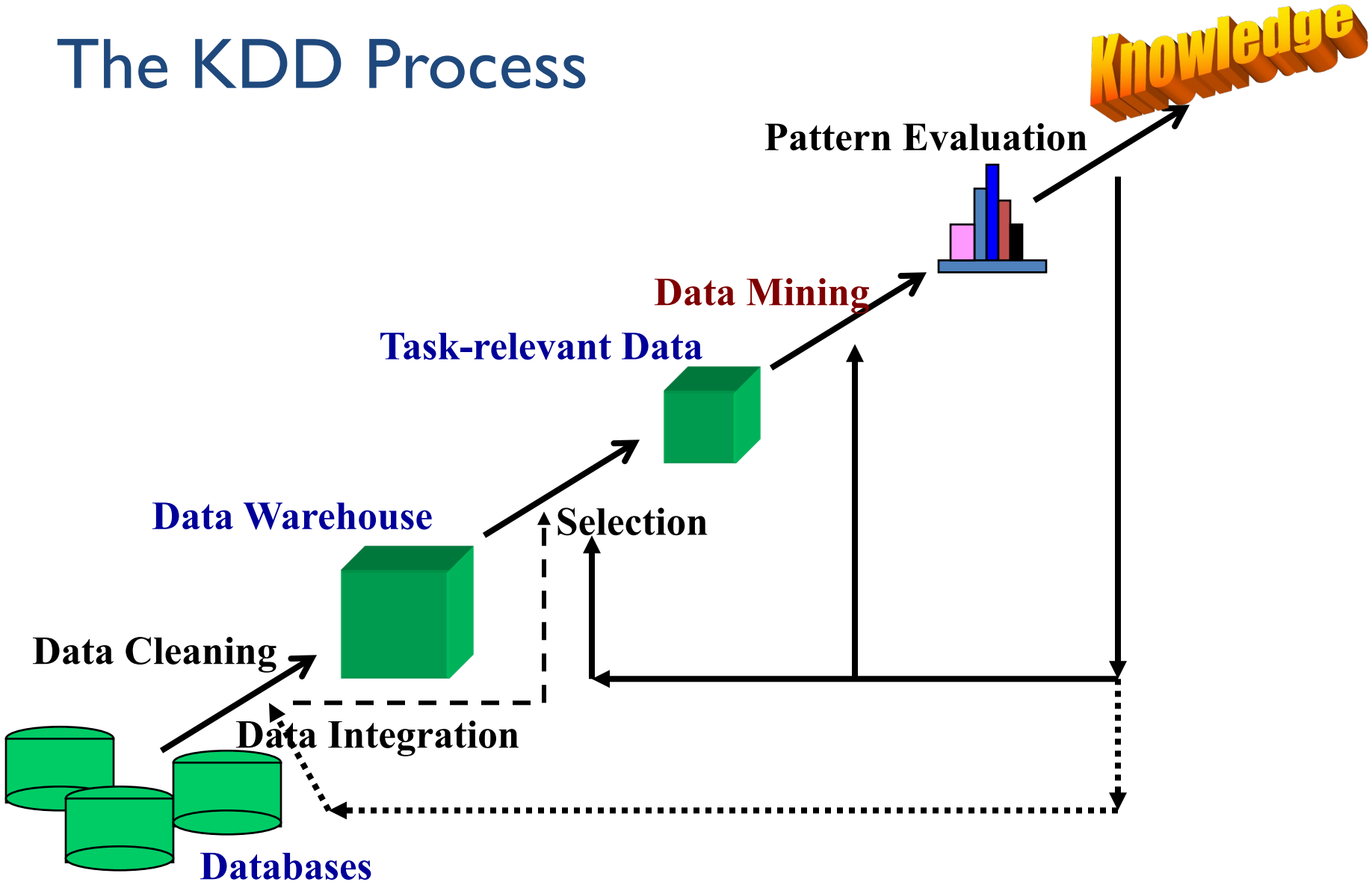
Finding alternative/ green energy sources

Reducing hunger and poverty by increasing agriculture production

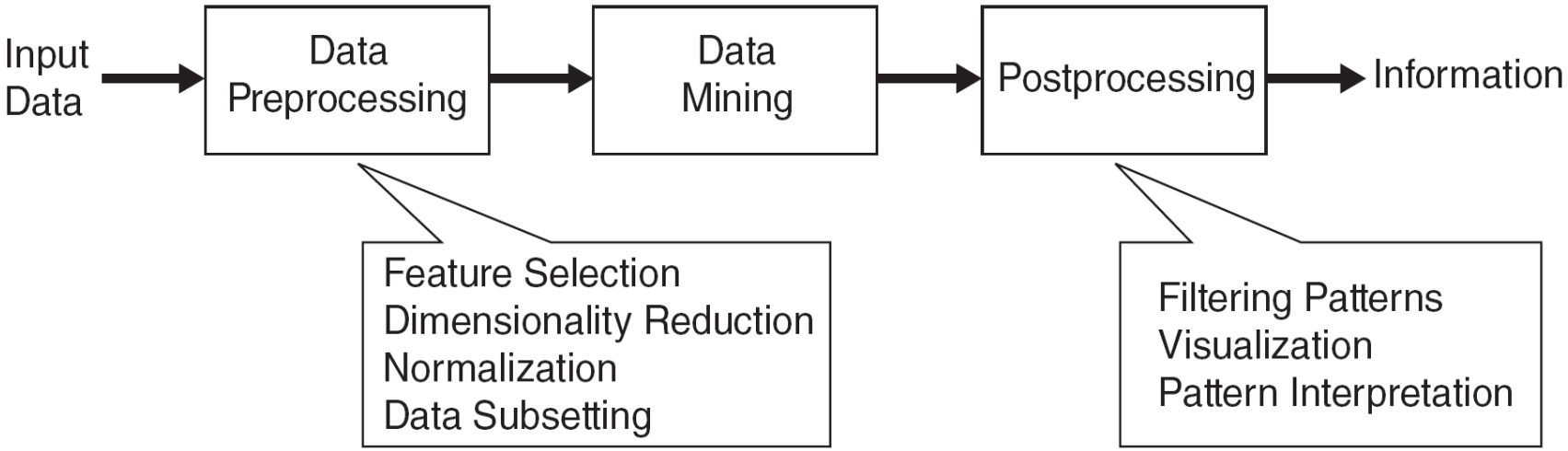
Data Mining: Confluence of Multiple Disciplines



