Introduction to Data Mining Methods and Tools

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DCII's Operations Research and Statistics Towards Integrated Analytics Research Cluster

Southern Methodist University

Wednesday, November 30, 2016

Agenda

- What is Data Mining?
- Data Mining Tasks
- Relationship to Statistics, Optimization, Machine Learning and AI
- Tools
- Data
- Legal, Privacy and Security Issues

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What is Data Mining?

One of many definitions:

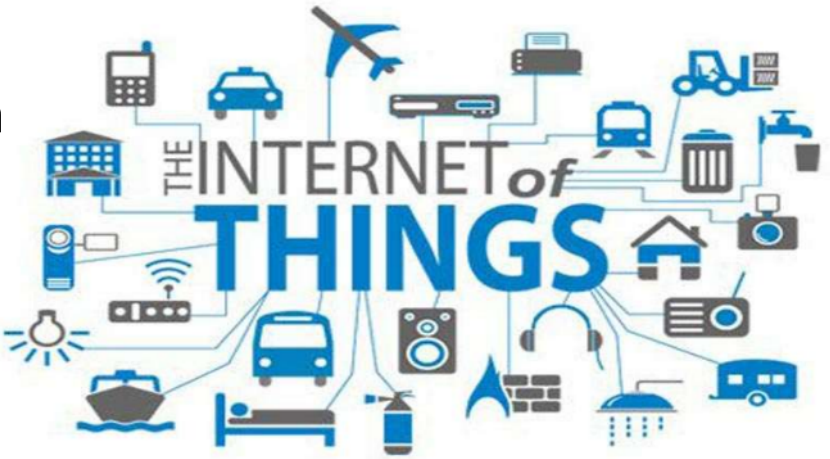
"*Data mining is the science of* ***extracting useful knowledge*** *from huge data repositories*"

ACM SIGKDD, Data Mining Curriculum: A Proposal

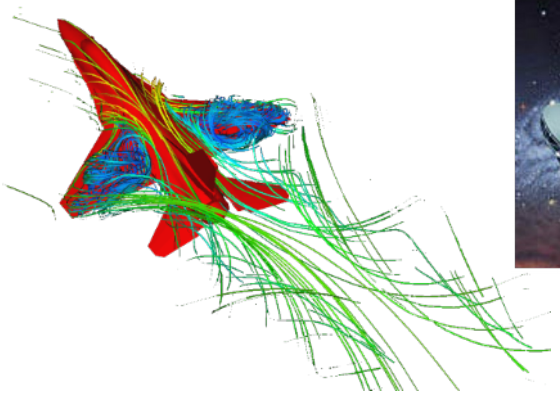
http://www.kdd.org/curriculum

Why Data Mining? Commercial Viewpoint

- Businesses collect and warehouse lots of **data**.
  - Purchases at department/grocery stores
  - Bank/credit card transactions
  - Web and social media data
  - Mobile and IOT
- **Computers** are cheaper and more powerful.
- **Competition** to provide better services.
  - Mass customization and recommendation systems
  - Targeted advertising
  - Improved logistics

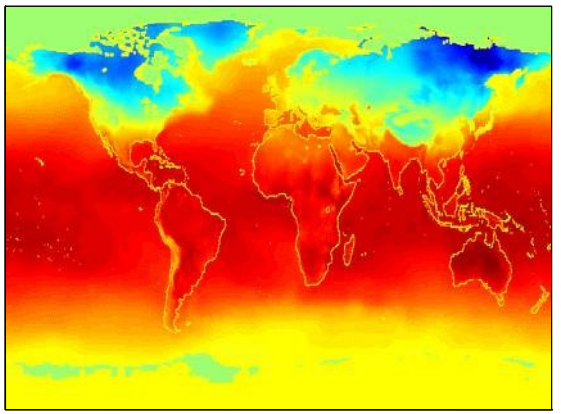


Why Mine Data? Scientific Viewpoint

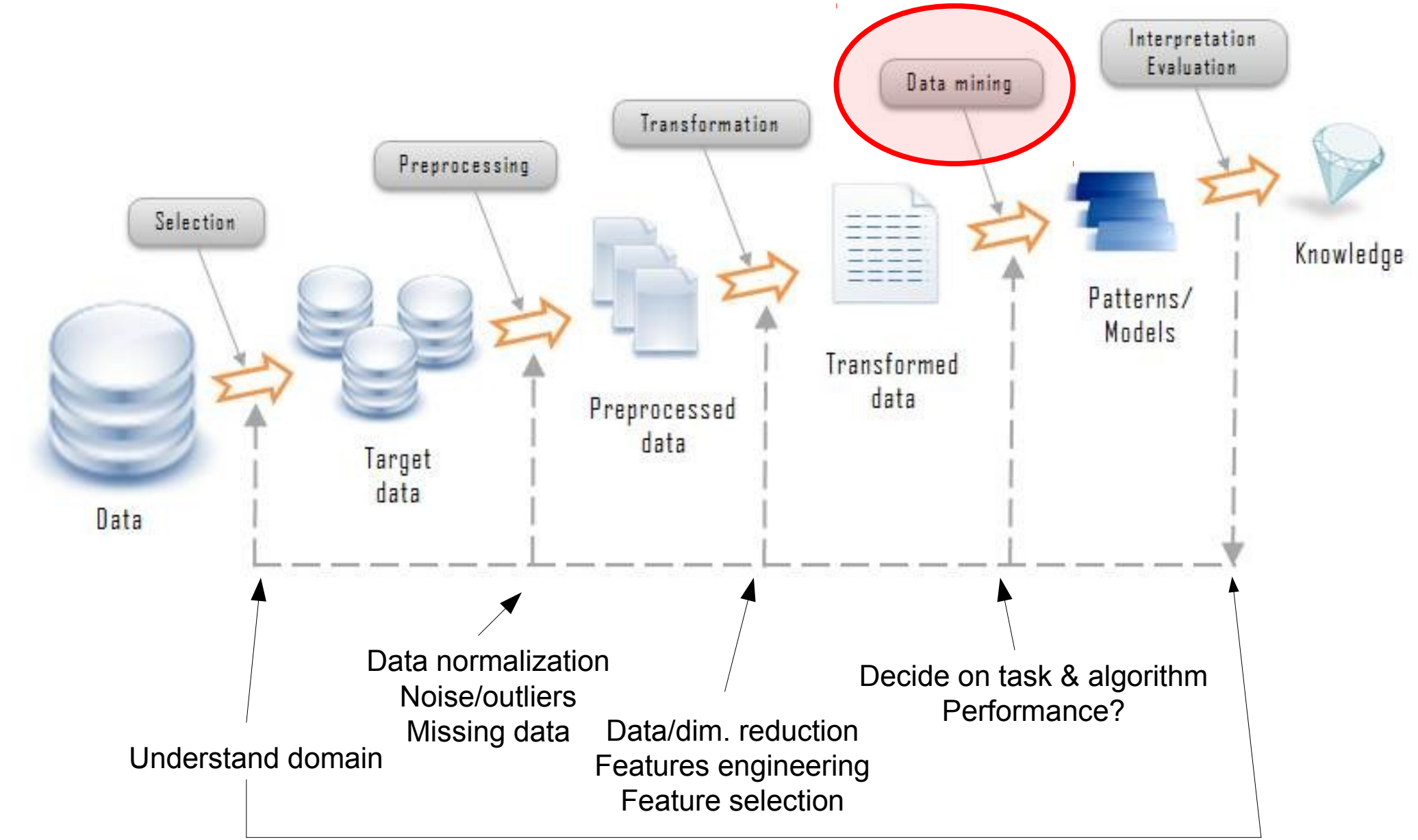


- Data collected and stored at enormous speeds (GB/hour)
  - remote sensors on a satellite
  - telescopes scanning the skies
  - microarrays generating gene expression data
  - scientific simulations generating terabytes of data

- Data mining may help scientists
  - identify **patterns and relationships**
  - to **classify and segment** data
  - **formulate hypotheses**



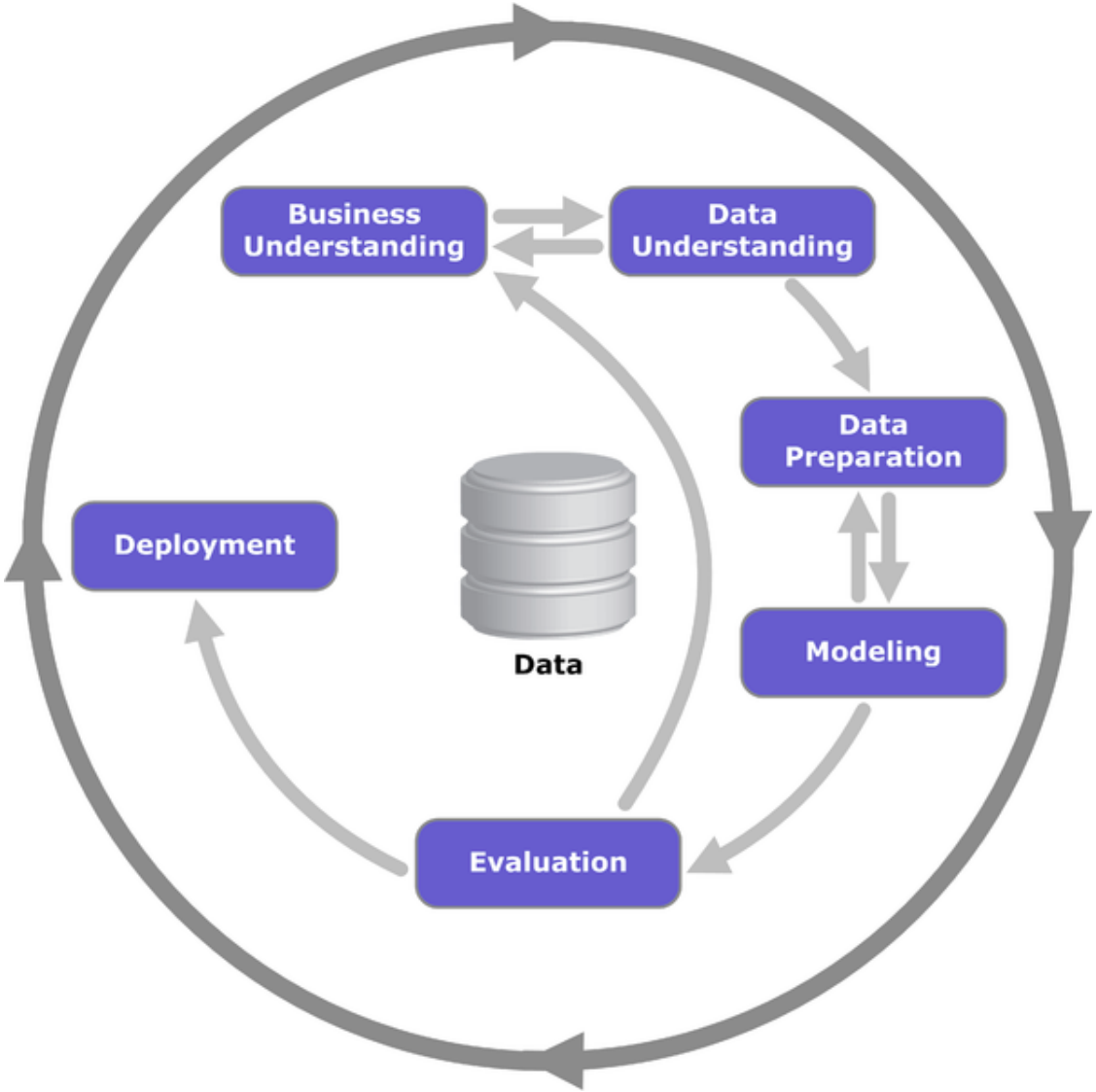
Knowledge Discovery in Databases (KDD) Process



Usama M. Fayyad, Gregory Piatetsky-Shapiro, and Padhraic Smyth. 1996. From data mining to knowledge discovery: an overview.

CRISP-DM Reference Model

- **C**ross **I**ndustry **S**tandard **P**rocess for **D**ata **M**ining
- De facto standard for conducting data mining and knowledge discovery projects.
- Defines tasks and outputs.
- Now developed by IBM as the Analytics Solutions Unified Method for Data Mining/Predictive Analytics (**ASUM-DM**).
- SAS has **SEMMA** and most consulting companies use their own process.



https://en.wikipedia.org/wiki/Cross_Industry_Standard_Process_for_Data_Mining

Tasks in the CRISP-DM Model

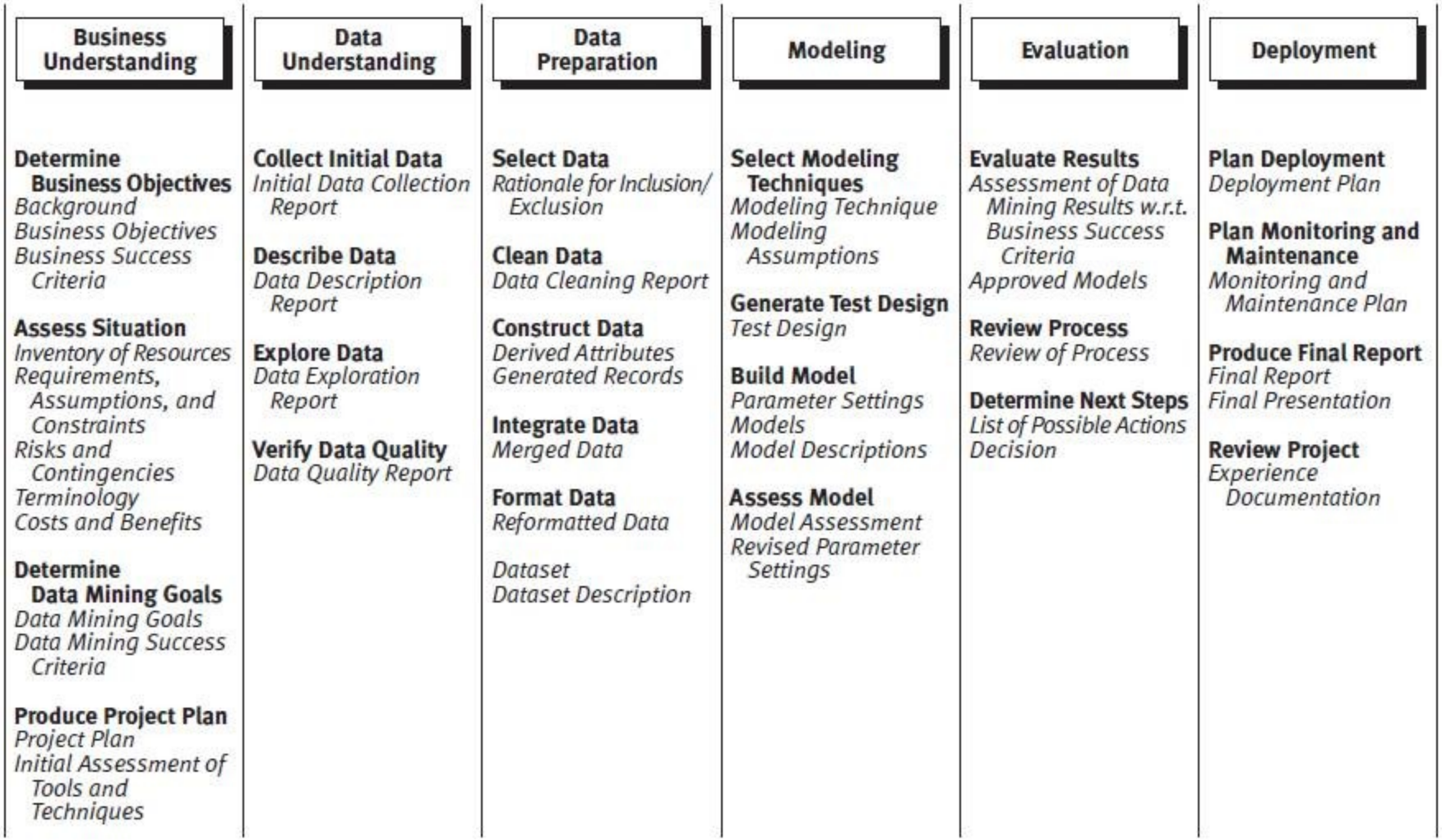


Figure 3: Generic tasks (bold) and outputs (italic) of the CRISP-DM reference model

