Data Mining & Machine Learning

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DIPARTIMENTO DI INFORMATICA - Università di Pisa
Data Mining

Riferimenti bibliografici

- Berthold et. al. Guide to Intelligent Data Analysis

- Provost, F., Fawcett, T. Data Science for Business (2012)
- Barry Linoff Data Mining Techniques for Marketing Sales and Customer Support, John Wiles & Sons, 2002
Contenuti del corso in dettaglio

- **Introduzione e Concetti Basici**
  - Le applicazioni
  - Il processo di knowledge discovery
  - Esempi di estrazione (Evasione fiscale, Business Intelligence)
  - La metodologia di sviluppo di un progetto DM CRISP

- **Il processo di estrazione della conoscenza**
  - Le fasi iniziali: data understanding, preparazione e pulizia dei dati
  - Introduzione alla piattaforma KNIME

- **Introduzione alle tecniche di base**
  - Classificazione: Alberi di decisione
  - Clustering
  - Pattern Mining

- **Overview of BigData Analytics**
  - Social Network analysis
  - Mobility Data Analysis
  - Social Media Analysis & Privacy
Evolution of Database Technology: from data management to data analysis

- **1960s:**
  - Data collection, database creation, IMS and network DBMS.

- **1970s:**
  - Relational data model, relational DBMS implementation.

- **1980s:**
  - RDBMS, advanced data models (extended-relational, OO, deductive, etc.) and application-oriented DBMS (spatial, scientific, engineering, etc.).

- **1990s:**
  - Data mining and data warehousing, multimedia databases, and Web technology.
Why Mine Data? Commercial Viewpoint

- Lots of data is being collected and warehoused
  - Web data, e-commerce
  - Purchases at department/grocery stores
  - 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 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

- Traditional techniques infeasible for raw data

- Data mining may help scientists
  - in classifying and segmenting data
  - in Hypothesis Formation
Mining Large Data Sets - Motivation

- There is often information “hidden” in the data that is not readily evident
- Human analysts may take weeks to discover useful information
- Much of the data is never analyzed at all

From: R. Grossman, C. Kamath, V. Kumar, “Data Mining for Scientific and Engineering Applications”
Motivations

“Necessity is the Mother of Invention”

Data explosion problem:
- Automated data collection tools, mature database technology and internet lead to tremendous amounts of data stored in databases, data warehouses and other information repositories.

We are drowning in information, but starving for knowledge! (John Naisbett)

Data warehousing and data mining:
- On-line analytical processing
- Extraction of interesting knowledge (rules, regularities, patterns, constraints) from data in large databases.
Why Data Mining

- **Increased Availability of Huge Amounts of Data**
  - point-of-sale customer data
  - digitization of text, images, video, voice, etc.
  - World Wide Web and Online collections

- **Data Too Large or Complex for Classical or Manual Analysis**
  - number of records in millions or billions
  - high dimensional data (too many fields/features/attributes)
  - often too sparse for rudimentary observations
  - high rate of growth (e.g., through logging or automatic data collection)
  - heterogeneous data sources

- **Business Necessity**
  - e-commerce
  - high degree of competition
  - personalization, customer loyalty, market segmentation
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
### 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’Rurke, O’Reilly… in Boston area)
- Group together similar documents returned by search engine according to their context (e.g. Amazon rainforest, Amazon.com,)
Sources of Data

- **Business Transactions**
  - widespread use of bar codes => storage of millions of transactions daily (e.g., Walmart: 2000 stores => 20M transactions per day)
  - most important problem: effective use of the data in a reasonable time frame for competitive decision-making
  - e-commerce data

- **Scientific Data**
  - data generated through multitude of experiments and observations
  - examples, geological data, satellite imaging data, NASA earth observations
  - rate of data collection far exceeds the speed by which we analyze the data
Sources of Data

- **Financial Data**
  - company information
  - economic data (GNP, price indexes, etc.)
  - stock markets

- **Personal / Statistical Data**
  - government census
  - medical histories
  - customer profiles
  - demographic data
  - data and statistics about sports and athletes
Sources of Data

- World Wide Web and Online Repositories
  - email, news, messages
  - Web documents, images, video, etc.
  - link structure of the hypertext from millions of Web sites
  - Web usage data (from server logs, network traffic, and user registrations)
  - online databases, and digital libraries
Classes of applications

Database analysis and decision support

- Market analysis
  - target marketing, customer relation management, market basket analysis, cross selling, market segmentation.

- Risk analysis
  - Forecasting, customer retention, improved underwriting, quality control, competitive analysis.