The KDD Process



What is Data Mining?



Primary & Secondary Data

Primary Data

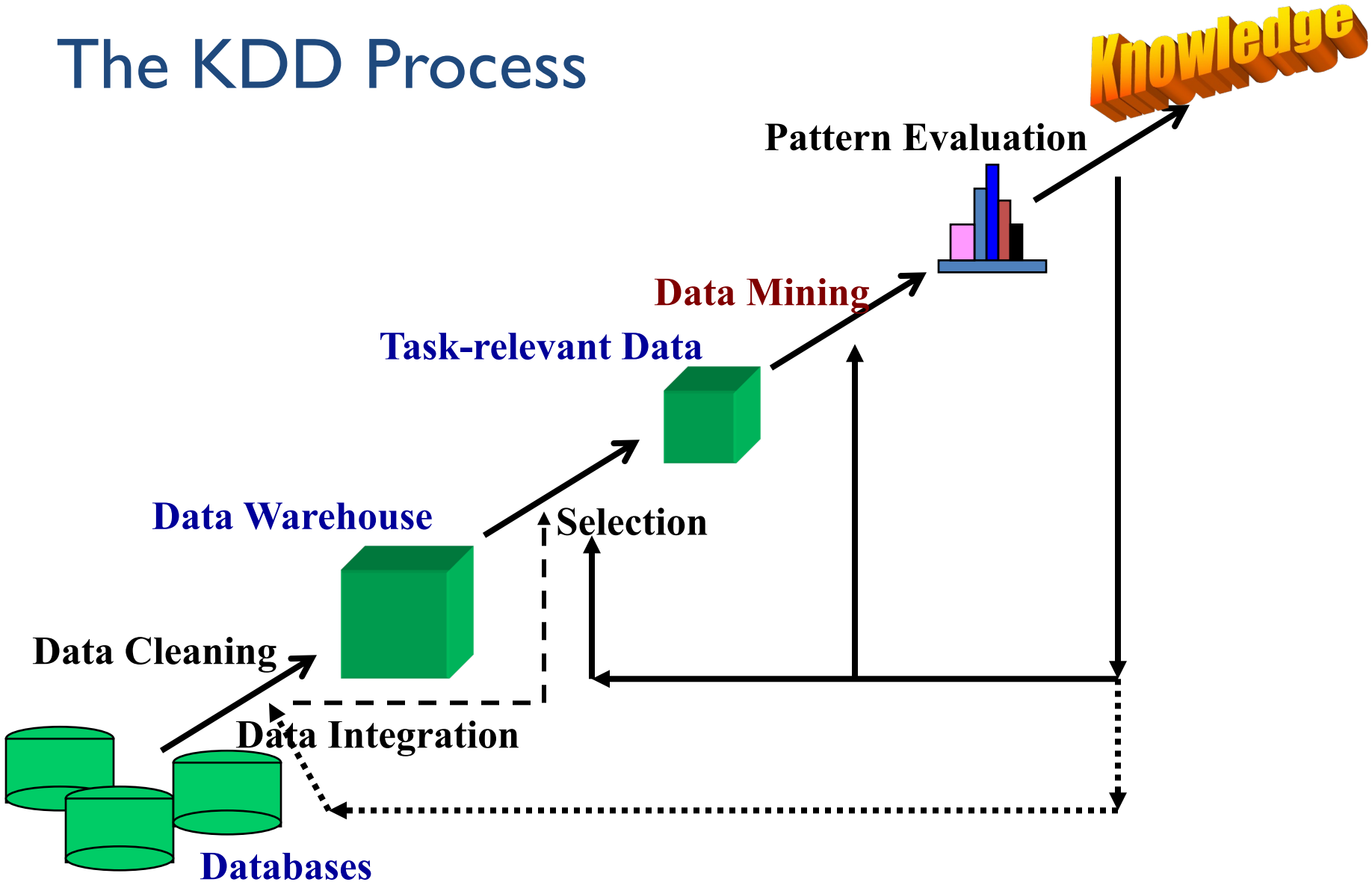
- **Original data** that has been collected for a specific purpose
- Primary data **is not altered by humans**