Agenda

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- Tools
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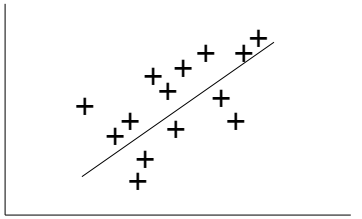
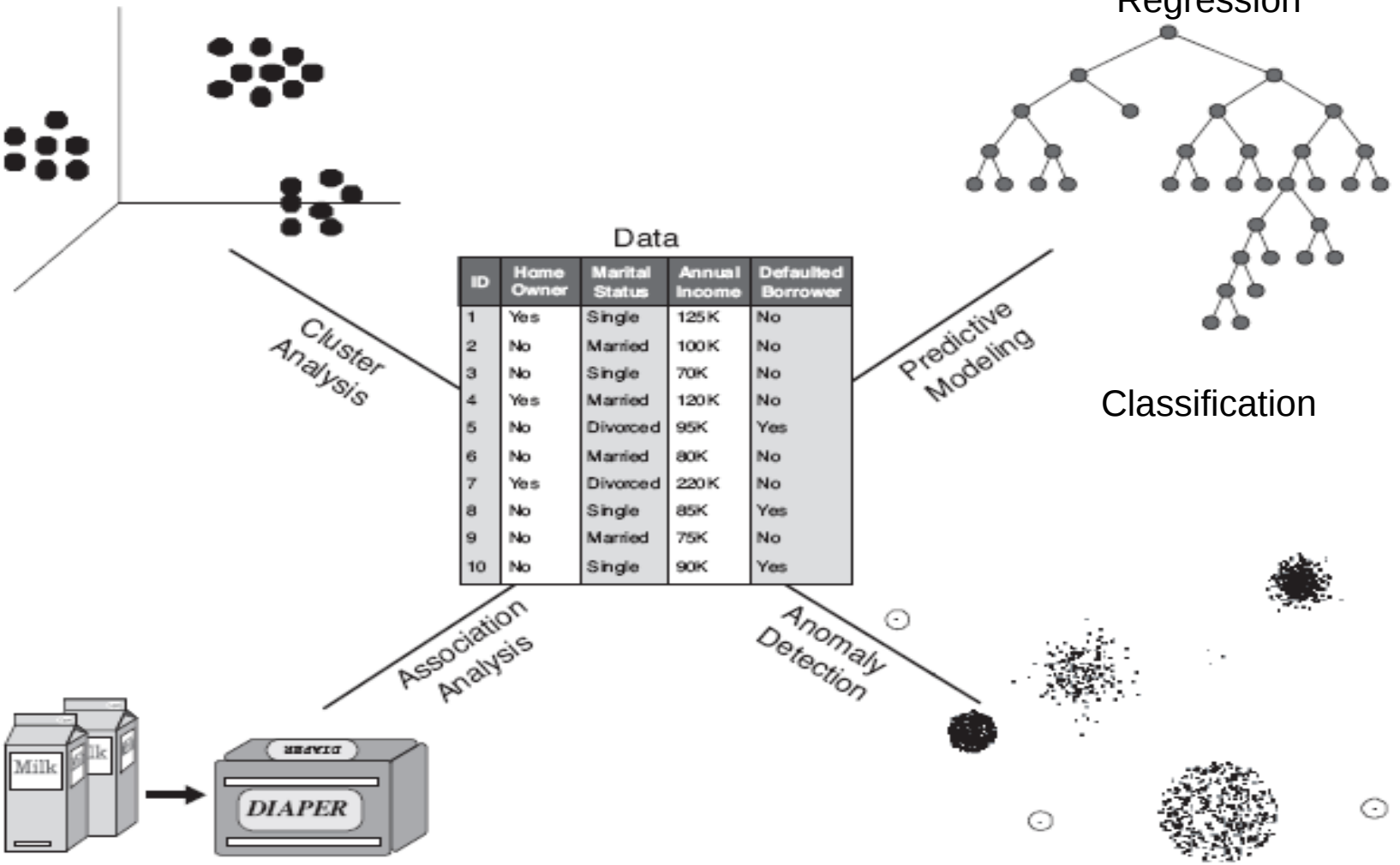
Data Mining Tasks

- **Descriptive Methods**
  - Find human-interpretable patterns that describe the data.
- **Predictive Methods**
  - Use some features (variables) to predict and unknown or future value of other variable.

Data Mining Tasks



Regression



ID	Home Owner	Marital Status	Annual Income	Defaulted Borrower
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	80K	No
7	Yes	Divorced	220K	No
8	No	Single	85K	Yes
9	No	Married	75K	No
10	No	Single	90K	Yes

Figure 1.3. Four of the core data mining tasks.

Data Mining Tasks

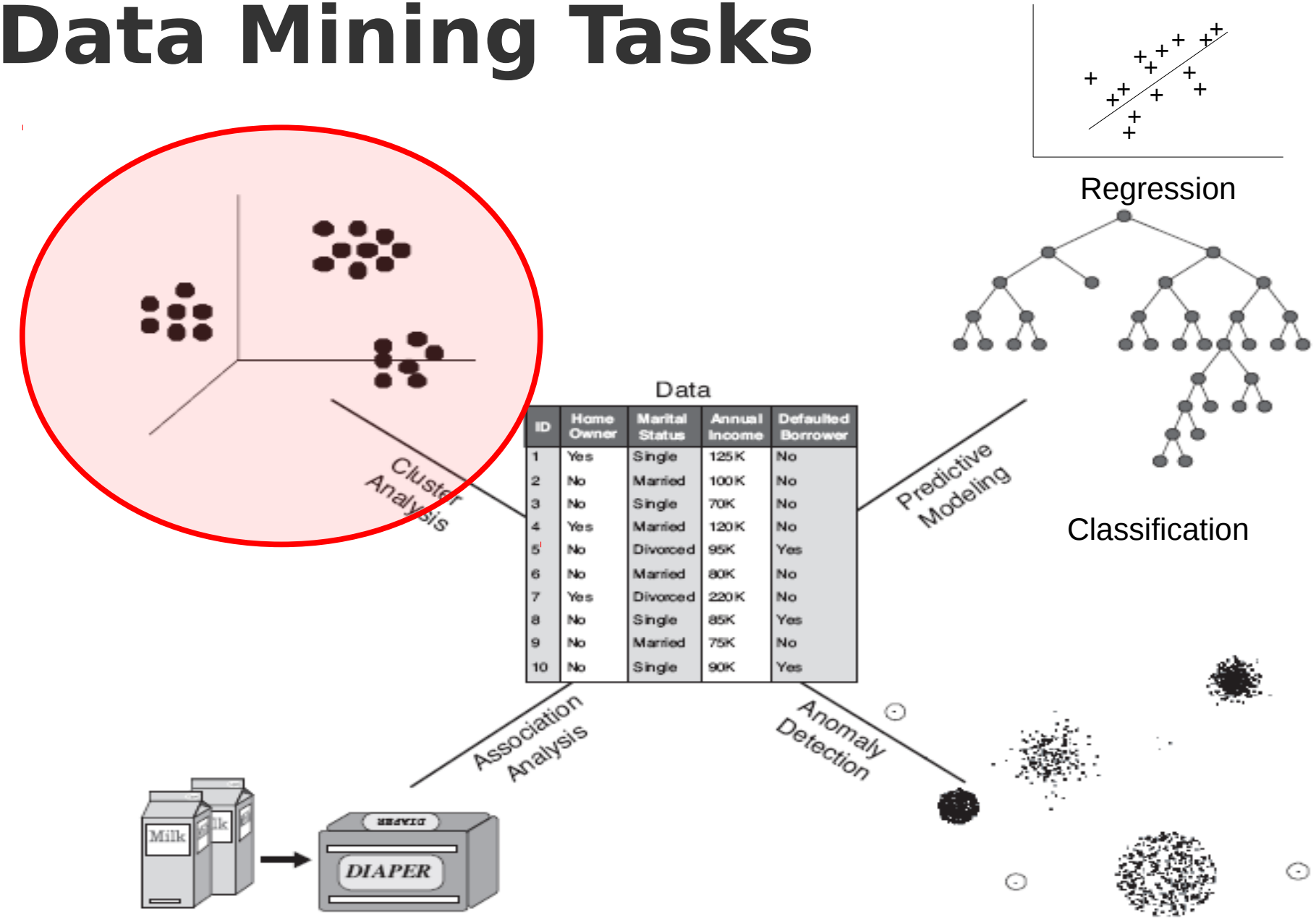


Figure 1.3. Four of the core data mining tasks.

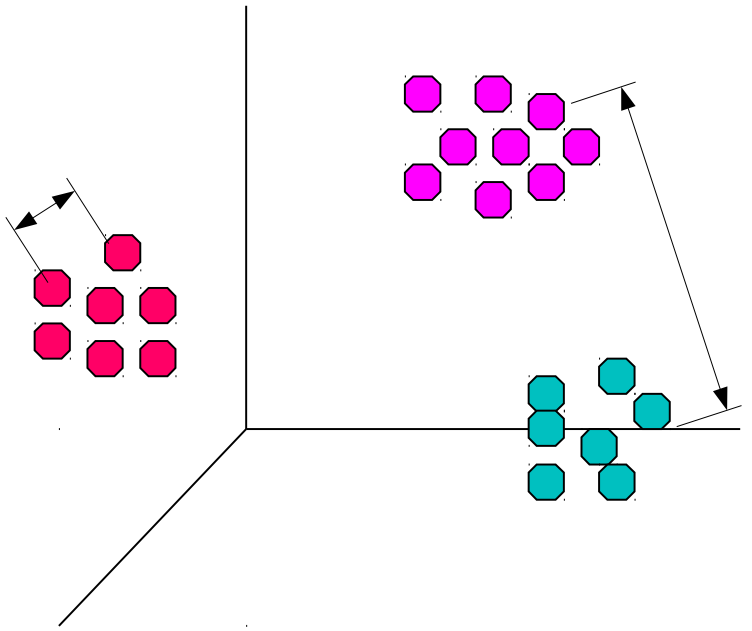
Clustering

Group points such that

- Data points in one cluster are more similar to one another.
- Data points in separate clusters are less similar to one another.

Ideal grouping is not known → **Unsupervised Learning**

Intracluster distances are minimized



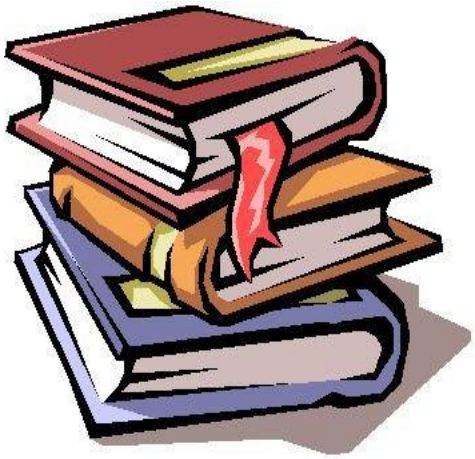
Intercluster distances are maximized

Euclidean distance based clustering in 3-D space.

Clustering
Market Segmentation

- **Goal**: subdivide a market into distinct subsets of customers. Use a different marketing mix for each segment.
- **Approach**:
  - Collect different attributes of customers based on their geographical and lifestyle related information and observed buying patterns.
  - Find clusters of similar customers.

Clustering Documents

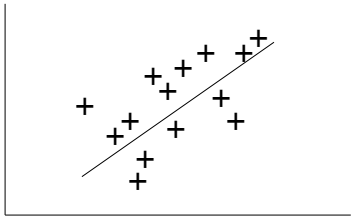


- **Goal**: Find groups of documents that are similar to each.
- **Approach**: Identify frequently occurring terms in each document. Define a similarity measure based on term co-occurrences. Use it to cluster.
- **Gain**: Can be used to organize documents or to create recommendations.

Clustering
Data Reduction

- **Goal**: Reduce the data size for predictive models.
- **Approach**: Group data given a subset of the available information and then use the group label instead of the original data as input for predictive models.

Data Mining Tasks



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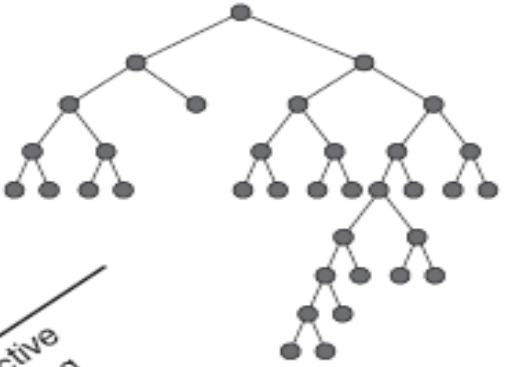

Classification

Data

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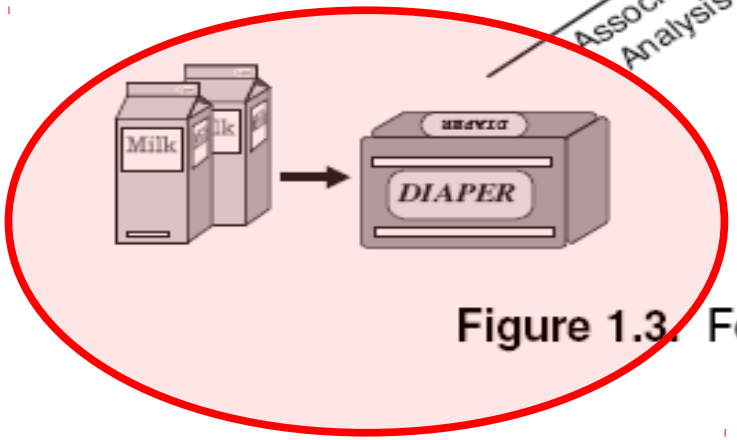
Cluster Analysis

Predictive Modeling

Association Analysis

Anomaly Detection



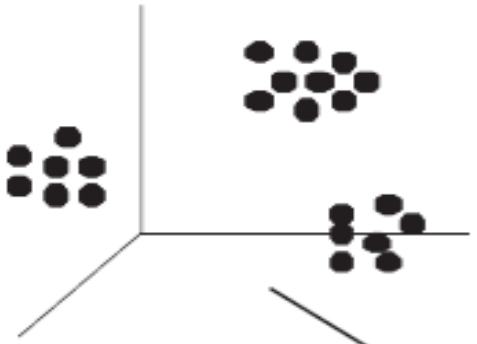


Figure 1.3. Four of the core data mining tasks.

Association Rule Discovery

- Given is a set of transactions. Each contains a number of items.
- Produce dependency rules of the form

  LHS → RHS

  which indicate that if the set of items in the LHS are in a transaction, then the transaction likely will also contain the RHS item.

TID	Items
1	Bread, Coke, Milk
2	Beer, Bread
3	Beer, Coke, Diaper, Milk
4	Beer, Bread, Diaper, Milk
5	Coke, Diaper, Milk

Transaction data

{Milk} → {Coke}
{Diaper, Milk} → {Beer}

Discovered Rules

Association Rule Discovery Marketing and Sales Promotion

- Let the rule discovered be

  {Potato Chips, … } → {Soft drink}

- **Soft drink as RHS:** What should be done to boost sales? Discount Potato Chips?
- **Potato Chips in LHS:** Shows which products would be affected if the store discontinues selling Potato Chips.
- **Potato Chips in LHS *and* Soft drink in RHS:** what products should be sold with Potato Chips to promote sales of Soft drinks!

Association Rule Discovery
Supermarket shelf management

- **Goal**: To identify items that are bought together by sufficiently many customers.
- **Approach**:
  - Process the point-of-sale data to find dependencies among items.
  - Place dependent items
    - close to each other (convenience).
    - far from each other to expose the customer to the maximum number of products in the store.

Association Rule Discovery
Inventory Management

- **Goal**: Anticipate the nature of repairs to keep the service vehicles equipped with right parts to speed up repair time.
- **Approach**: Process the data on tools and parts required in previous repairs at different consumer locations and discover co-occurrence patterns.

Data Mining Tasks

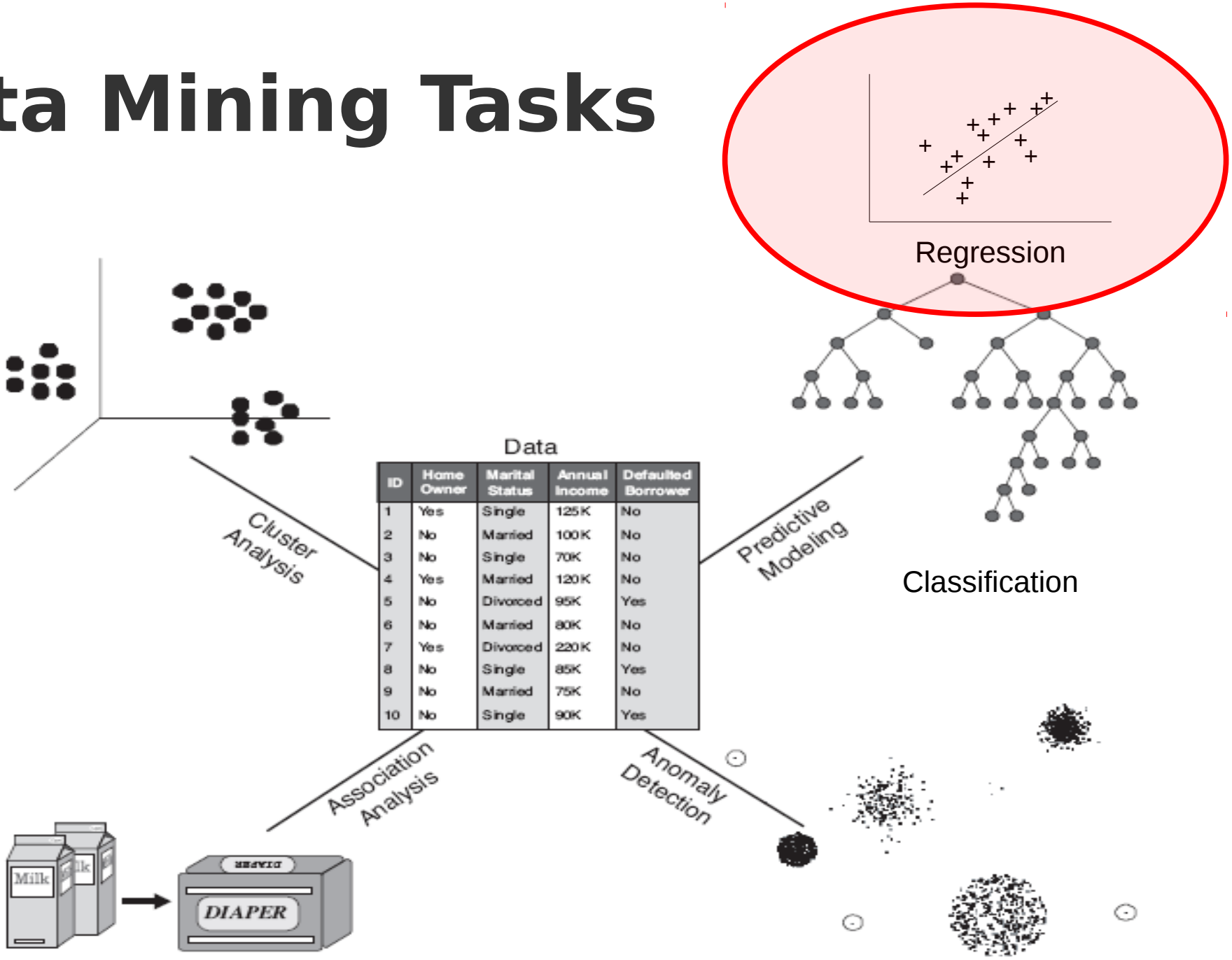
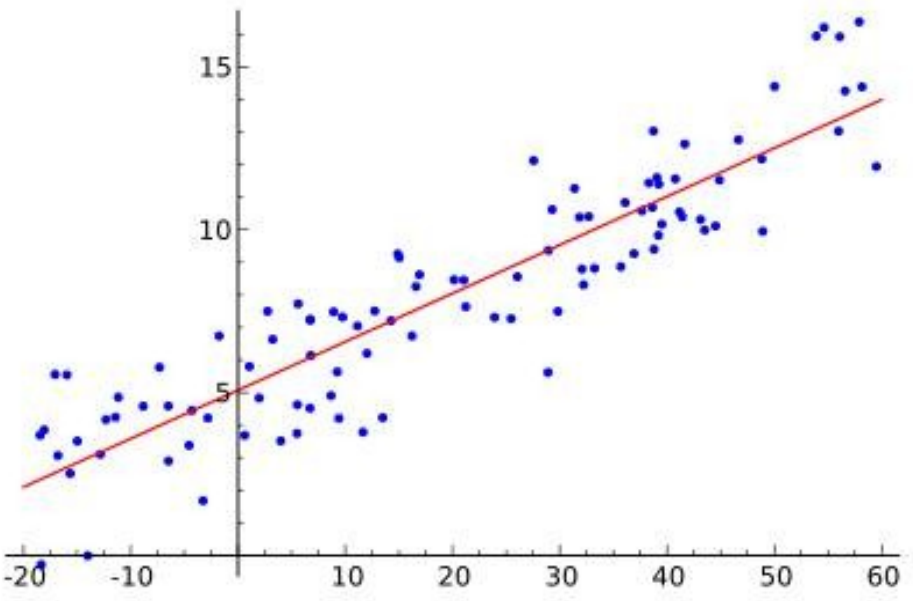