- Fraud detection

New Applications from New sources of data

- Text (news group, email, documents)
- Web analysis and intelligent search
Market Analysis

Where are the data sources for analysis?
- Credit card transactions, loyalty cards, discount coupons, customer complaint calls, plus (public) lifestyle studies.

Target marketing
- Find clusters of “model” customers who share the same characteristics: interest, income level, spending habits, etc.

Determine customer purchasing patterns over time
- Conversion of single to a joint bank account: marriage, etc.

Cross-market analysis
- Associations/co-relations between product sales
- Prediction based on the association information.
Customer profiling

- data mining can tell you what types of customers buy what products (clustering or classification).

Identifying customer requirements

- identifying the best products for different customers
- use prediction to find what factors will attract new customers

Summary information

- various multidimensional summary reports;
- statistical summary information (data central tendency and variation)
Risk Analysis

- **Finance planning and asset evaluation:**
  - cash flow analysis and prediction
  - contingent claim analysis to evaluate assets
  - trend analysis

- **Resource planning:**
  - summarize and compare the resources and spending

- **Competition:**
  - monitor competitors and market directions (*CI*: competitive intelligence).
  - group customers into classes and class-based pricing procedures
  - set pricing strategy in a highly competitive market
Applications:
- widely used in health care, retail, credit card services, telecommunications (phone card fraud), etc.

Approach:
- use historical data to build models of fraudulent behavior and use data mining to help identify similar instances.

Examples:
- auto insurance: detect a group of people who stage accidents to collect on insurance
- money laundering: detect suspicious money transactions (US Treasury's Financial Crimes Enforcement Network)
- medical insurance: detect professional patients and ring of doctors and ring of references
**Fraud Detection (2)**

**More examples:**

- **Detecting inappropriate medical treatment:**
  - Australian Health Insurance Commission identifies that in many cases blanket screening tests were requested (save Australian $1m/yr).

- **Detecting telephone fraud:**
  - Telephone call model: destination of the call, duration, time of day or week. Analyze patterns that deviate from an expected norm.

- **Retail:** Analysts estimate that 38% of retail shrink is due to dishonest employees.
Other applications

Sports
- IBM Advanced Scout analyzed NBA game statistics (shots blocked, assists, and fouls) to gain competitive advantage for New York Knicks and Miami Heat.

Astronomy
- JPL and the Palomar Observatory discovered 22 quasars with the help of data mining

Internet Web Surf-Aid
- IBM Surf-Aid applies data mining algorithms to Web access logs for market-related pages to discover customer preference and behavior pages, analyzing effectiveness of Web marketing, improving Web site organization, etc.
What is Knowledge Discovery in Databases (KDD)? A process!

- The selection and processing of data for:
  - the identification of novel, accurate, and useful patterns, and
  - the modeling of real-world phenomena.

- Data mining is a major component of the KDD process - automated discovery of patterns and the development of predictive and explanatory models.
Data Mining: Confluence of Multiple Disciplines

- Database Technology
- Statistics
- Machine Learning (AI)
- Information Science
- Visualization
- Other Disciplines
The KDD Process in Practice

- KDD is an Iterative Process
  - art + engineering ....and science
The KDD process

- Data Sources
  - Data Consolidation
    - Consolidated Data
  - Warehouse
    - Prepared Data
    - Patterns & Models
      - $p(x) = 0.02$
  - Selection and Preprocessing
  - Data Mining
  - Interpretation and Evaluation
  - Knowledge

Giannotti & Pedreschi
The steps of the KDD process

- Learning the application domain:
  - relevant prior knowledge and goals of application
- Data consolidation: Creating a target data set
- Selection and Preprocessing
  - Data cleaning: (may take 60% of effort!)
  - Data reduction and projection:
    - find useful features, dimensionality/variable reduction, invariant representation.
- Choosing functions of data mining
  - summarization, classification, regression, association, clustering.
- Choosing the mining algorithm(s)
- Data mining: search for patterns of interest
- Interpretation and evaluation: analysis of results.
  - visualization, transformation, removing redundant patterns, ...
- Use of discovered knowledge
The virtuous cycle