Secondary Data

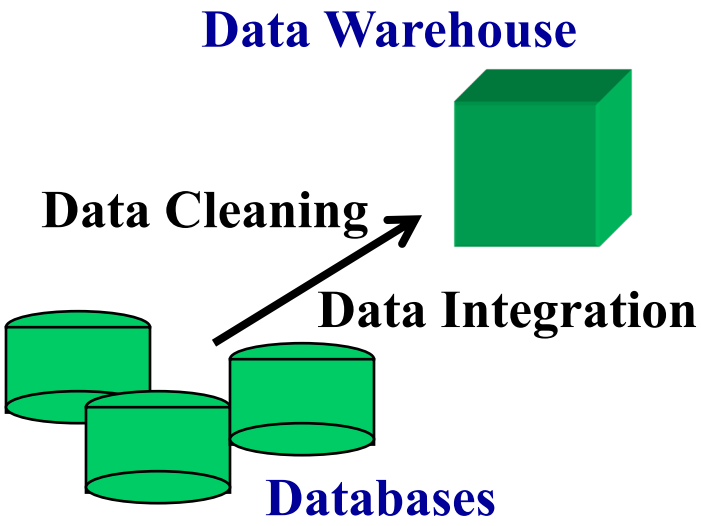
- **Data that** has been already collected and **made available for other purposes**
- Secondary data may be obtained **from many sources**

Varierty of Data Sources

The KDD Process



Data Integration and Preparation

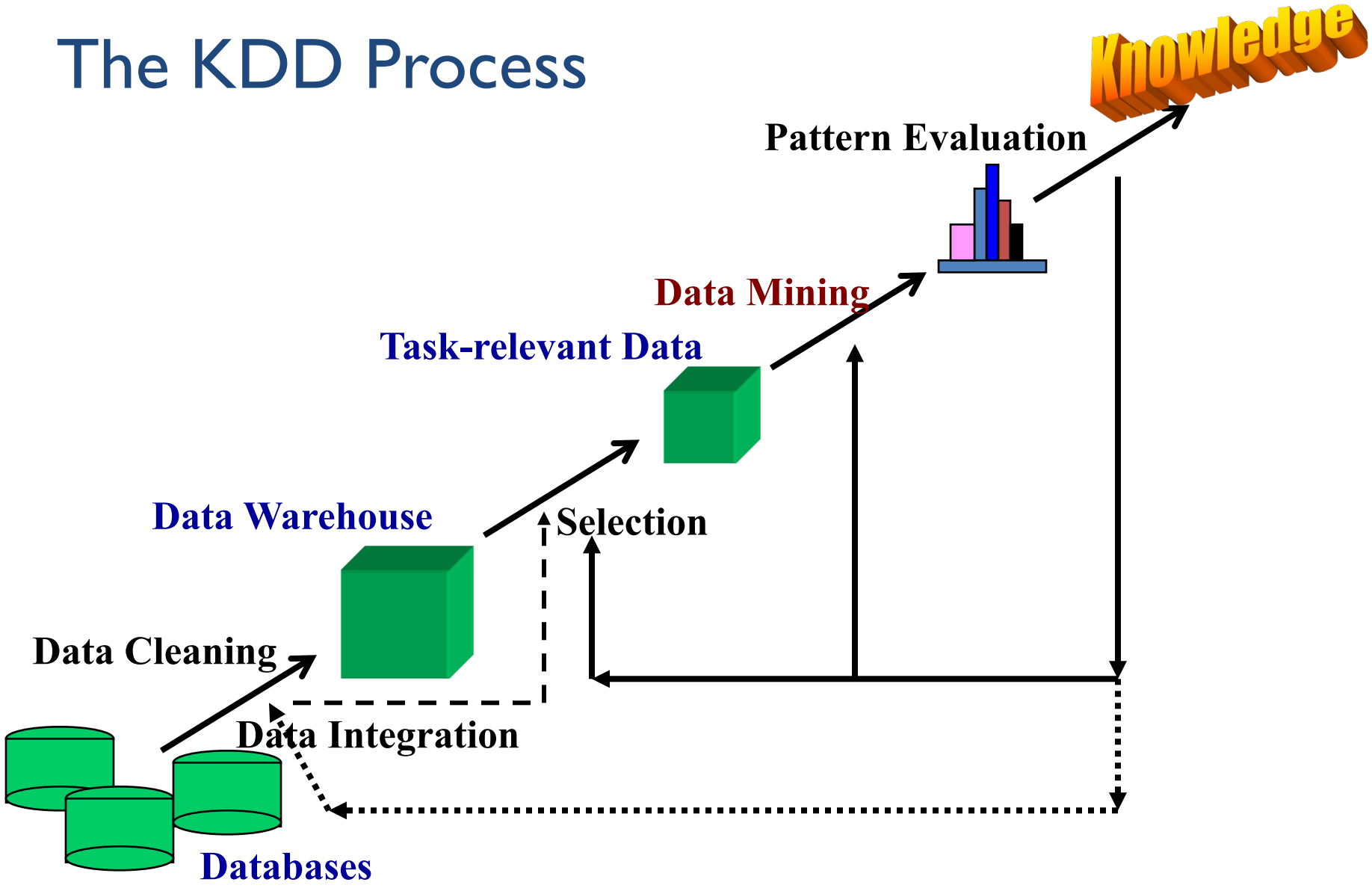


Data Integration involves the process of data understanding, data cleaning, merging data coming from multiple sources and transfoming them to load them into a **Data Warehouse**