Figure 1.3. Four of the core data mining tasks.

Regression

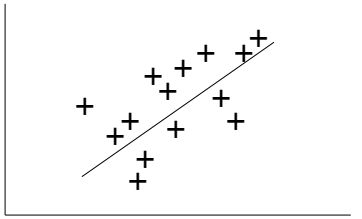
- Predict a value of a given continuous valued variable based on the values of other variables, assuming a linear or nonlinear model of dependency.
- Studied in statistics and econometrics.



Applications:

- Predicting sales amounts of new product based on advertising expenditure.
- Predicting wind velocities as a function of temperature, humidity, air pressure, etc.
- Time series prediction of stock market indices (autoregressive models).

Data Mining Tasks



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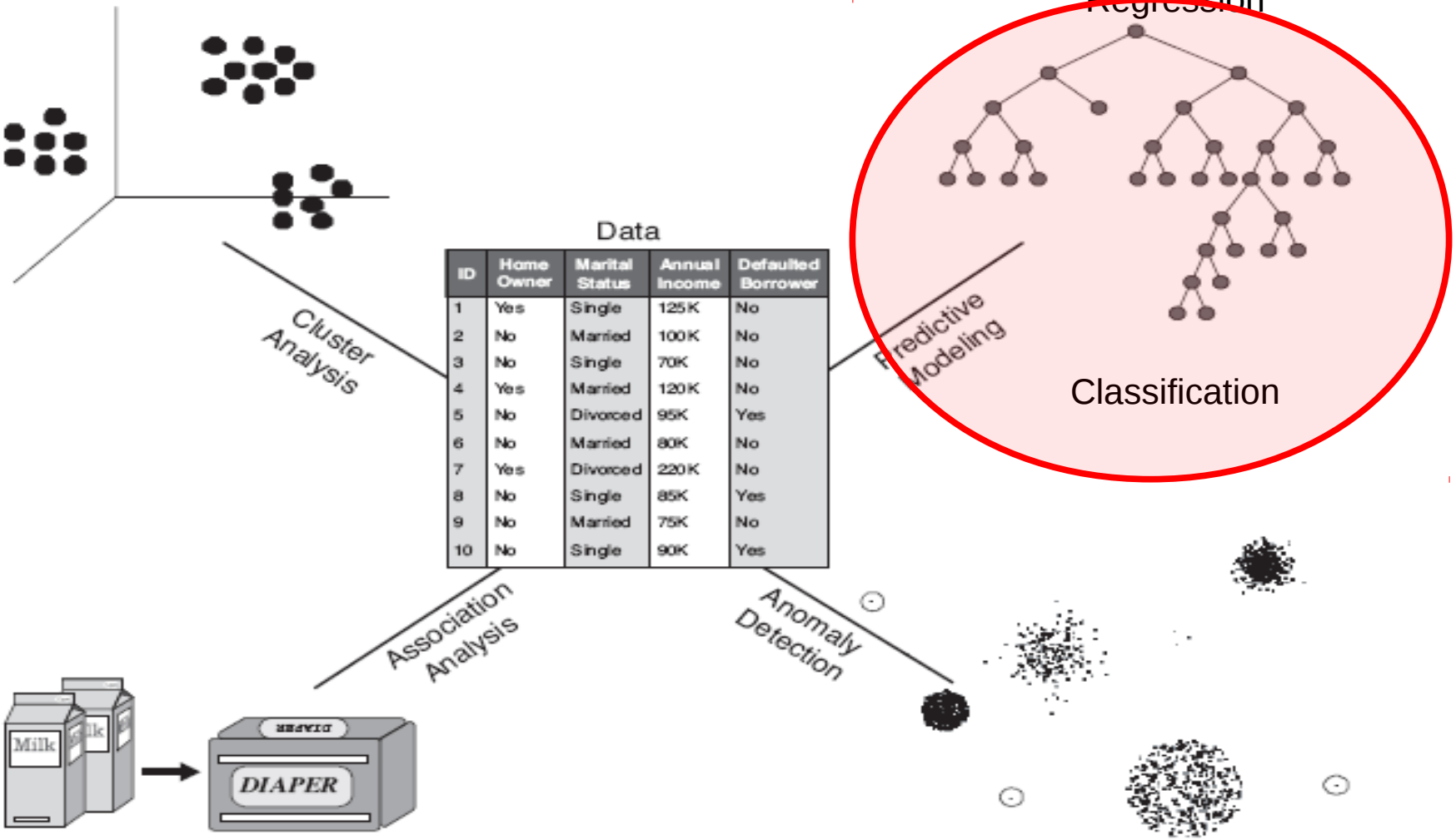

Figure 1.3. Four of the core data mining tasks.

Classification

Find a **model** for the class attribute as a function of the values of other attributes/features.

Class information is available → **Supervised Learning**

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
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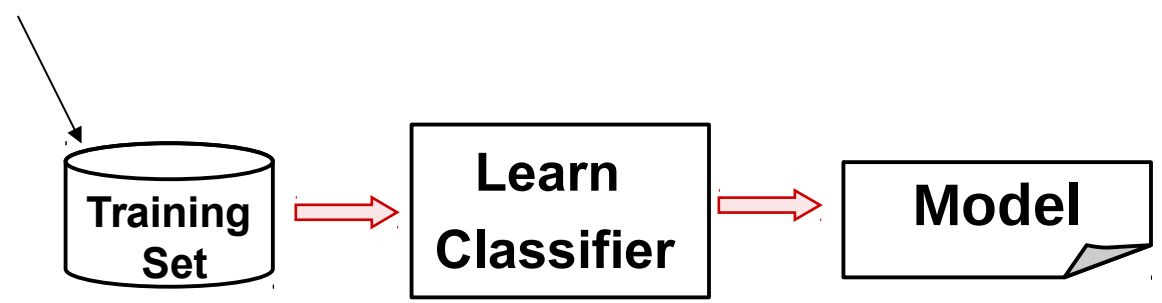

Classification

Find a **model** for the class attribute as a function of the values of other attributes/features.

Goal: assign new records to a class as accurately as possible.

class

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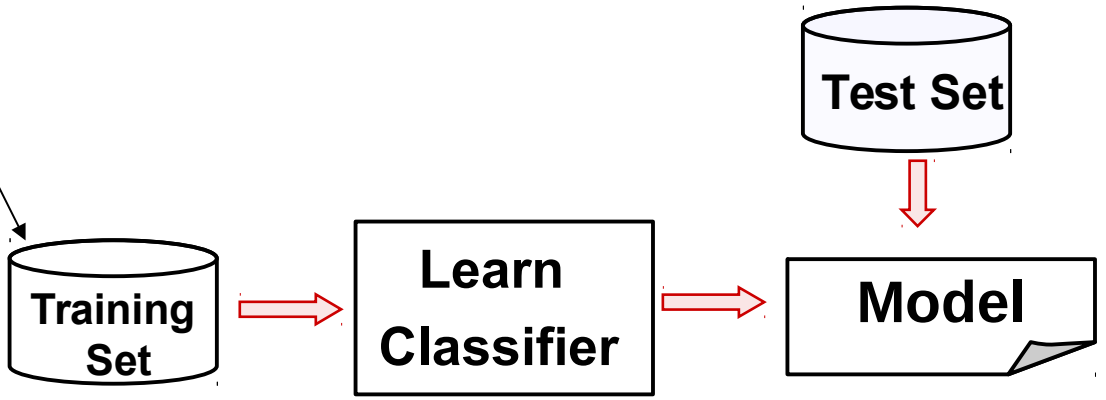
Refund	Marital Status	Taxable Income	Cheat
No	Single	75K	?
Yes	Married	50K	?
No	Married	150K	?
Yes	Divorced	90K	?
No	Single	40K	?
No	Married	80K	?



Classification
Direct Marketing

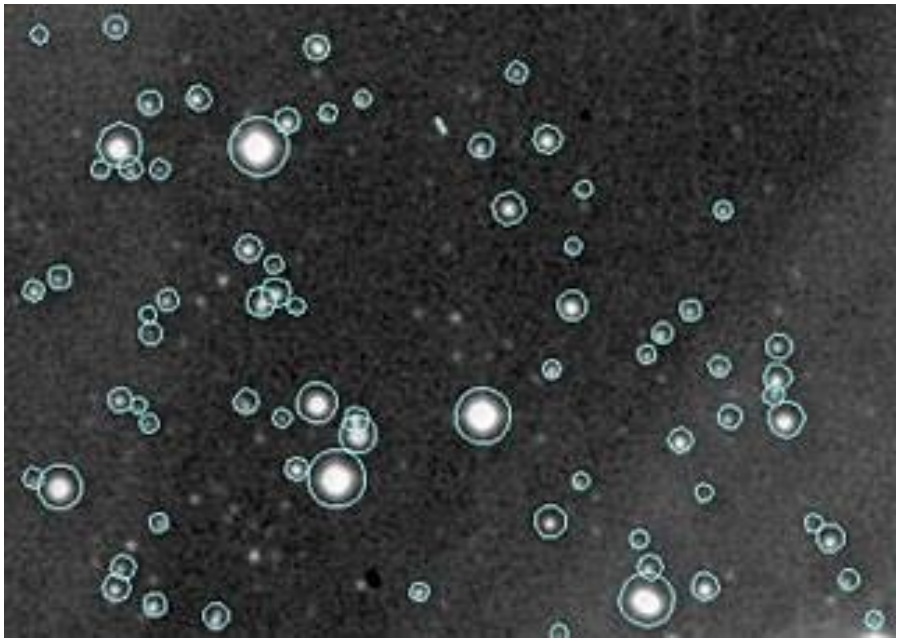
- **Goal**: Reduce cost of mailing by **targeting** a set of consumers likely to buy a **new** product.
- **Approach**:
  - Use the **data** for a similar product introduced before or from a focus group. We have customer information (e.g., demographics, lifestyle, previous purchases) and know which customers decided to buy and which decided otherwise. This *buy/don't buy* decision forms the **class attribute.**
  - Use this information as input attributes to **learn a classifier model.**
  - Apply the model to new customers to **predict** if they will buy the product.

Classification
Customer Attrition/Churn

- **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 (frequency, recency, complaints, demographics, etc.).
  - **Label** the customers as loyal or disloyal.
  - Find a **model** for disloyalty.
  - **Rank** each customer on a loyal/disloyal scale (e.g., churn probability).

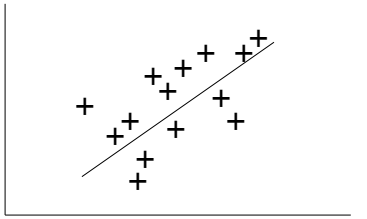
Classification
Sky Survey Cataloging

- **Goal:** To predict class (star or galaxy) of sky objects, especially visually faint ones, based on the telescopic survey images (from Palomar Observatory).
- **Approach**:
  - Segment the image to **identify objects**.
  - **Derive features** per object (40).
  - Use known objects to **model the class** based on these features.
- **Result:** Found 16 new high red-shift quasars.



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

Data Mining Tasks



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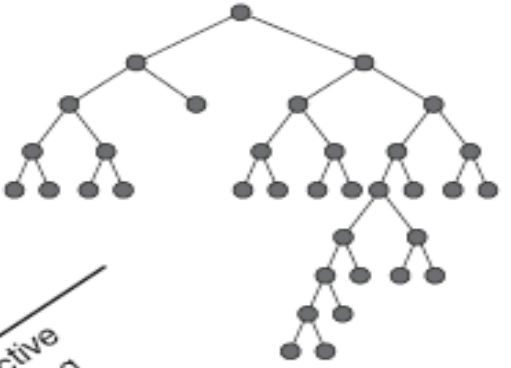
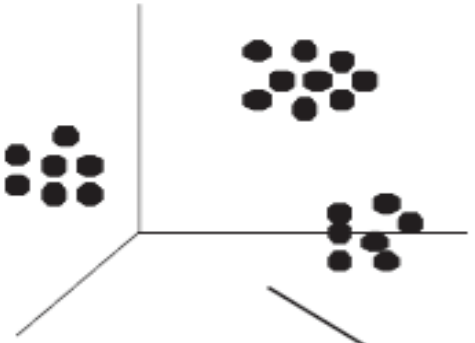


Classification



Cluster Analysis

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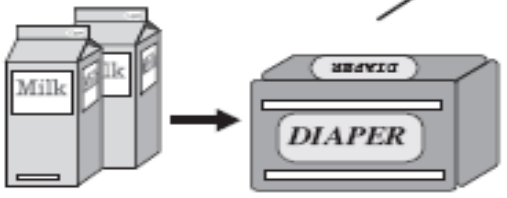
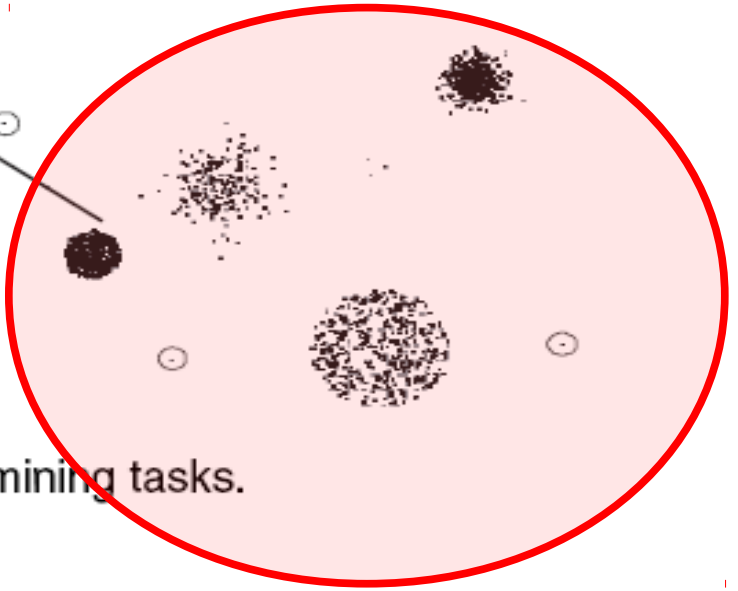
Predictive Modeling

Association Analysis



Anomaly Detection



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Deviation/Anomaly Detection

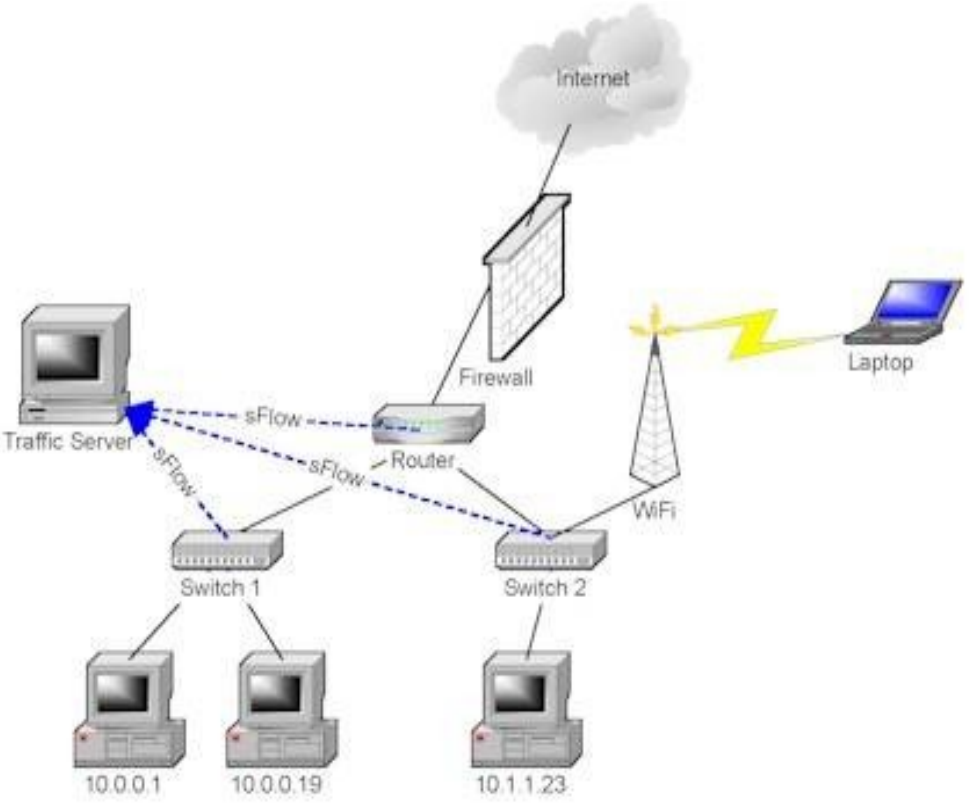
Detect significant deviations from normal behavior.