Problem
- Identify Problem or Opportunity

Knowledge
- Act on Knowledge

Strategy
- Measure effect of Action

Results
Increasing potential to support business decisions

Making Decisions

Data Presentation

Visualization Techniques

Data Mining

Information Discovery

Data Exploration

Statistical Analysis, Querying and Reporting

Data Warehouses / Data Marts

OLAP, MDA

Data Sources

Paper, Files, Information Providers, Database Systems, OLTP

End User

Business Analyst

Data Analyst

DBA
Roles in the KDD process

<table>
<thead>
<tr>
<th>Domain Experts</th>
<th>Mining Specialists</th>
<th>Data Administrator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Analysis</td>
<td>Data Analysis</td>
<td>Business Feedback</td>
</tr>
<tr>
<td>Data Gathering</td>
<td>Data Preparation</td>
<td>Business Application</td>
</tr>
<tr>
<td>Data Mining</td>
<td>Result Interpretation</td>
<td></td>
</tr>
</tbody>
</table>

Business Goal
A business intelligence environment

- Operational Data
- Business Data Warehouse
- Business Information Warehouse
- Data Mining
  - Customer Segmentation
  - Basket Analysis
  - Fraud Detection
  - Target Marketing
- Query / OLAP
  - Business Queries
  - Multi Dimensional Analysis

Extraction / Replication
Data Cleaning
Meta Data Management
THE KDD PROCESS
The KDD process

Data Consolidation

Data Sources

Warehouse

Consolidated Data

Selection and Preprocessing

Data Mining

Interpretation and Evaluation

Knowledge

Patterns & Models

Prepared Data

p(x) = 0.02
Garbage in \[\rightarrow\] Garbage out

- The quality of results relates directly to quality of the data
- 50\%-70\% of KDD process effort is spent on data consolidation and preparation
- Major justification for a corporate data warehouse
Data consolidation

From data sources to consolidated data repository

- RDBMS
- Legacy DBMS
- Flat Files
- External

Data Consolidation and Cleansing

Warehouse

Object/Relation DBMS
Multidimensional DBMS
Deductive Database
Flat files
Data consolidation

- Determine preliminary list of attributes
- Consolidate data into working database
  - Internal and External sources
- Eliminate or estimate missing values
- Remove *outliers* (obvious exceptions)
- Determine prior probabilities of categories and deal with *volume bias*
The KDD process

Data Consolidation

Selection and Preprocessing

Data Mining

Interpretation and Evaluation

Knowledge

$\mathbb{P}(x) = 0.02$
Data selection and preprocessing

- **Generate a set of examples**
  - choose sampling method
  - consider sample complexity
  - deal with volume bias issues

- **Reduce attribute dimensionality**
  - remove redundant and/or correlating attributes
  - combine attributes (sum, multiply, difference)

- **Reduce attribute value ranges**
  - group symbolic discrete values
  - quantify continuous numeric values

- **Transform data**
  - de-correlate and normalize values
  - map time-series data to static representation

- **OLAP and visualization tools play key role**
The KDD process

Data Mining

Selection and Preprocessing

Data Consolidation

Interpretation and Evaluation

Knowledge

Warehouse

\[ p(x) = 0.02 \]
Supervised (Directed) Knowledge Discovery

**Purpose:** Explain value of some field in terms of all the others (goal-oriented)

**Method:** select the target field based on some hypothesis about the data; ask the algorithm to tell us how to predict or classify new instances

**Examples:**
- what products show increased sale when cream cheese is discounted
- which banner ad to use on a web page for a given user coming to the site
Unsupervised (Undirected) Knowledge Discovery (Exploratory Methods)

- **Purpose**: Find patterns in the data that may be interesting (no target specified)
- **Task**: clustering, association rules (affinity grouping)
- **Examples**:
  - which products in the catalog often sell together
  - market segmentation (groups of customers/users with similar characteristics)
Data Mining Tasks

- Automated Exploration/Discovery
  - e.g. discovering new market segments
  - clustering analysis

- Prediction/Classification
  - e.g. forecasting gross sales given current factors
  - regression, neural networks, genetic algorithms, decision trees

- Explanation/Description
  - e.g. characterizing customers by demographics
    purchase history
  - decision trees, association rules

\[
\text{if age} > 35 \quad \text{and income} < $35k \\
\text{then ...}
\]
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.

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

- **Classification** [Predictive]
- **Clustering** [Descriptive]
- **Association Rule Discovery** [Descriptive]
- **Sequential Pattern Discovery** [Descriptive]
- **Regression** [Predictive]
- **Deviation Detection** [Predictive]
Prediction and classification

- **Learning** a predictive model
- **Classification** of a new case/sample
- **Many methods:**
  - Artificial neural networks
  - Inductive decision tree and rule systems
  - Genetic algorithms
  - Nearest neighbor clustering algorithms
  - Statistical (parametric, and non-parametric)
Objective: Develop a general model or hypothesis from specific examples

- Function approximation (curve fitting)
- Classification (concept learning, pattern recognition)
Classification: Definition

- **Given a collection of records** (*training set*)
  - Each record contains a set of *attributes*, one of the attributes is the *class*.