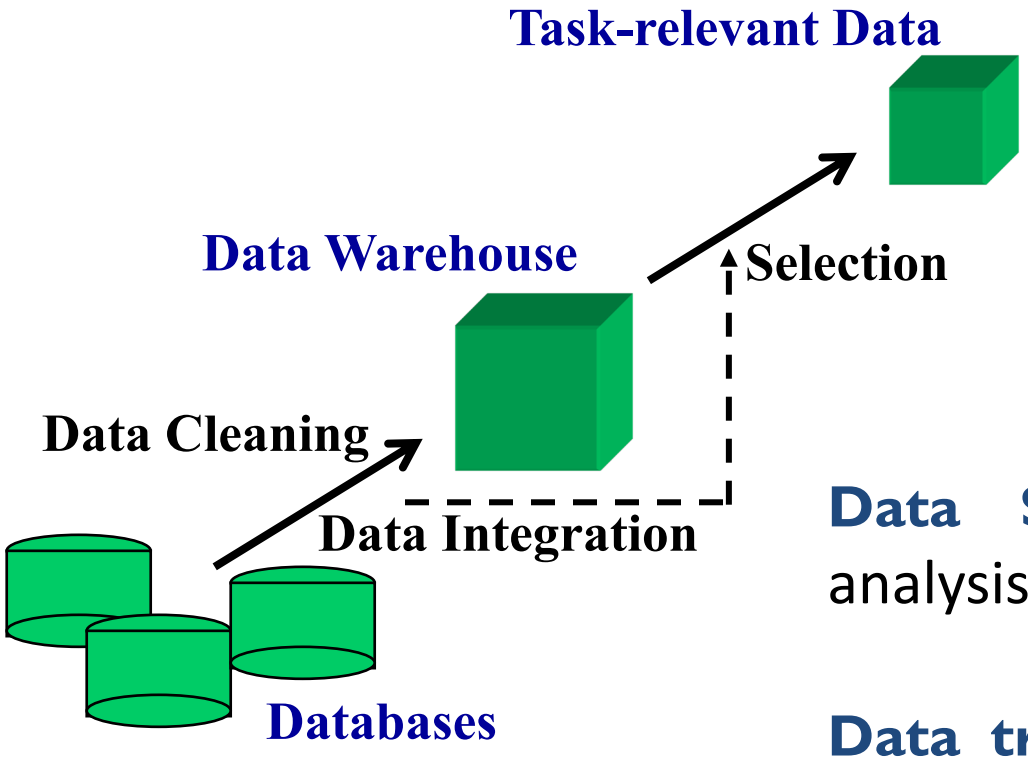
Data Warehouse is a database targeted to answer **specific business questions**

Developing a data analytics project requires the
BUSINESS UNDERSTANDING

The KDD Process



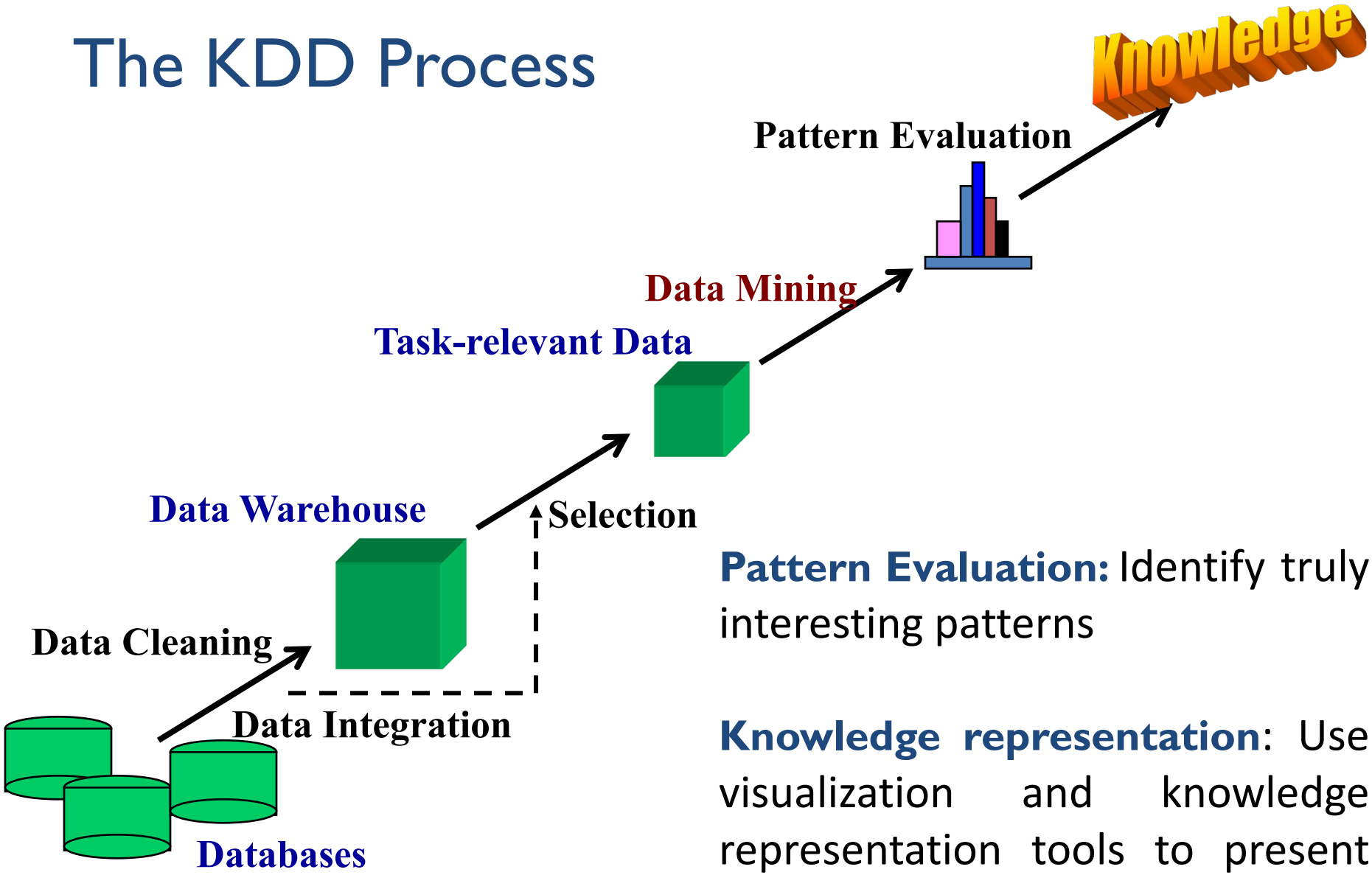
Data Selection and Transformation



Data Selection: Data relevant to analysis tasks are retrieved from data

Data transformation: Transform data into appropriate form for mining (summary, aggregation, etc.)