Applications:

- Credit Card Fraud Detection

- Network Intrusion Detection

Typical network traffic at University level may reach over 100 million connections per day



Other Data Mining Tasks

- **Text mining** – document clustering, topic models
- **Graph mining** – social networks
- **Data stream mining**/real time data mining
- **Mining spatiotemporal data** (e.g., moving objects)
- **Visual data mining**
- **Distributed data mining**

Challenges of Data Mining

- Scalability
- Dimensionality
- Complexity and heterogeneous data
- Data quality
- Data ownership and privacy

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- **Relationship to Statistics, Optimization, Machine Learning and AI**
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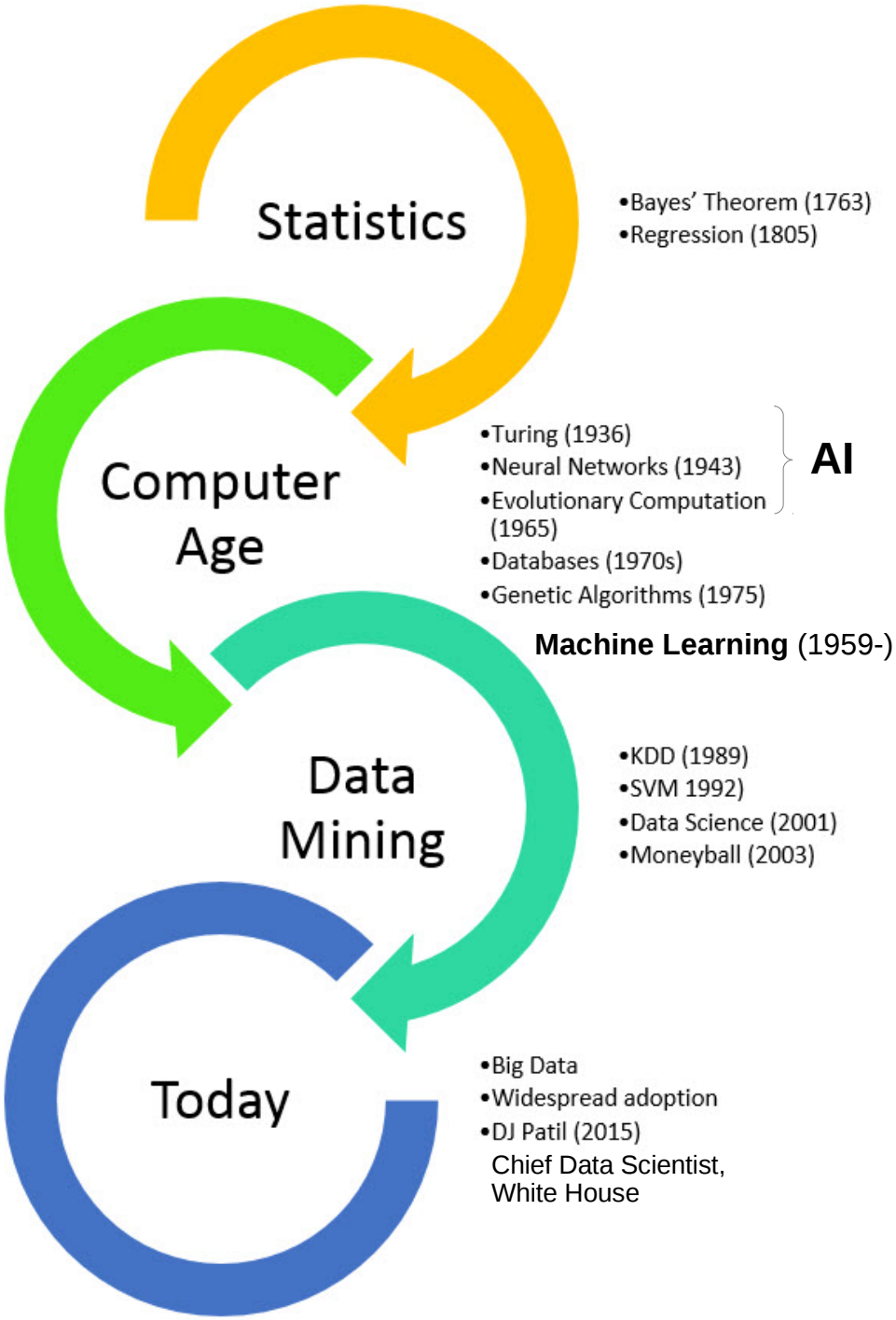
Origins of Data Mining

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

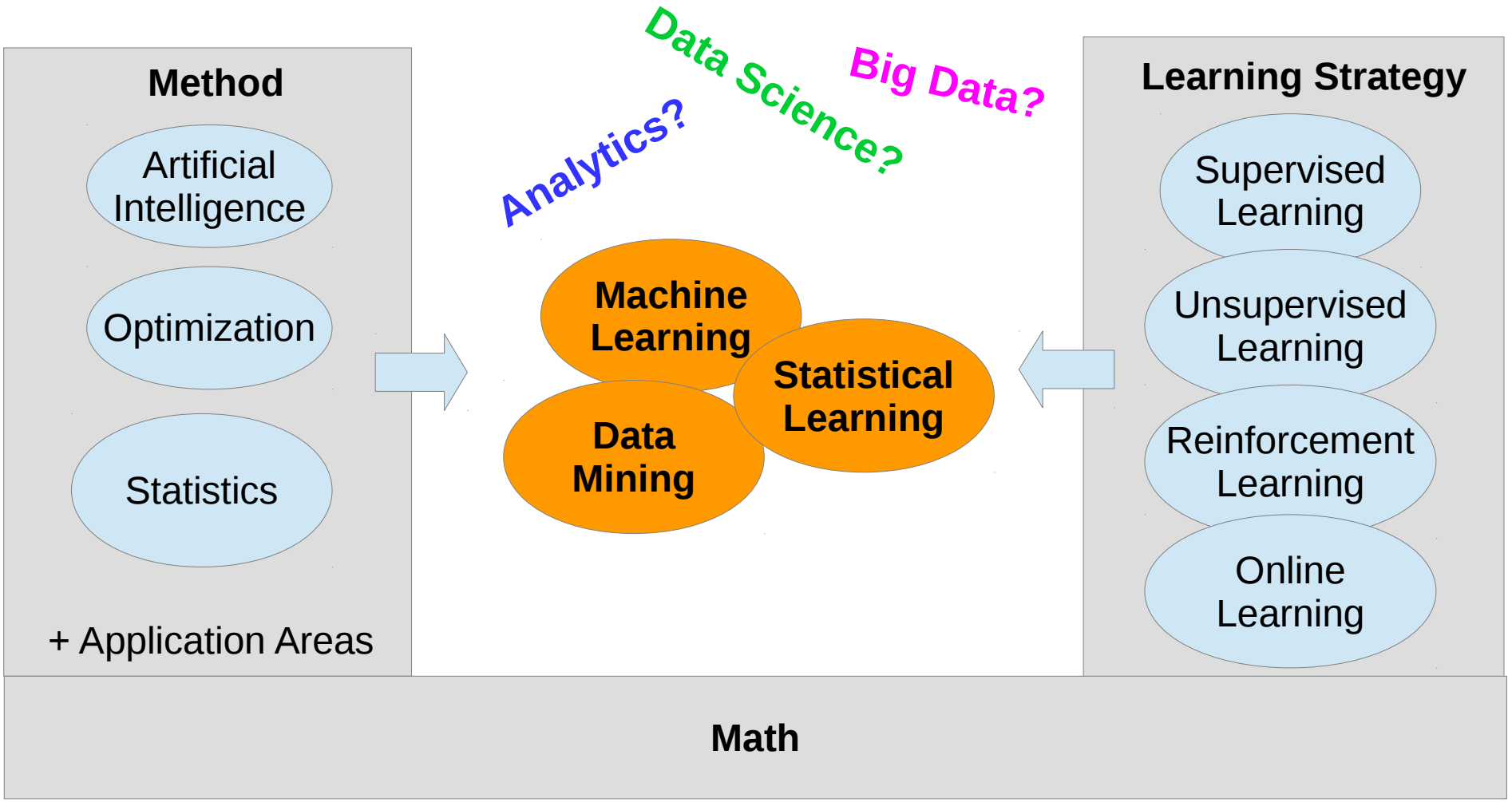
There are differences in terms of

- used data and
- the goals.



https://rayli.net/blog/data/history-of-data-mining/

Relationship to other Fields



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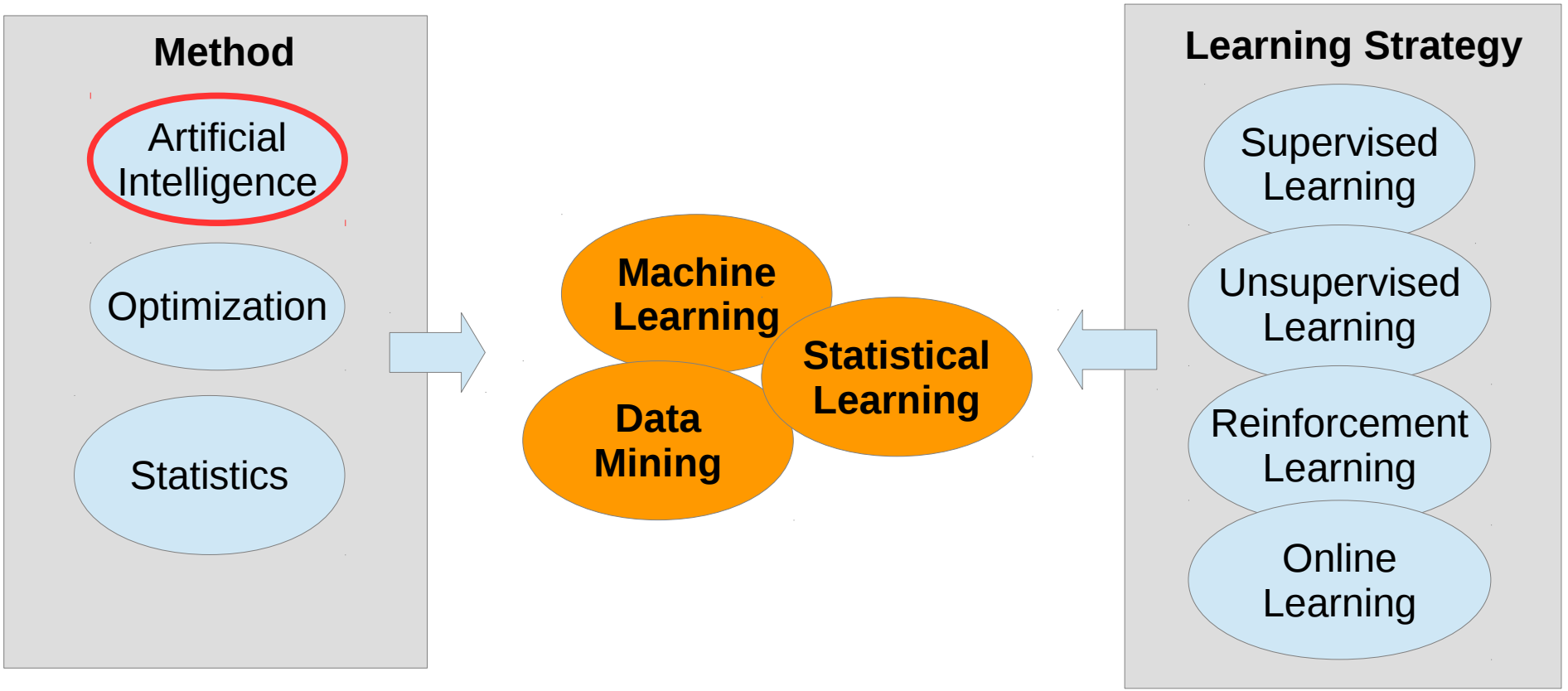
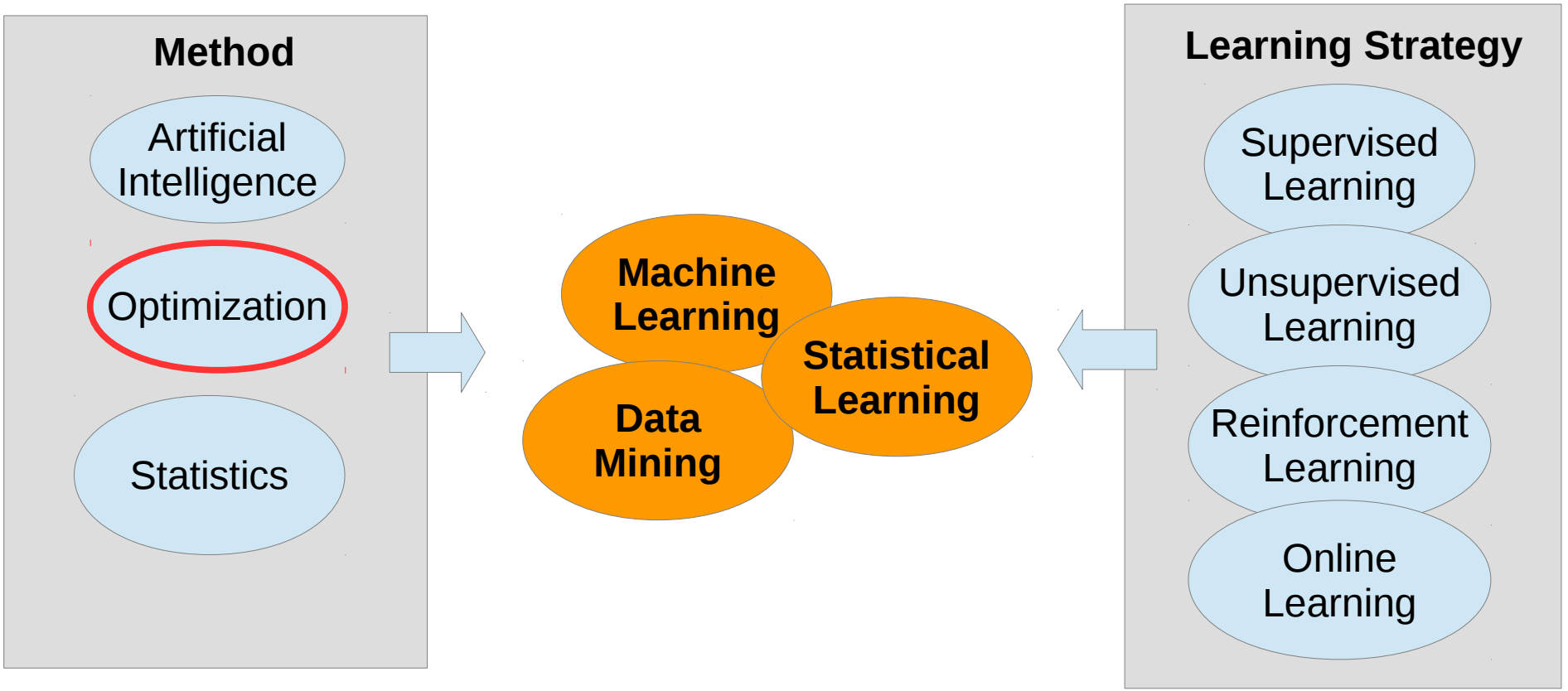