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

- **Goal:** *previously unseen* records should be assigned a class as accurately as possible.

  - A *test set* is used to determine the accuracy of the model. Usually, the given data set is divided into training and test sets, with training set used to build the model and test set used to validate it.
### Classification Example

<table>
<thead>
<tr>
<th>Tid</th>
<th>Refund</th>
<th>Marital Status</th>
<th>Taxable Income</th>
<th>Cheat</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>Single</td>
<td>125K</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
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<td>Married</td>
<td>100K</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>No</td>
<td>Single</td>
<td>70K</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>Married</td>
<td>120K</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>No</td>
<td>Divorced</td>
<td>95K</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>No</td>
<td>Married</td>
<td>60K</td>
<td>No</td>
</tr>
<tr>
<td>7</td>
<td>Yes</td>
<td>Divorced</td>
<td>220K</td>
<td>No</td>
</tr>
<tr>
<td>8</td>
<td>No</td>
<td>Single</td>
<td>85K</td>
<td>Yes</td>
</tr>
<tr>
<td>9</td>
<td>No</td>
<td>Married</td>
<td>75K</td>
<td>No</td>
</tr>
<tr>
<td>10</td>
<td>No</td>
<td>Single</td>
<td>90K</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Refund</th>
<th>Marital Status</th>
<th>Taxable Income</th>
<th>Cheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>Single</td>
<td>75K</td>
<td>?</td>
</tr>
<tr>
<td>Yes</td>
<td>Married</td>
<td>50K</td>
<td>?</td>
</tr>
<tr>
<td>No</td>
<td>Married</td>
<td>150K</td>
<td>?</td>
</tr>
<tr>
<td>Yes</td>
<td>Divorced</td>
<td>90K</td>
<td>?</td>
</tr>
<tr>
<td>No</td>
<td>Single</td>
<td>40K</td>
<td>?</td>
</tr>
<tr>
<td>No</td>
<td>Married</td>
<td>80K</td>
<td>?</td>
</tr>
</tbody>
</table>

**Training Set**

**Test Set**

**Learn Classifier**

**Model**
Classification: Application 1

- **Direct Marketing**
  - **Goal:** Reduce cost of mailing by targeting a set of consumers likely to buy a new cell-phone product.
  - **Approach:**
    - Use the data for a similar product introduced before.
    - We know which customers decided to buy and which decided otherwise. This \{buy, don't buy\} decision forms the **class attribute**.
    - Collect various demographic, lifestyle, and company-interaction related information about all such customers.
      - Type of business, where they stay, how much they earn, etc.
    - Use this information as input attributes to learn a classifier model.

From [Berry & Linoff] Data Mining Techniques, 1997
Classification: Application 2

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 3

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.
  - 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.

From [Berry & Linoff] Data Mining Techniques, 1997
Generalization and regression

- The objective of learning is to achieve good generalization to new unseen cases.
- Generalization can be defined as a mathematical interpolation or regression over a set of training points.
- Models can be validated with a previously unseen test set or using cross-validation methods.

\[ f(x) \]

\[ x \]
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.

- Greatly studied in statistics, neural network fields.

- Examples:
  - 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.
Explanation and description

- Learn a generalized hypothesis (model) from selected data
- Description/Interpretation of model provides new knowledge

Methods:
- Inductive decision tree and rule systems
- Association rule systems
- Link Analysis
- ...
Automated exploration and discovery

- **Clustering**: partitioning a set of data into a set of classes, called *clusters*, whose members share some interesting common properties.

- **Distance-based numerical clustering**
  - metric grouping of examples (K-NN)
  - graphical visualization can be used

- **Bayesian clustering**
  - search for the number of classes which result in best fit of a probability distribution to the data
  - AutoClass (NASA) one of best examples
Clustering Definition

Given a set of data points, each having a set of attributes, and a similarity measure among them, find clusters such that

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

Similarity Measures:
- Euclidean Distance if attributes are continuous.
- Other Problem-specific Measures.
Illustrating Clustering

- Euclidean Distance Based Clustering in 3-D space.

Intracluster distances are minimized

Intercluster distances are maximized
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.
**Pattern Mining**

- Determine what items often go together (usually in transactional databases)
- Often Referred to as Market Basket Analysis
  - used in retail for planning arrangement on shelves
  - used for identifying cross-selling opportunities
  - “should” be used to determine best link structure for a Web site
- Examples
  - people who buy milk and beer also tend to buy diapers
  - people who access pages A and B are likely to place an online order
- Suitable data mining tools
  - association rule discovery
  - clustering
  - Nearest Neighbor analysis (memory-based reasoning)
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.