The KDD Process



Pattern Evaluation: Identify truly interesting patterns

Knowledge representation: Use visualization and knowledge representation tools to present the mined data to the user

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.

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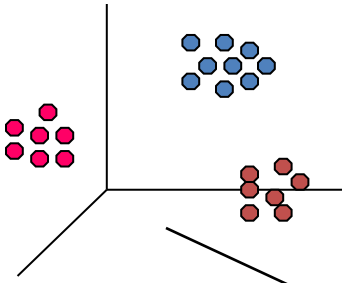
  - Find human-interpretable patterns that describe the data.

From [Fayyad, et.al.] Advances in Knowledge Discovery and Data Mining, 1996

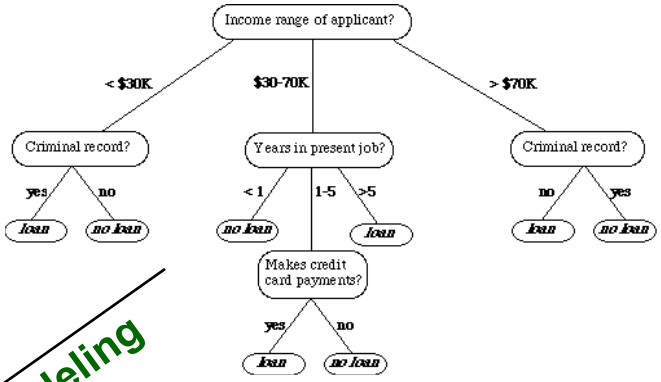
Data Mining Tasks ...



Clustering

Data

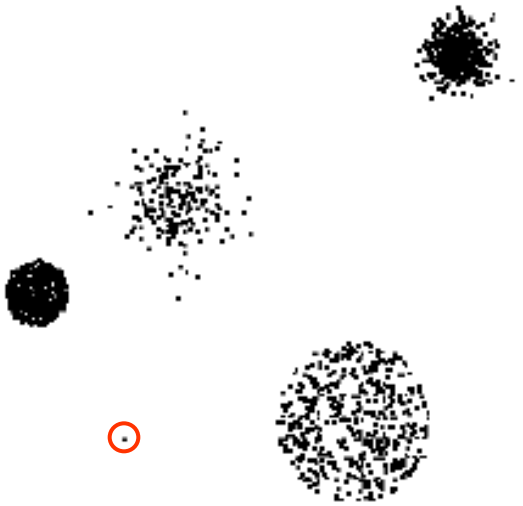
Tid	Refund	Marital Status	Taxable Income	Cheat
1	Yes	Single	125K	No
2	No	Married	100K	No
3	No	Single	70K	No
4	Yes	Married	120K	No
5	No	Divorced	95K	Yes
6	No	Married	60K	No
7	Yes	Divorced	220K	No
8	No	Single	85K	Yes
9	No	Married	75K	No
10	No	Single	90K	Yes
11	No	Married	60K	No
12	Yes	Divorced	220K	No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