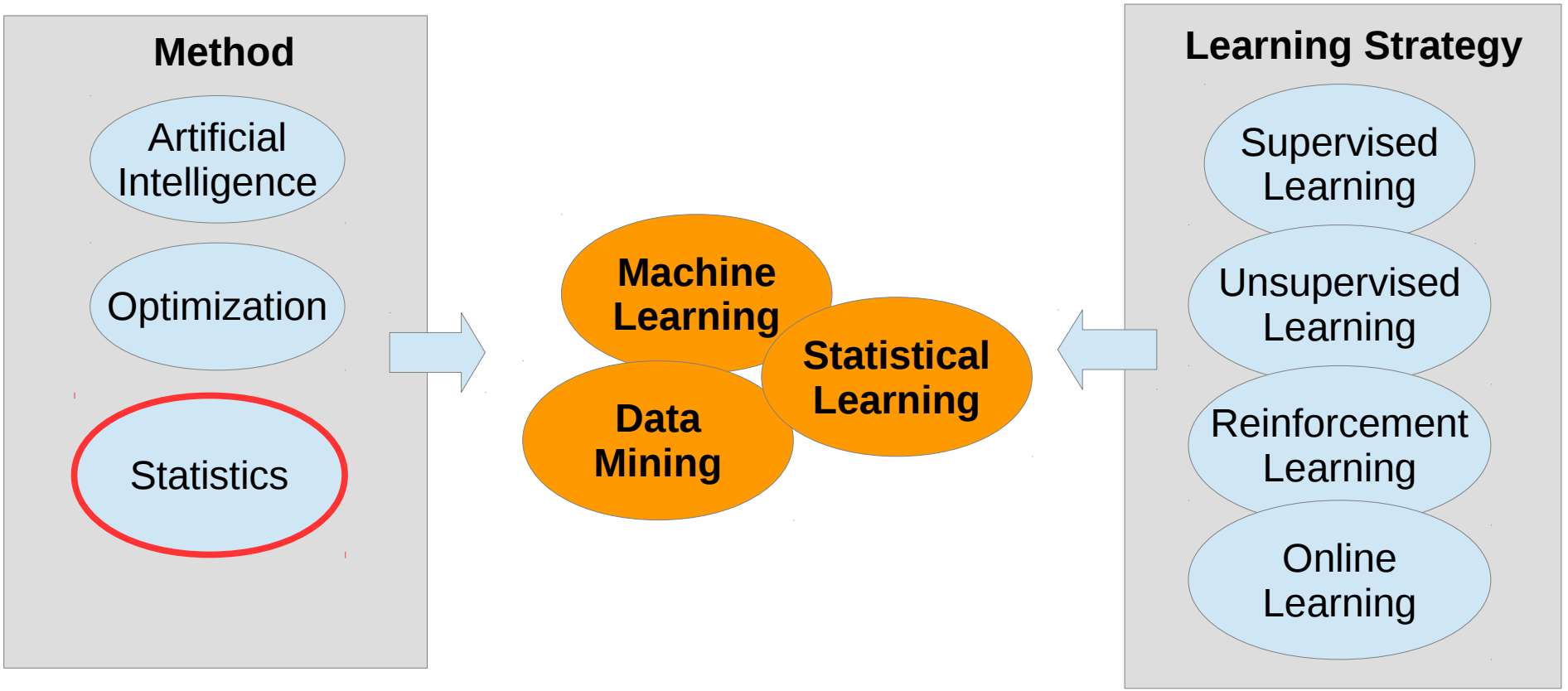
Artificial Intelligence: Create an **autonomous agent** that perceives its environment and takes actions that maximize its chance of reaching some goal.
Areas: reasoning, knowledge representation, planning, learning, natural language processing, and vision.

Relationship to other Fields



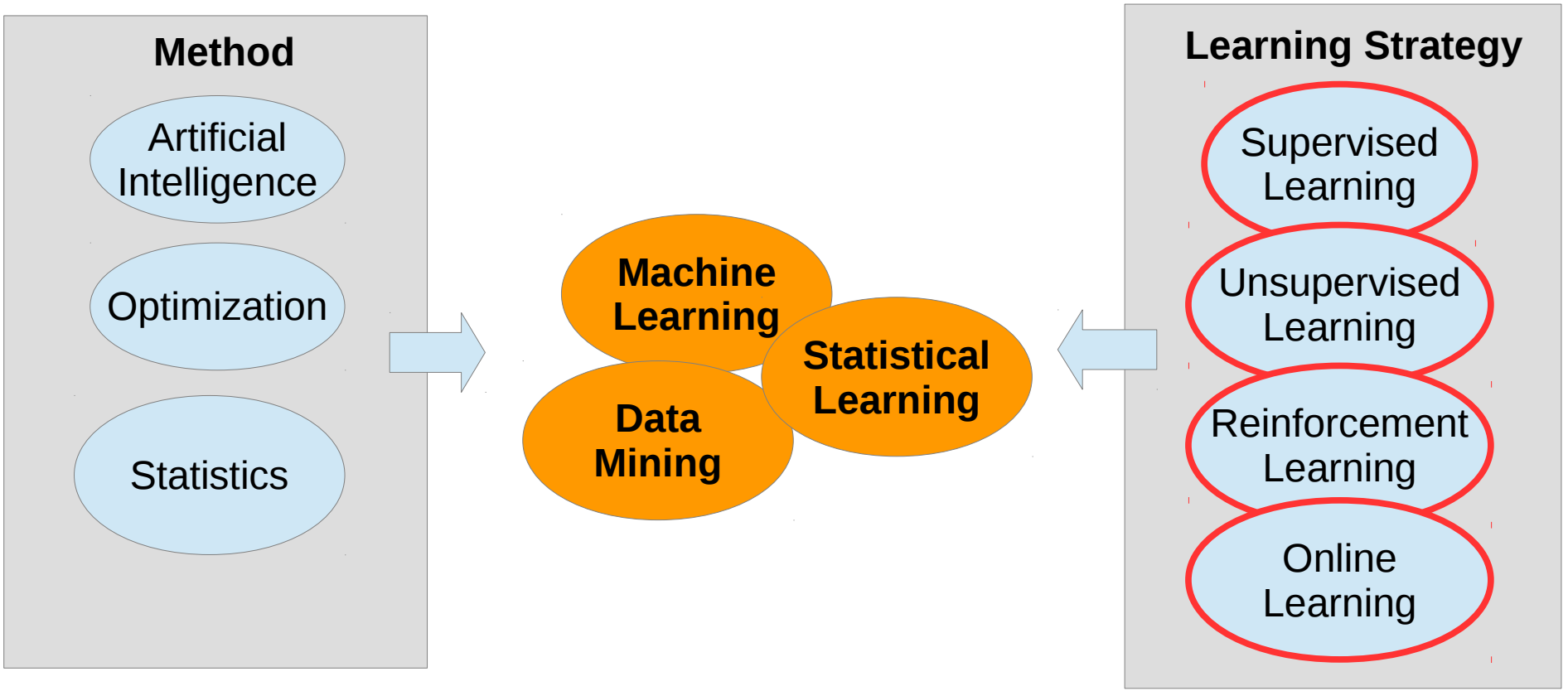
Optimization: Selection of a best alternative from some set of available alternatives with regard to some criterion.
Techniques: Linear programming, integer programming, nonlinear programming, stochastic and robust optimization, heuristics, etc.

Relationship to other Fields



Statistics: Study of the collection, analysis, interpretation, presentation, and organization of data.
Techniques: Descriptive statistics, statistical inference (estimation, testing), design of experiments.

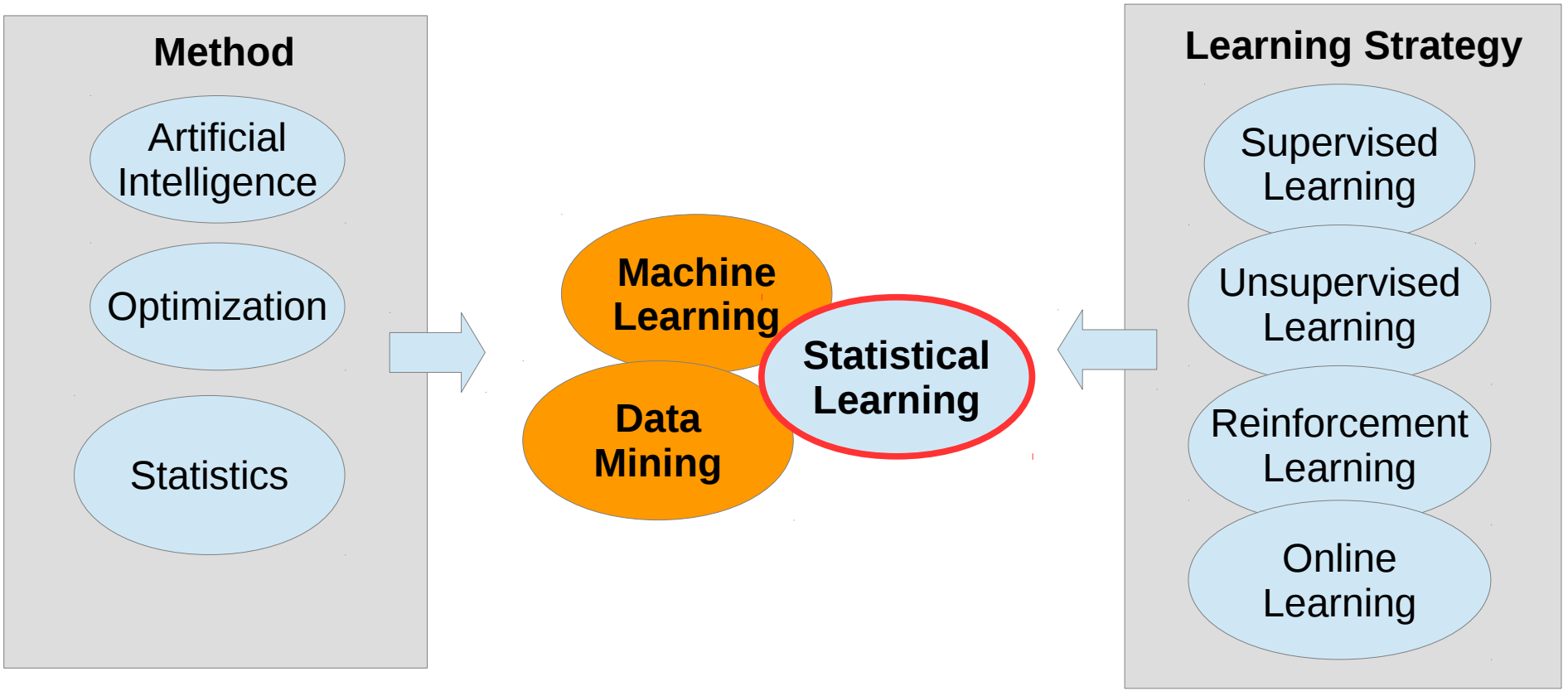
Relationship to other Fields



Learning Strategy: From what data do we learn?

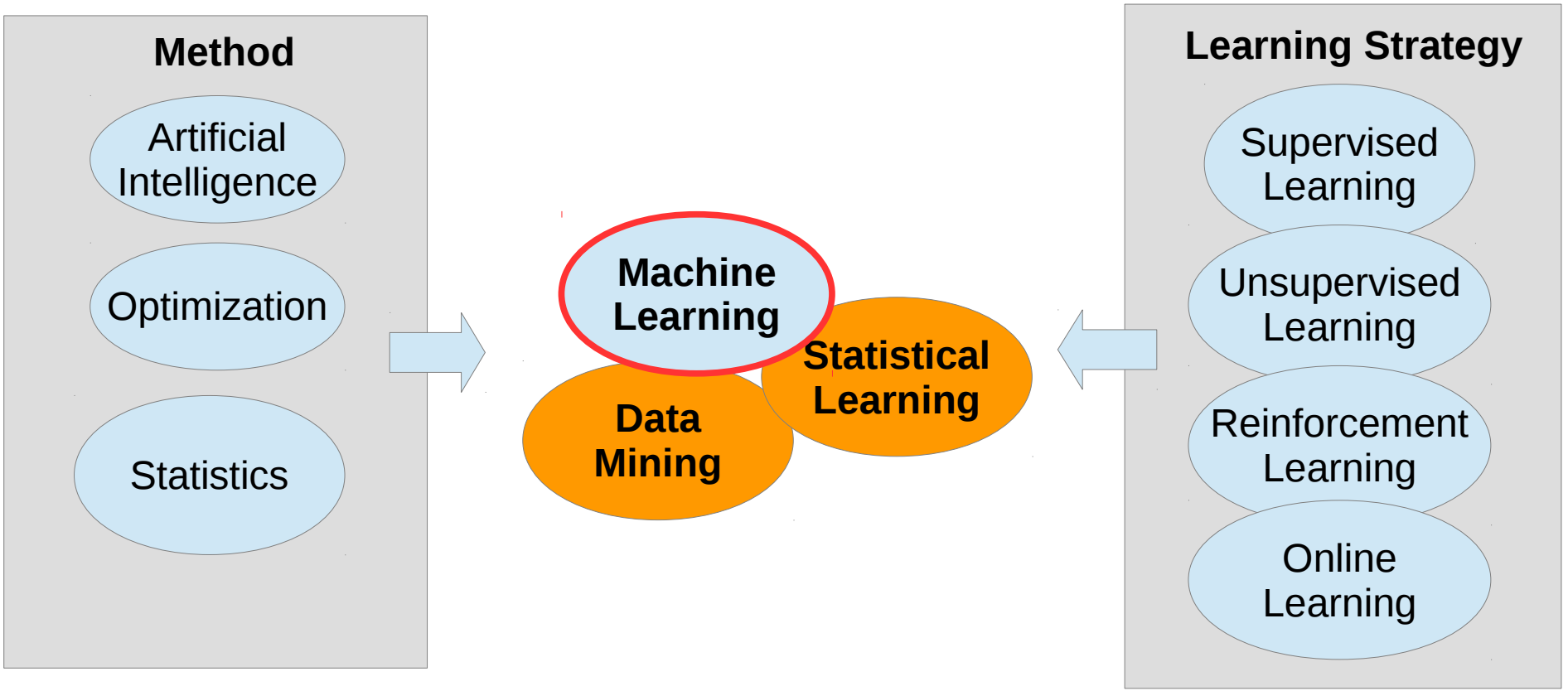
- Is a training set with correct answers available? → Supervised learning
- Long-term structure of rewards? → Reinforcement learning
- No answer and no reward structure? → Unsupervised learning
- Do we have to update the model regularly? → Online learning

Relationship to other Fields



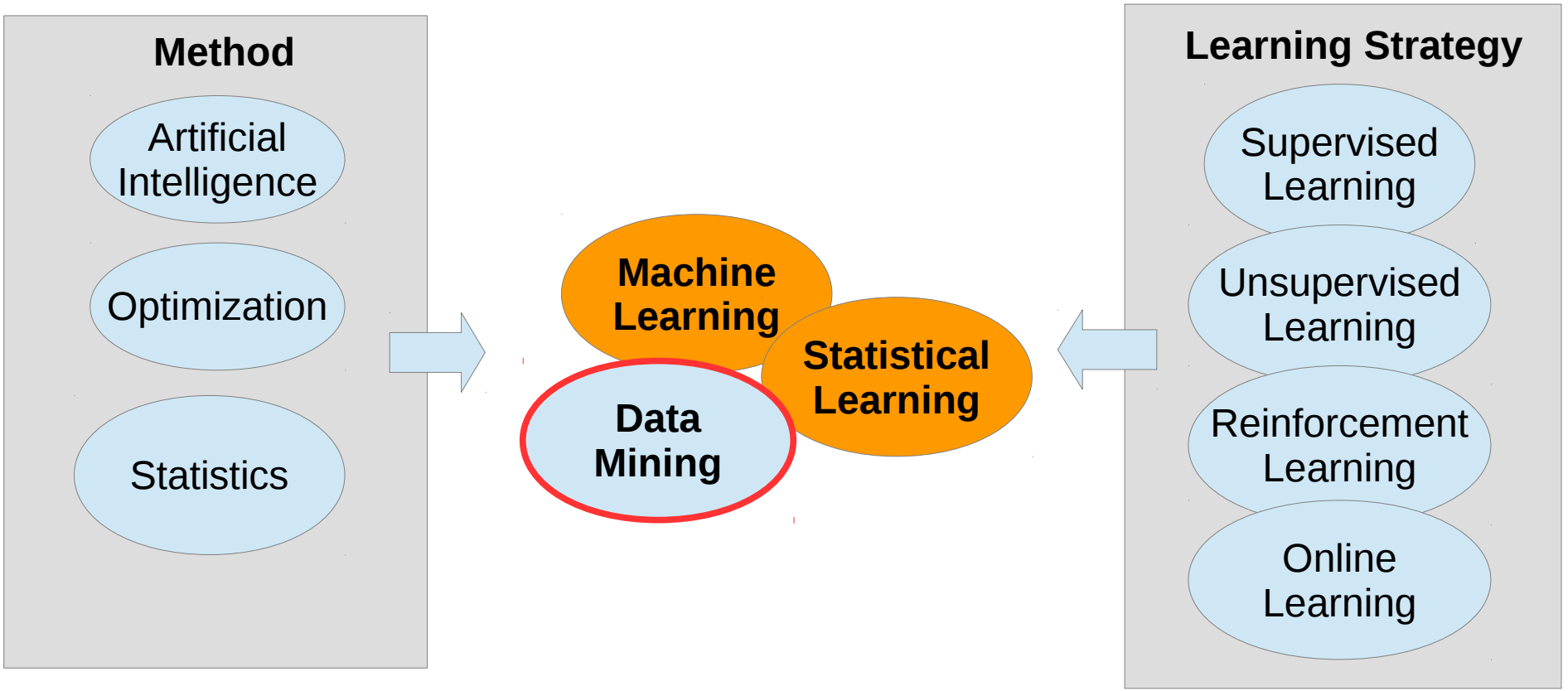
Statistical learning: deals with the problem of finding a **predictive function** based on data.
Tools: (Linear) classifiers, regression and regularization.