Predictive Modeling

Association Rules

Anomaly Detection



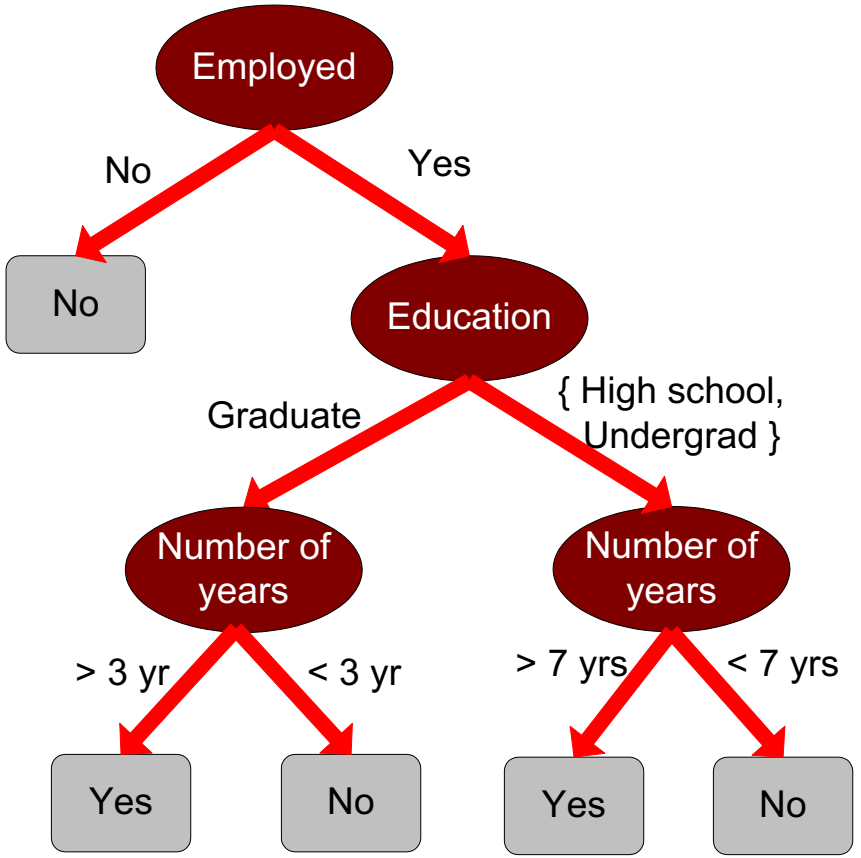
Predictive Modeling: Classification

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

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
…	…	…	…	…

Model for predicting credit worthiness

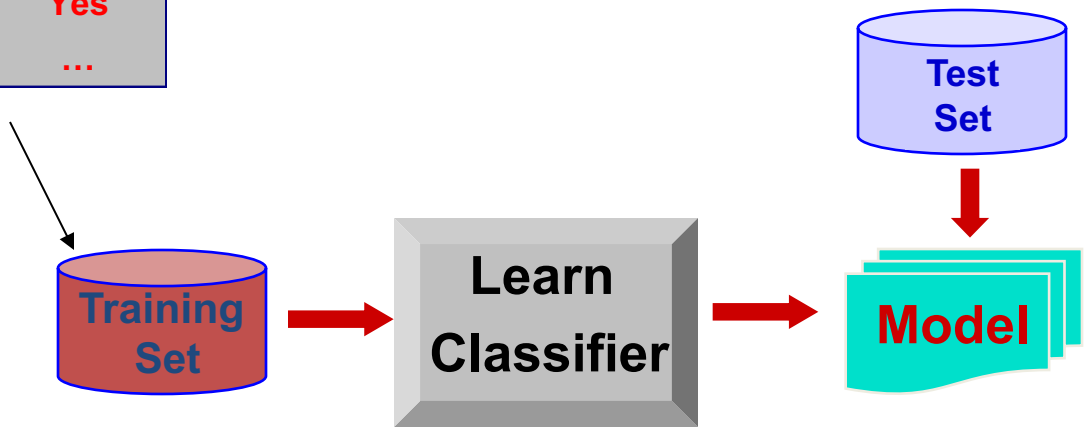


Classification Example

categorical categorical quantitative class

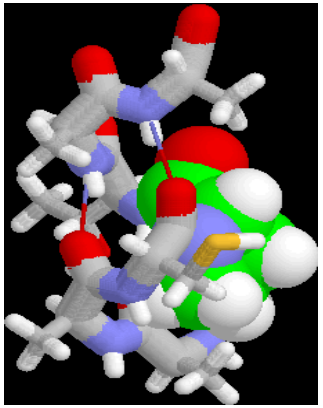
Tid	Employed	Level of Education	# years at present address	Credit Worthy
1	Yes	Graduate	5	Yes
2	Yes	High School	2	No
3	No	Undergrad	1	No
4	Yes	High School	10	Yes
…	…	…	…	…

Tid	Employed	Level of Education	# years at present address	Credit Worthy
1	Yes	Undergrad	7	?
2	No	Graduate	3	?
3	Yes	High School	2	?
…	…	…	…	…

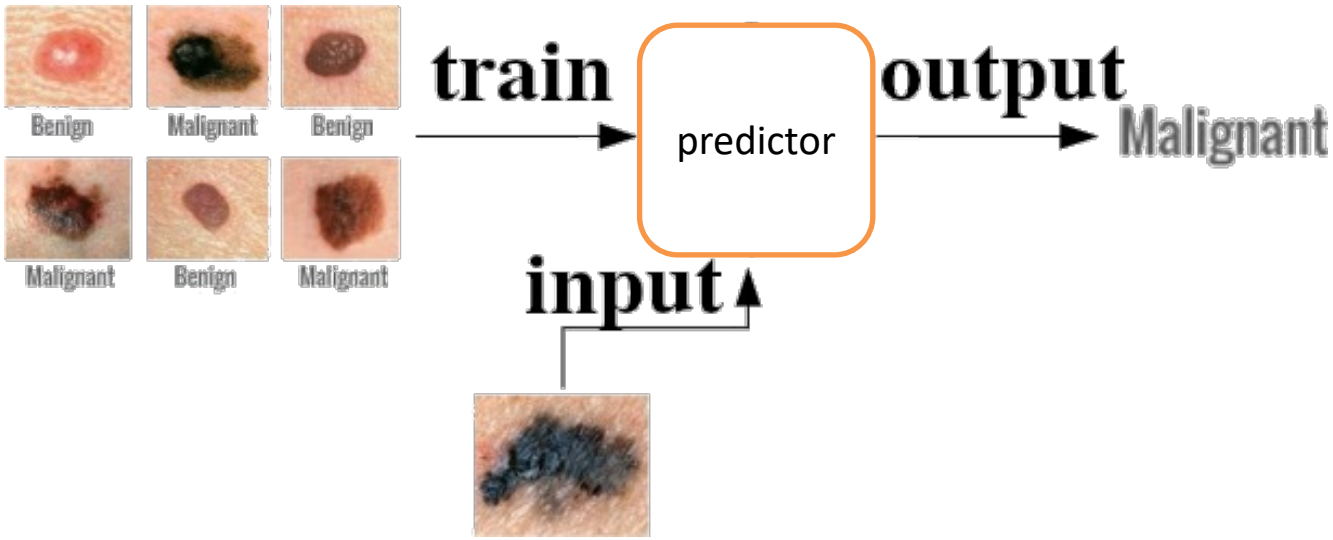


Examples of Classification Task

- Classifying credit card transactions as legitimate or fraudulent
- Classifying land covers (water bodies, urban areas, forests, etc.) using satellite data
- Categorizing news stories as finance, weather, entertainment, sports, etc
- 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



AI = Machine Learning + Big Data



Classification: Application 1

Fraud Detection

- **Goal:** Predict fraudulent cases in credit card transactions.
- **Approach:**
  - 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.

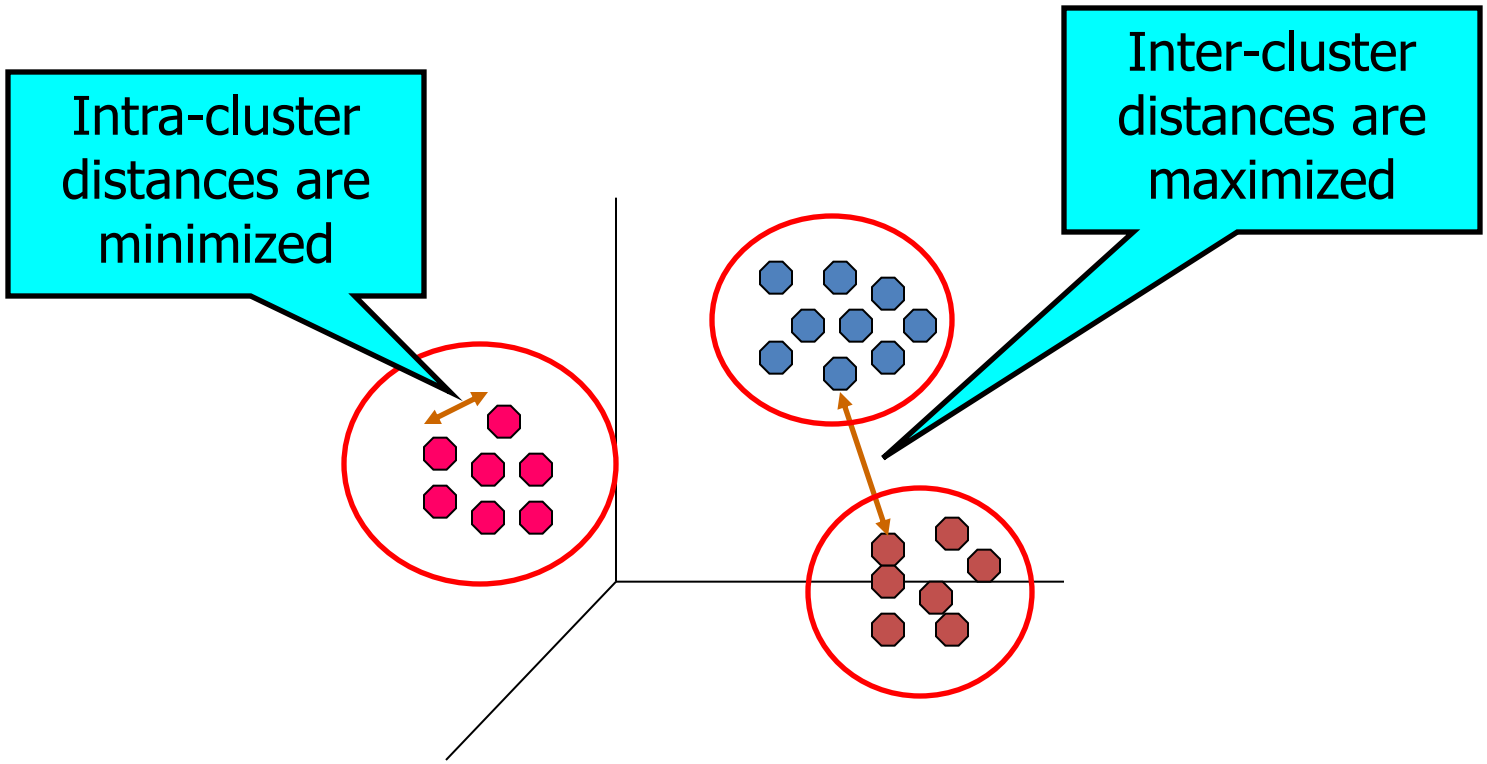
Classification: Application 2

Churn prediction for telephone customers

- **Goal:** To predict whether a customer is likely to be lost to a competitor.
- **Approach:**
  - 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 time-of-the day he calls most, his financial status, marital status, etc.
  - Label the customers as loyal or disloyal.
  - Find a model for loyalty.