Relationship to other Fields



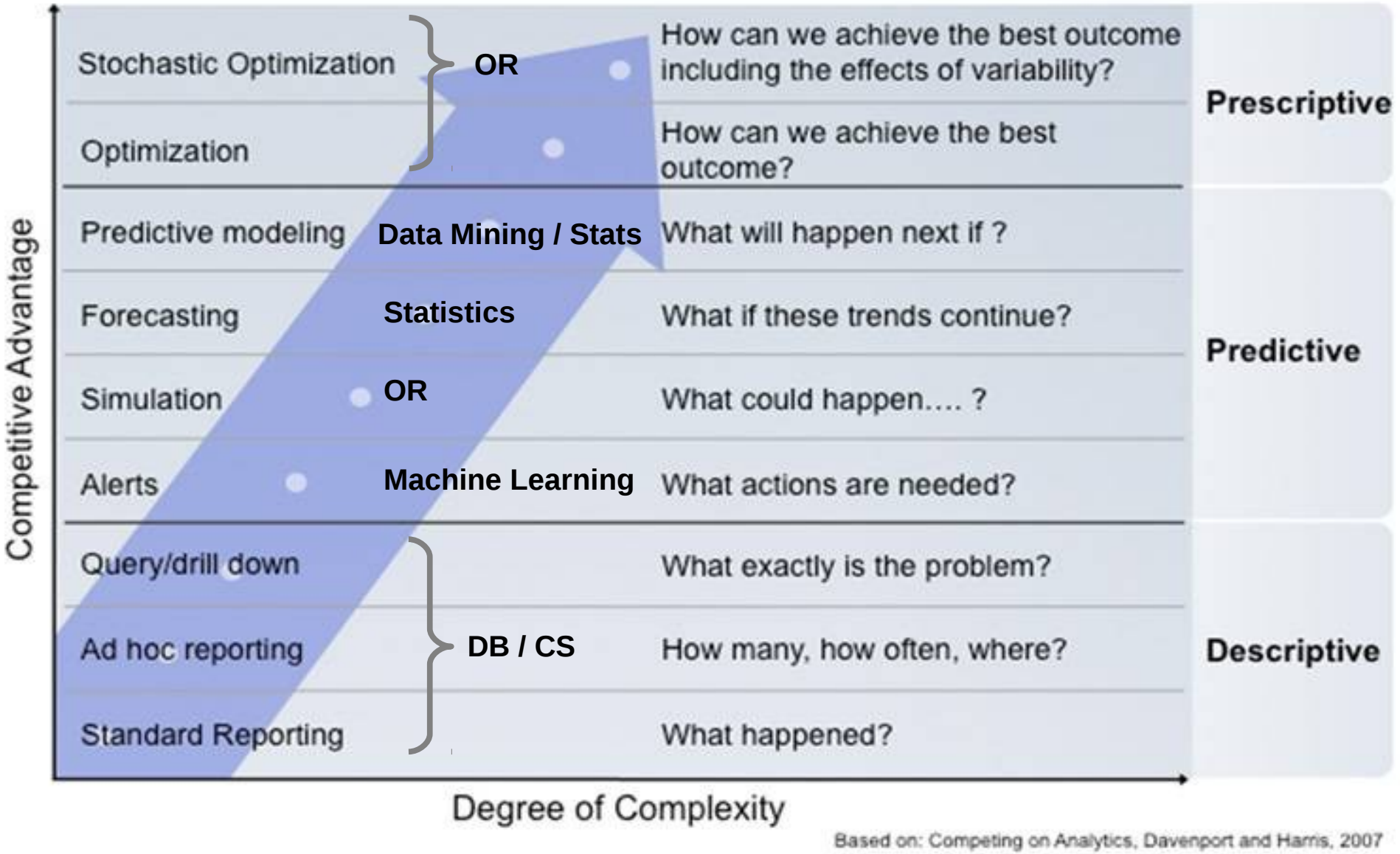
Machine Learning involves the study of algorithms that can extract information **automatically**, i.e., without on-line human guidance.
Techniques: Focus on supervised learning.

Relationship to other Fields



Data Mining: Manually analyze a given dataset to gain insights and predict potential outcomes.
Techniques: Any applicable technique from databases, statistics, machine/statistical learning. New methods were developed by the Data Mining community.

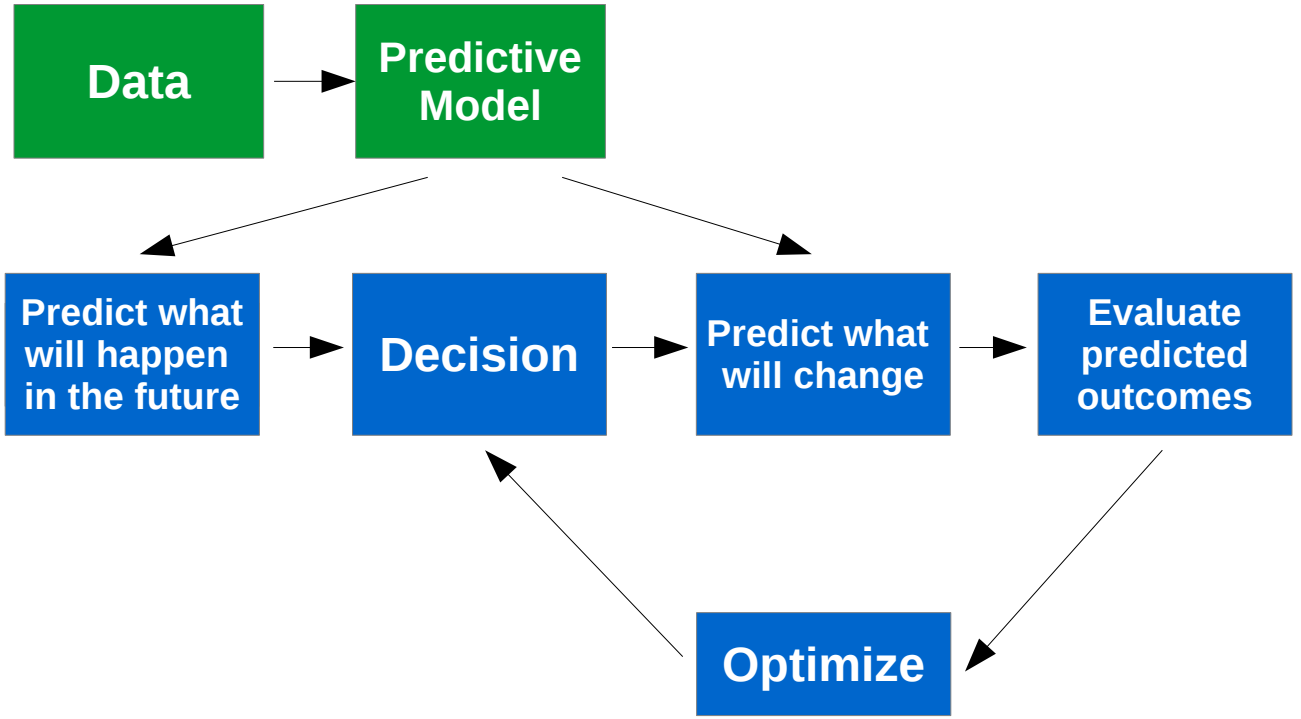
Data Mining & Analytics



Based on: Competing on Analytics, Davenport and Harris, 2007

Prescriptive Analytics

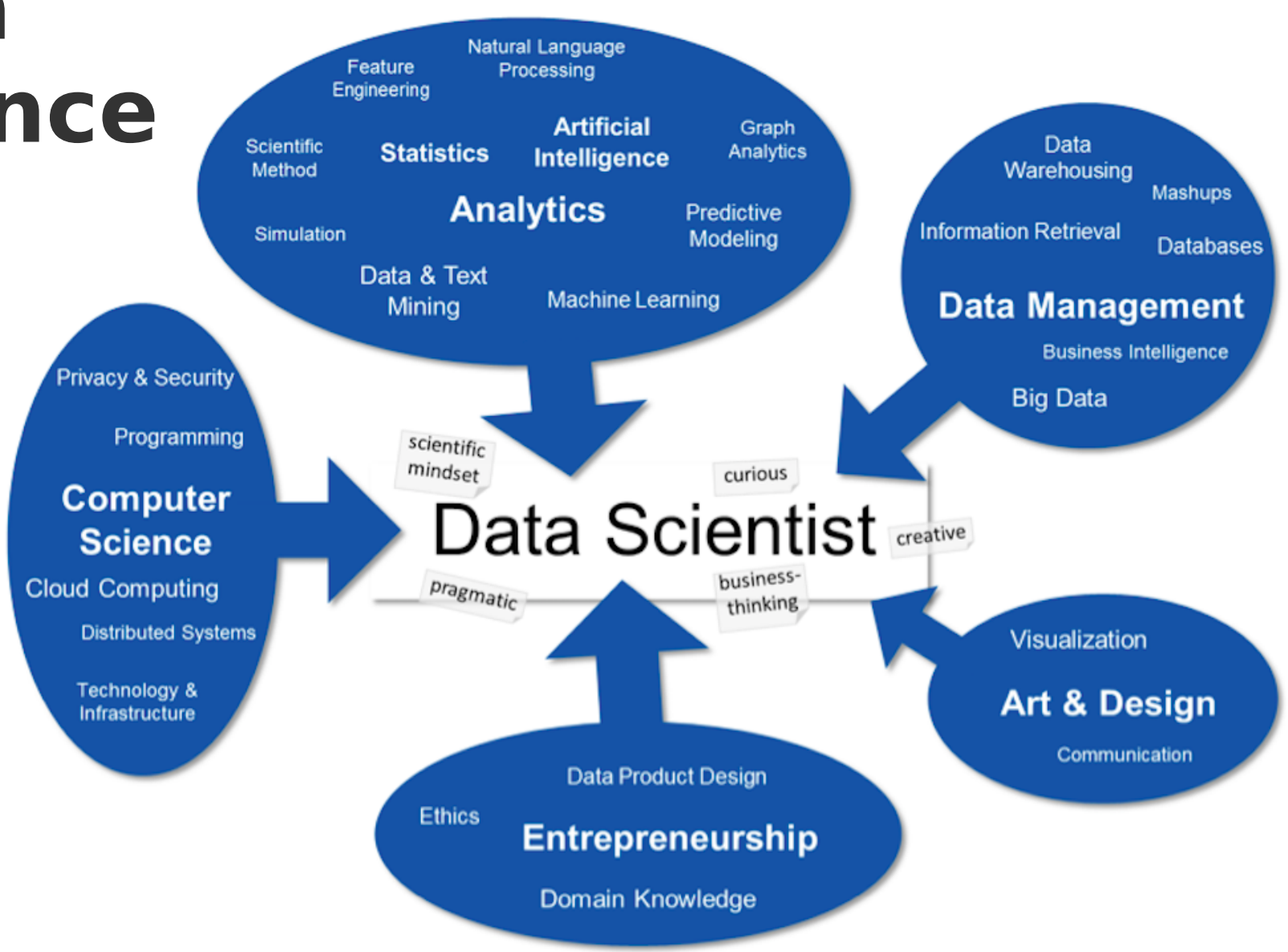
What decisions should we make now
to achieve the best future outcome?



Issues:

- What are the decision variables? Causality?
- Relationship can be non-linear. Convex?
- Uncertainty about quality and reliability of the predictive model.

Data Science



Source: T. Stadelmann, et al., Applied Data Science in Europe

Good luck finding this person!
Probably a team effort!

Agenda

- What is Data Mining?
- Data mining techniques
- Relationship to Statistics, Optimization, Machine Learning and AI
- **Tools**
- Data
- Legal, Privacy and Security Issues

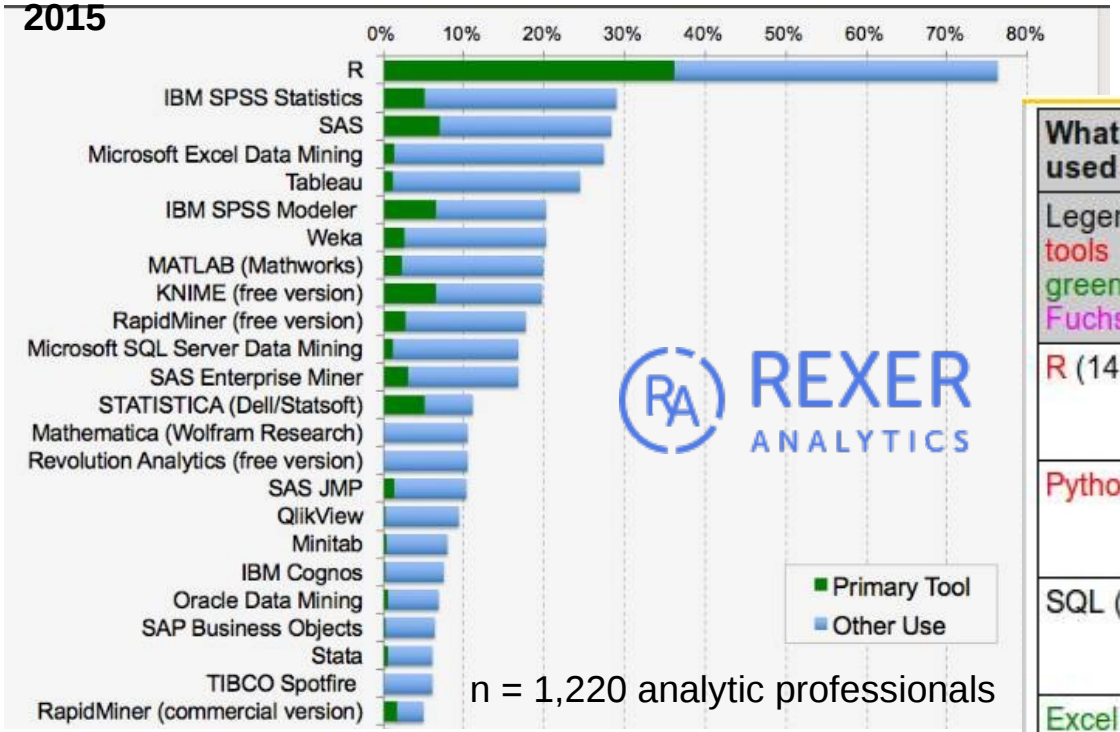
Tools
Commercial Players

Gartner

Gartner 2016 Magic Quadrant for Advanced Analytics Platforms (changes from 2015)

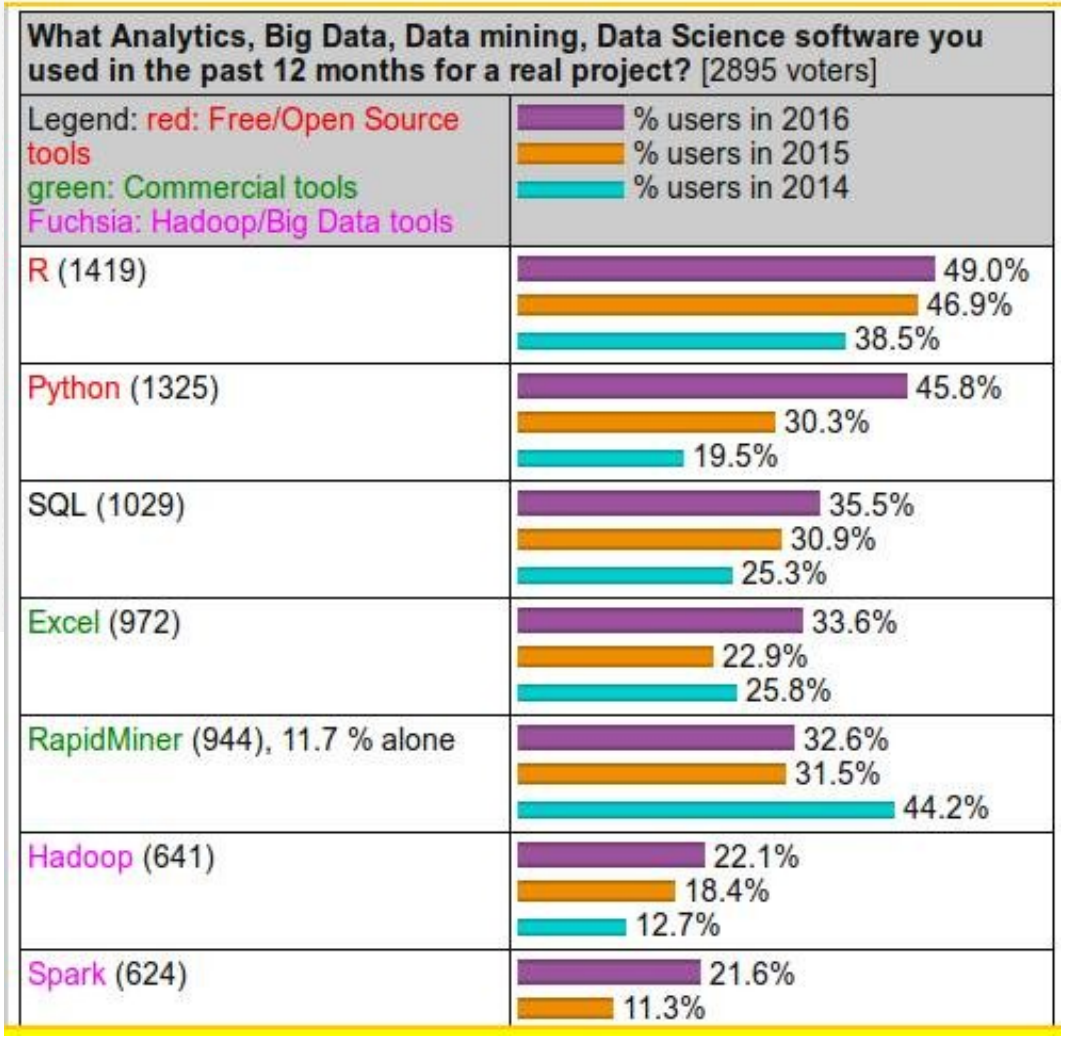
Tools Popularity

Rexer Analytics 2015



http://www.rexeranalytics.com/Data-Miner-Survey-2015-Intro.html

KDnuggets



http://www.kdnuggets.com/2016/06/r-python-top-analytics-data-mining-data-science-software.html

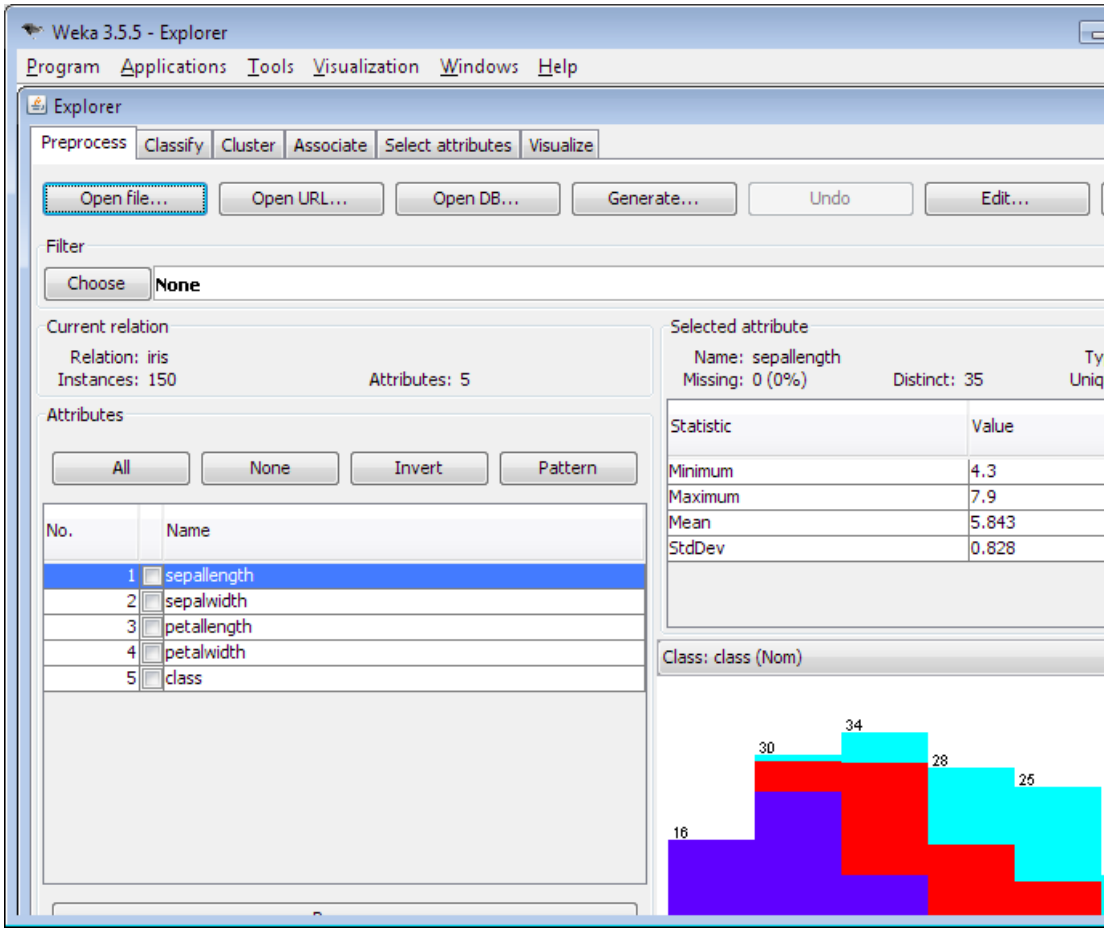
Tools Types

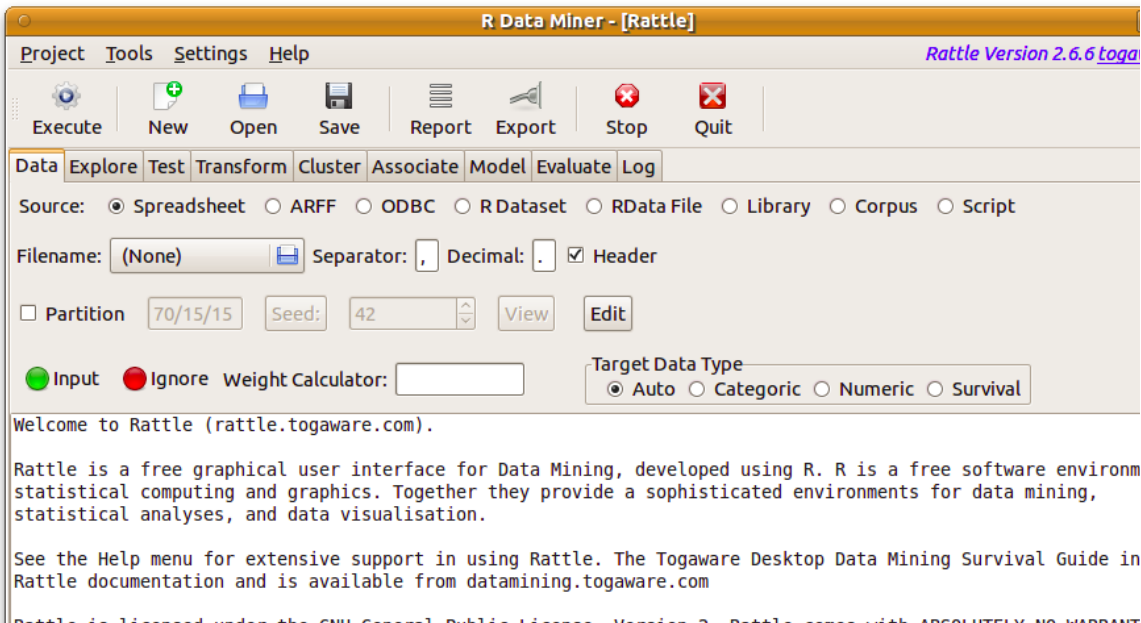
- Simple graphical user interface
- Process oriented
- Programming oriented

Tools
Simple GUI

- **Weka:** Waikato Environment for Knowledge Analysis (Java API)

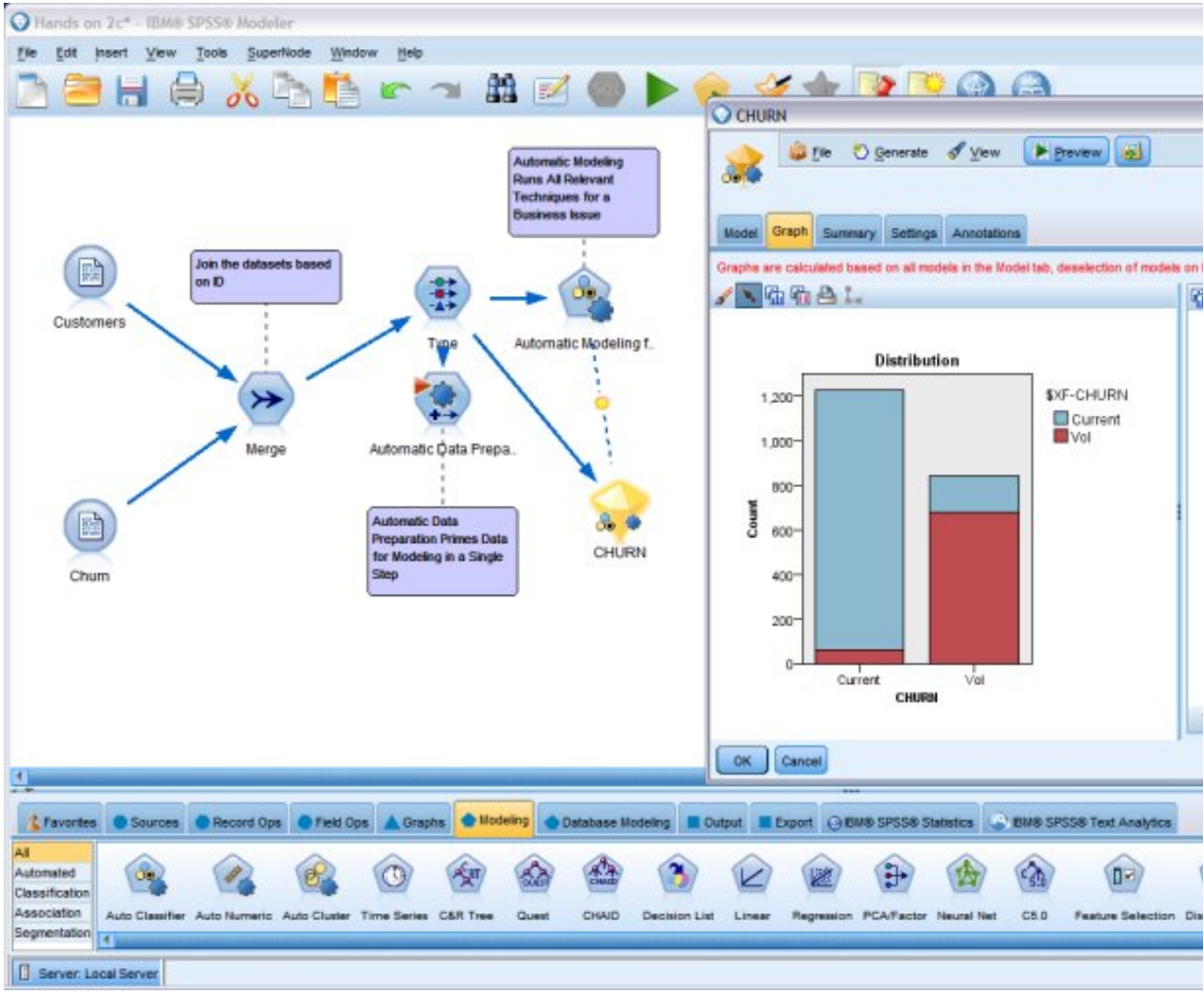
- **Rattle:** GUI for Data Mining using R





Tools
Process oriented

- SAS Enterprise Miner
- IBM SPSS Modeler
- RapidMiner
- Knime
- Orange



Tools
Programming oriented

- **R**
  - Rattle for beginners
  - RStudio IDE, markdown, shiny
  - Microsoft Open R

- **Python**
  - Scikit-learn, pandas
  - IPython, notebooks

machine learning in Python

→ Both have similar capabilities. Slightly different focus:

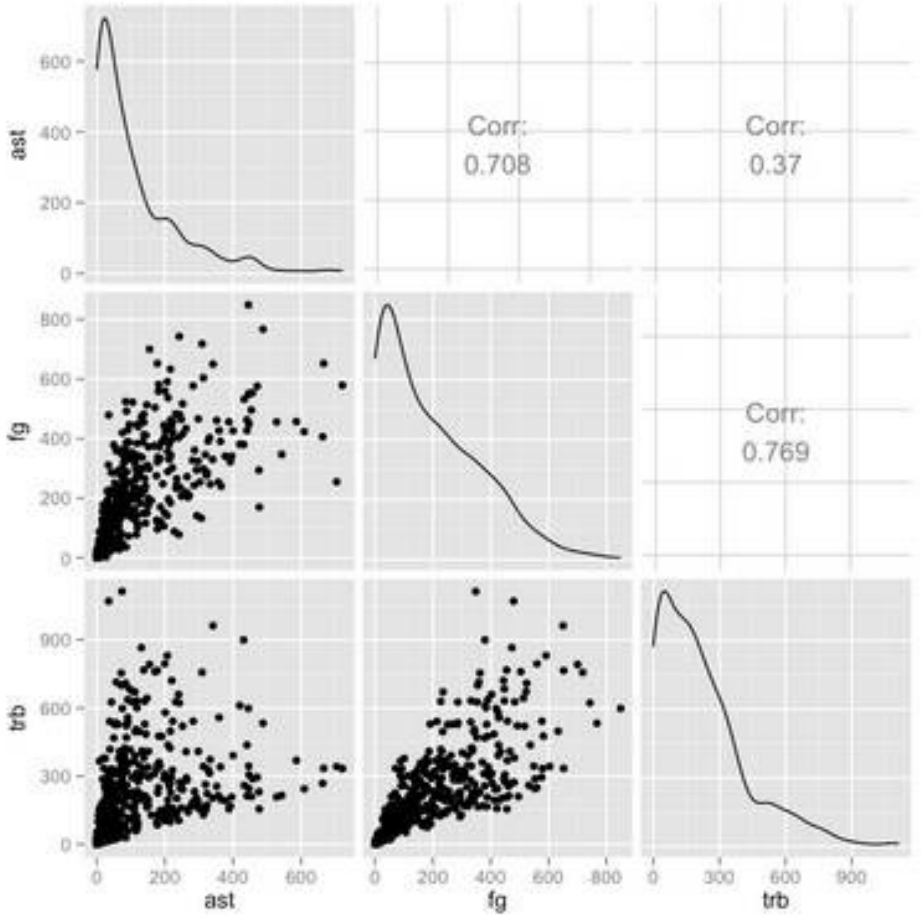
- R: statistical computing and visualization
- Python: Machine learning and big data

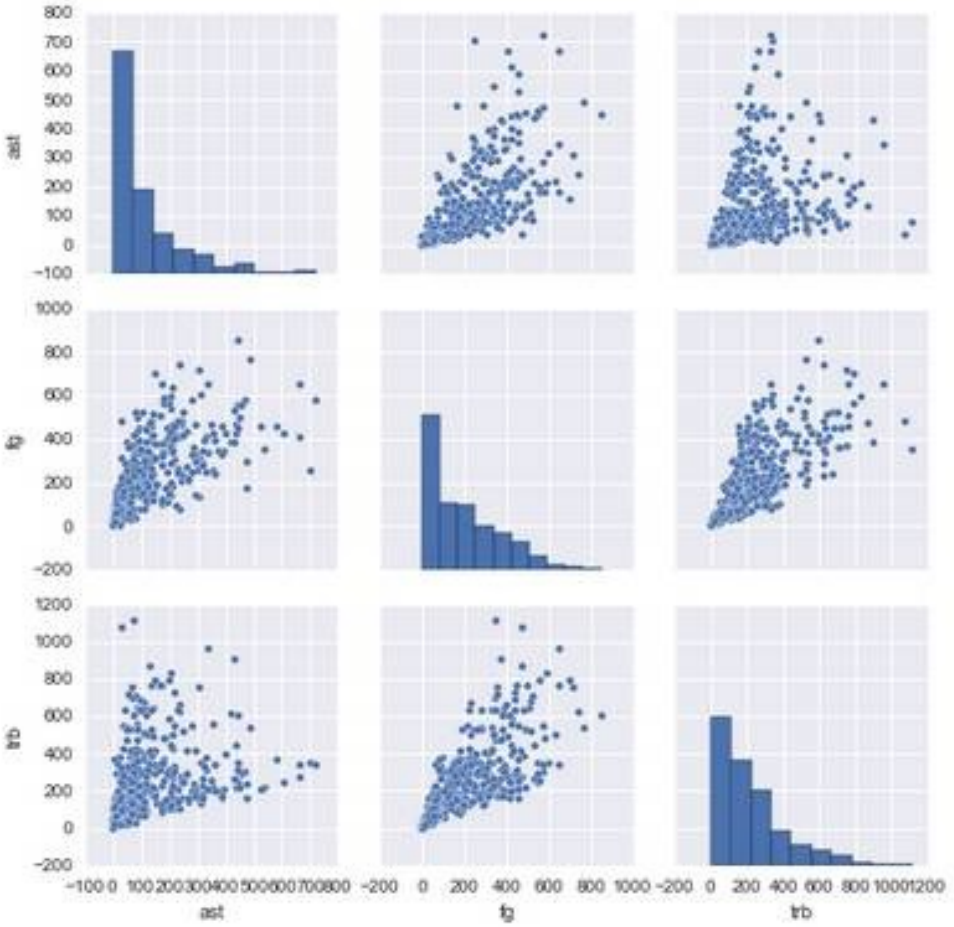
R

```r
library(GGally)
ggpairs(nba[,c("ast", "fg", "trb")])
```

Python

```python
import seaborn as sns
import matplotlib.pyplot as plt
sns.pairplot(nba[["ast", "fg", "trb"]])
plt.show()
```





https://www.dataquest.io/blog/python-vs-r/

Getting Started with R or Python

- **R** Code Examples for Introduction to Data Mining

  https://github.com/mhahsler/Introduction_to_Data_Mining_R_Examples

- **Python:** Data Science in Python

  http://www.kdnuggets.com/2014/01/tutorial-data-science-python.html

Agenda

- What is Data Mining?
- Data mining techniques
- Relationship to Statistics, Optimization, Machine Learning and AI
- Tools
- **Data**
- Legal, Privacy and Security Issues