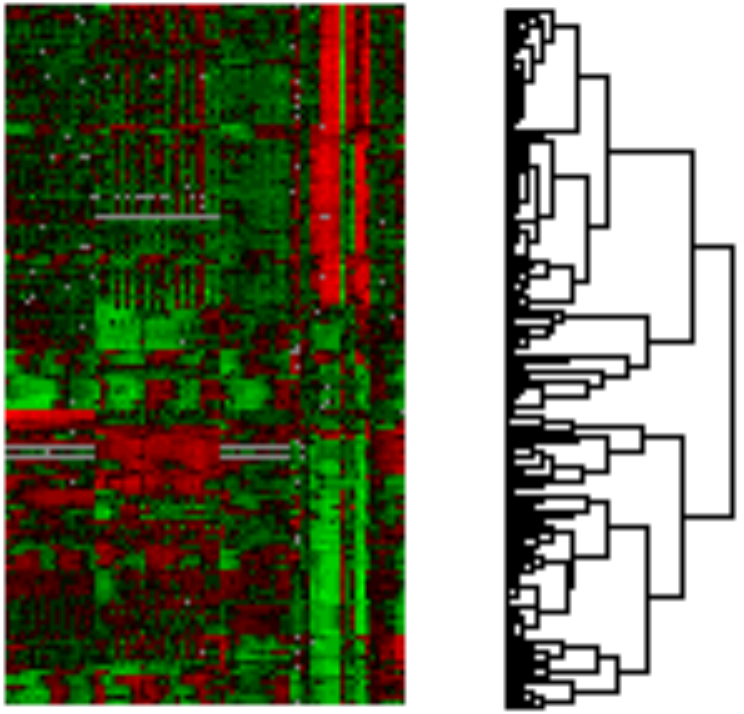
Clustering

- 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

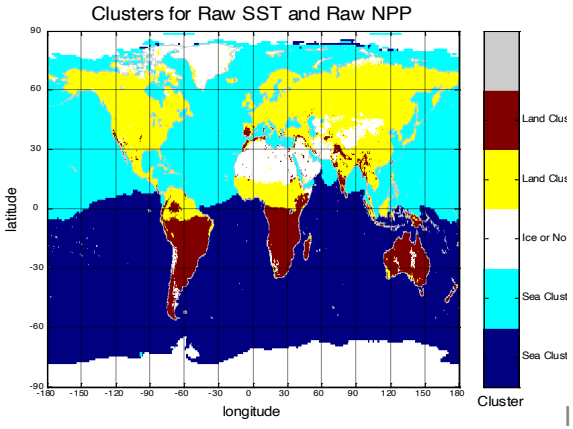


Applications of Cluster Analysis

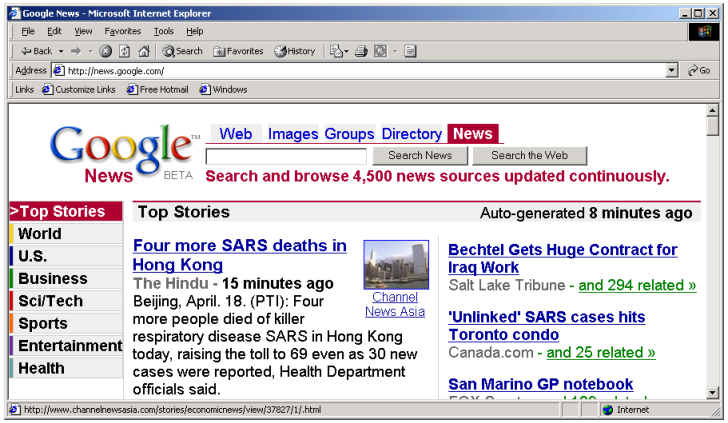
- **Understanding**
  - Custom profiling for targeted marketing
  - Group related documents for browsing
  - Group genes and proteins that have similar functionality
  - Group stocks with similar price fluctuations
- **Summarization**
  - Reduce the size of large data sets



Courtesy: Michael Eisen



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



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.
- **Approach:**
  - 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.

A Behavior Based Segmentation

Using unsupervised clustering segmentation for a grocery chain which would like better product assortment for its high profitable customers

Potential Inputs

Value	• Basket Size • Visit Frequency
Basket	• Spend by category • Type of category • Brand spend (i.e. private label)
Promotions	• % bought on targeted promotion • % bought from flyer
Time	• Time of day • Day of week
Location	• Store format • Area population density

Clustering approach

Deal Seeking Mom

Key Differentiators

- Full store shop
- High avg. basket size / # trips

- High % purchased on promotion
- Rewards seeker

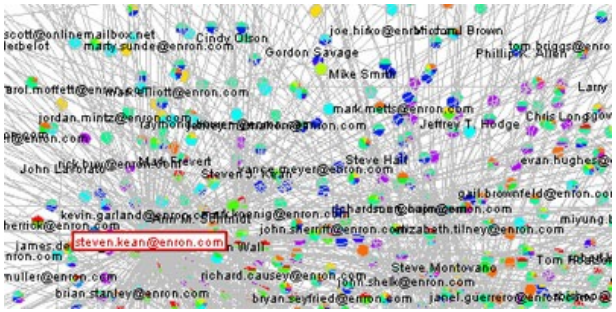
- High spend categories
  - Fresh produce
  - Organic food
  - Multipack juice, snack

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

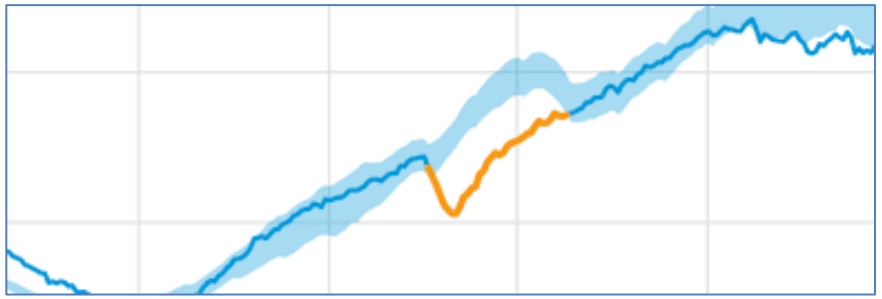
Rules Discovered:
{Milk} --> {Coke}
{Diaper, Milk} --> {Beer}

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

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.

Motivating Challenges

Traditional techniques may be unsuitable due to some challenges:

- Scalability
- High Dimensionality
- Heterogeneous and Complex Data
- Data Ownership and Distribution
- Non-traditional Analysis