Data

WebSiteUsers.csv - Notepad

File Edit Format View Help

```
Web Customer ID,Email,Country,Telephone,First name,Surname,Company,,,
456,A@A.com,United Kindom,123,A,A,A,,,
457,B@B.com,United States,124,B,B,B,,,
458,C@C.com,Aran Emerates,125,C,C,C,,,
459,D@D.com,New Zealand,126,D,D,D,,,
460,E@E.com,United Kindom,127,E,E,E,,,
461,F@F.com,United States,128,F,F,F,,,
462,G@G.com,Aran Emerates,129,G,G,G,,,
463,H@H.com,New Zealand,130,H,H,H,,,
464,I@I.com,United Kindom,131,I,I,I,,,
465,J@J.com,United States,132,J,J,J,,,
466,K@K.com,Aran Emerates,133,K,K,K,,,
467,L@L.com,New Zealand,134,L,L,L,,,
468,M@M.com,United Kindom,135,M,M,M,,,
469,,United States,136,N,N,N,,,
470,O@O.com,Aran Emerates,137,O,O,O,,,
471,P@P.com,New Zealand,138,P,P,P,,,
472,,United Kindom,139,Q,Q,Q,,,
473,R@R.com,United States,140,R,R,R,,,
474,S@S.com,Aran Emerates,141,S,S,S,,,
475,T@T.com,New Zealand,142,T,T,T,,,
476,U@U.com,United Kindom,143,U,U,U,,,
477,V@V.com,United States,144,V,V,V,,,
478,W@W.com,Aran Emerates,145,W,W,W,,,
479,X@X.com,New Zealand,146,X,X,X,,,
480,Y@Y.com,United Kindom,147,Y,Y,Y,,,
481,Z@Z.com,United States,148,Z,Z,Z,,,
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Microsoft Excel - Excel training sample 3.xls

File Edit View Insert Format Tools Data Window Help

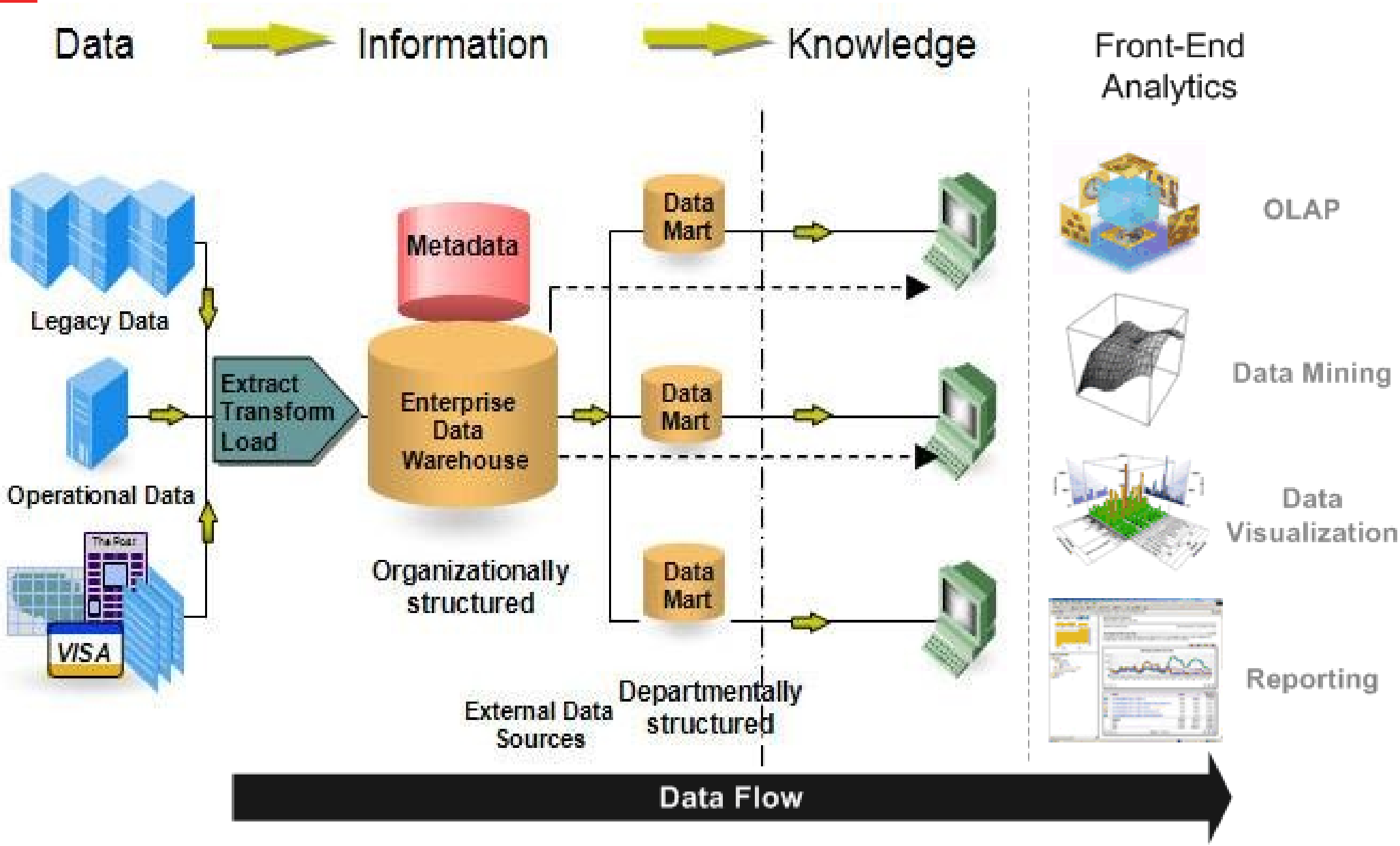
Arial 10

SnagIt Window

E20

	A	B	C	D	E	F
1	Date	Amount	Budgeted	Difference	Department	Category
2	9/1/2005	$ 3,498.56	$ 3,200.00	$ 298.56	Grounds	Equipment
3	9/1/2005	$ 1,912.11	$ 2,000.00	$ (87.89)	IT	Software
4	9/3/2005	$ 2,121.21	$ 2,100.00	$ 21.21	Telephones	Services
5	9/8/2005	$ 1,837.27	$ 2,000.00	$ (162.73)	IT	Consulting
6	9/10/2005	$ 323.99	$ 150.00	$ 173.99	Grounds	Supplies
7	9/12/2005	$ 81.61	$ 100.00	$ (18.39)	Telephones	Supplies
8	9/14/2005	$ 2,500.00	$ 4,000.00	$ (1,500.00)	Administration	Consulting
9	9/14/2005	$ 1,000.00	$ 500.00	$ 500.00	IT	Services
10	9/15/2005	$ 31,872.22	$ 32,000.00	$ (127.78)	Administration	Payroll
11	9/15/2005	$ 10,330.31	$ 10,000.00	$ 330.31	Grounds	Payroll
12	9/15/2005	$ 12,897.69	$ 12,500.00	$ 397.69	IT	Payroll

Data Warehouse

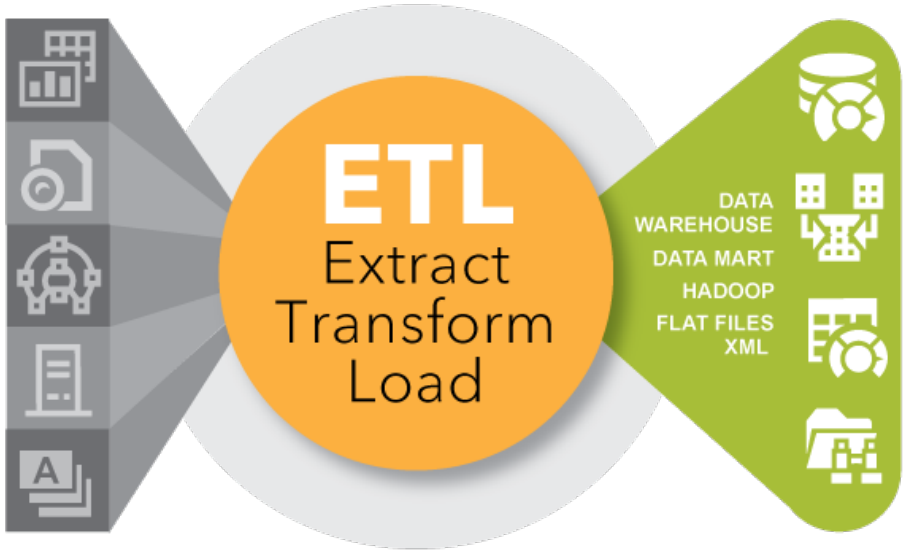


http://www.fulcrumlogic.com/data_warehousing.shtml

Data Warehouse

- **Subject Oriented:** Data warehouses are designed to help you analyze data (e.g., sales data is organized by product and customer).
- **Integrated:** Integrates data from disparate sources into a consistent format.
- **Nonvolatile**: Data in the data warehouse are never overwritten or deleted.
- **Time Variant**: maintains both historical and (nearly) current data.

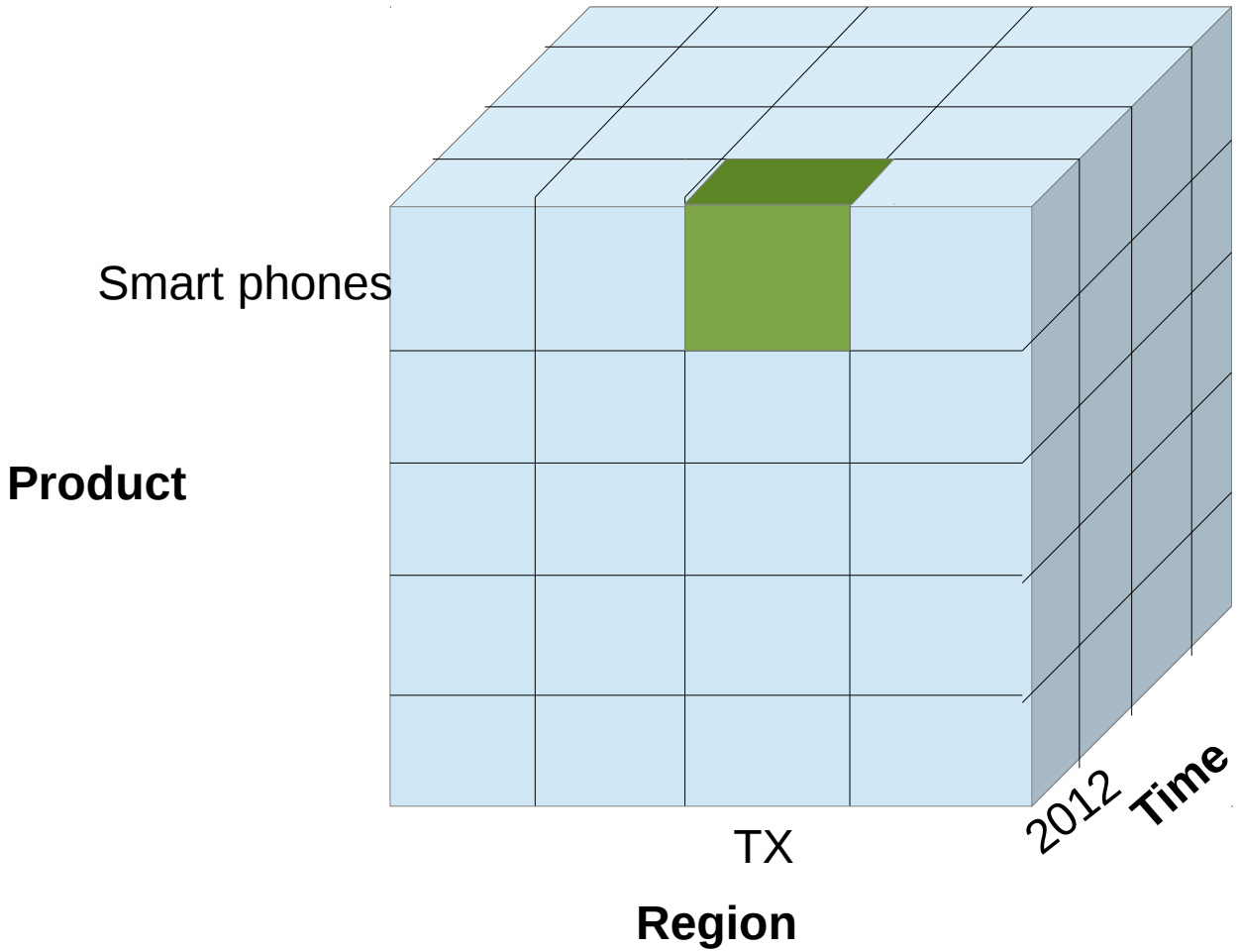
ETL
Extract, Transform and Load



Source: SAS, ETL: What it is and why it matters

- **Extracting** data from outside sources
- **Transforming** data to fit analytical needs. E.g.,
  - Clean missing data, wrong data, etc.
  - Normalize and translate (e.g., 1 → "female")
  - Join from several sources
  - Calculate and aggregate data
- **Loading** data into the data warehouse

OLAP
OnLine Analytical Processing



Operations:

- Slice
- Dice
- Drill-down
- Roll-up
- Pivot

For fast operation OLAP requires a special database structure (Snow-flake scheme)

Big Data

"Big data is a term for data sets that are so large or complex that ***traditional data processing applications are inadequate*** *to deal with them."* Wikipedia

3 V's: Volume, velocity, variety, (veracity) Gartner

THE APACHE SOFTWARE FOUNDATION

OLTP/OLAP RDBMS	In-Memory, Data Flow Engine	Analytical SQL-on-Hadoop	NoSQL Database	Machine Learning	Search	Scripting	Integration & Streaming	Management & Coordination
splice MACHINE	Spark	Hive, cloudera IMPALA, APACHE DRILL	APACHE HBASE	Spark MLlib, mahout, R	Apache Solr	Pig	kafka, oozie, APACHE STORM	Apache Ambari, Apache Zookeeper, cloudera Manager

Resource Management	YARN, MESOS	Distributed Computation: MapReduce
Distributed Storage	HDFS	

Agenda

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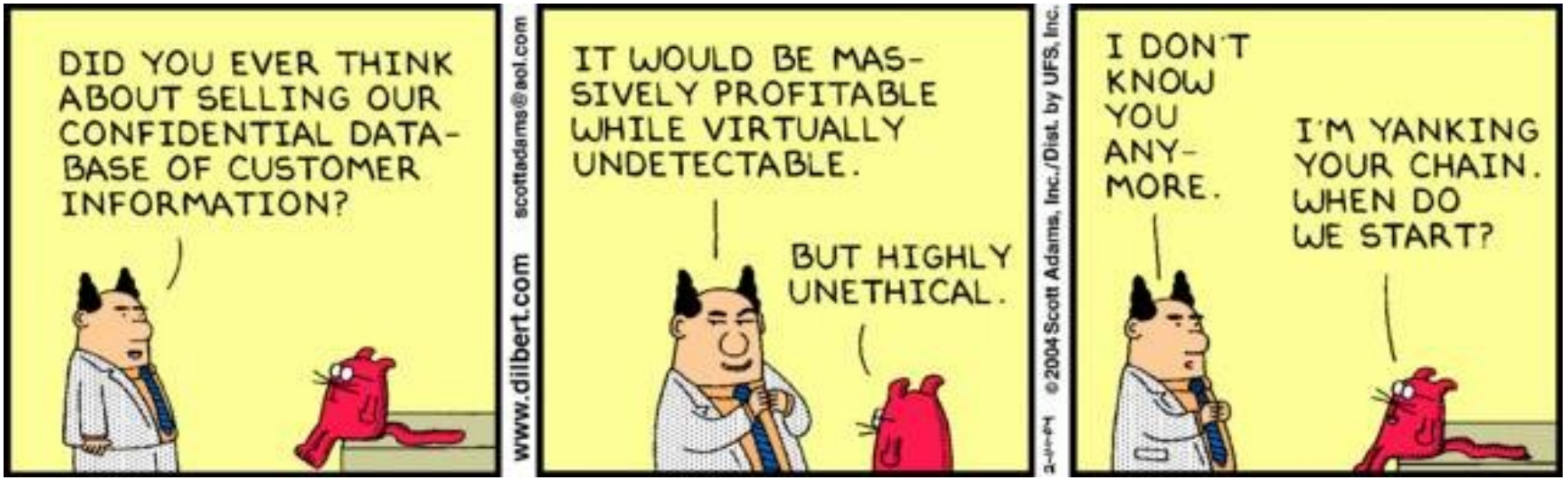
Legal, Privacy and Security Issues



?

Legal, Privacy and Security Issues

- Are we allowed to **collect** the data?
- Are we allowed to **use** the data?
- Is **privacy** preserved in the process?
- Is it **ethical** to use and act on the data?

- **Problem:** Internet is global but legislation is local!

Legal, Privacy and Security Issues

The New York Times

Data-Gathering via Apps Presents a Gray Legal Area

By KEVIN J. O'BRIEN

Published: October 28, 2012

BERLIN — Angry Birds, the top-selling paid mobile app for the iPhone in the United States and Europe, has been downloaded more than a billion times by devoted game players around the world, who often spend hours slinging squawking fowl at groups of egg-stealing pigs.

When Jason Hong, an associate professor at the Human-Computer Interaction Institute at Carnegie Mellon University, surveyed 40 users, all but two were *unaware that the game was storing their locations so that they could later be the targets of ads*....


Pokémon
GO

Here is what the small print says...

USA Today Network Josh Hafner, 2:38 p.m. EDT July 13, 2016

Pokémon Go's constant location tracking and camera access required for gameplay, paired with its skyrocketing popularity, could provide data like no app before it.

***"Their privacy policy is vague,"** Hong said. "I'd say deliberately vague, because of the lack of clarity on the business model."*

...

*The agreement says Pokémon Go collects data about its users as a **"business asset."** This includes data used to personally identify players such as email addresses and other information pulled from Google and Facebook accounts players use to sign up for the game.*

If Niantic is ever sold, the agreement states, all that data can go to another company.

Conclusion

Data Mining is **interdisciplinary** and overlaps significantly with many fields including

- statistics,
- CS (machine learning, AI, data bases)
- optimization.

Data Mining requires a **team effort** with members who have expertise in

- data management,
- statistics,
- programming,
- communication, and
- the application domain.