<table>
<thead>
<tr>
<th>TID</th>
<th>Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bread, Coke, Milk</td>
</tr>
<tr>
<td>2</td>
<td>Beer, Bread</td>
</tr>
<tr>
<td>3</td>
<td>Beer, Coke, Diaper, Milk</td>
</tr>
<tr>
<td>4</td>
<td>Beer, Bread, Diaper, Milk</td>
</tr>
<tr>
<td>5</td>
<td>Coke, Diaper, Milk</td>
</tr>
</tbody>
</table>

Rules Discovered:

- \{Milk\} --> \{Coke\}
- \{Diaper, Milk\} --> \{Beer\}
Marketing and Sales Promotion:

- Let the rule discovered be
  \[ \{\text{Bagels, } \ldots\} \rightarrow \{\text{Potato Chips}\} \]
- **Potato Chips as consequent** => Can be used to determine what should be done to boost its sales.
- **Bagels in the antecedent** => Can be used to see which products would be affected if the store discontinues selling bagels.
- **Bagels in antecedent and Potato chips in consequent** => Can be used to see what products should be sold with Bagels to promote sale of Potato chips!
Supermarket shelf management.

Goal: To identify items that are bought together by sufficiently many customers.

Approach: Process the point-of-sale data collected with barcode scanners to find dependencies among items.

A classic rule --

- If a customer buys diaper and milk, then he is very likely to buy beer.
- So, don’t be surprised if you find six-packs stacked next to diapers!
Given is a set of objects, with each object associated with its own timeline of events, find rules that predict strong sequential dependencies among different events.

Rules are formed by first discovering patterns. Event occurrences in the patterns are governed by timing constraints.
Exception/deviation detection

- Generate a model of normal activity
- Deviation from model causes alert

Methods:
- Artificial neural networks
- Inductive decision tree and rule systems
- Statistical methods
- Visualization tools
Outlier and exception data analysis

- Time-series analysis (trend and deviation):
  - Trend and deviation analysis: regression, sequential pattern, similar sequences, trend and deviation, e.g., stock analysis.
  - Similarity-based pattern-directed analysis
  - Full vs. partial periodicity analysis
  - Other pattern-directed or statistical analysis
The KDD process

- Selection and Preprocessing
- Data Consolidation and Warehousing

Data Mining

Interpretation and Evaluation

Knowledge

\[ p(x) \leq 0.02 \]
Are all the discovered pattern interesting?

- A data mining system/query may generate thousands of patterns, not all of them are interesting.

- **Interestingness measures:**
  - 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 beliefs in the data, e.g., unexpectedness, novelty, etc.
Interpretation and evaluation

Evaluation
- Statistical validation and significance testing
- Qualitative review by experts in the field
- Pilot surveys to evaluate model accuracy

Interpretation
- Inductive tree and rule models can be read directly
- Clustering results can be graphed and tabled
- Code can be automatically generated by some systems (IDTs, Regression models)
THE MOVIEGOER DATABASE
A database schema designed for tracking moviegoers' past movie viewing data. The main entities include:

- **moviegoers**
  - Moviegoer ID
  - Name
  - Sex
  - Age
  - Source ID
  - Movie ID

- **sources**
  - Source ID
  - Source

- **past-movies**
  - Moviegoer ID
  - Movie ID

- **movies**
  - Movie ID
  - Name
  - Rating
SELECT moviegoers.name, moviegoers.sex, moviegoers.age, sources.source, movies.name
FROM movies, sources, moviegoers
WHERE sources.source_ID = moviegoers.source_ID AND movies.movie_ID = moviegoers.movie_ID
ORDER BY moviegoers.name;

<table>
<thead>
<tr>
<th>moviegoers.name</th>
<th>sex</th>
<th>age</th>
<th>source</th>
<th>movies.name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amy</td>
<td>f</td>
<td>27</td>
<td>Oberlin</td>
<td>Independence Day</td>
</tr>
<tr>
<td>Andrew</td>
<td>m</td>
<td>25</td>
<td>Oberlin</td>
<td>12 Monkeys</td>
</tr>
<tr>
<td>Andy</td>
<td>m</td>
<td>34</td>
<td>Oberlin</td>
<td>The Birdcage</td>
</tr>
<tr>
<td>Anne</td>
<td>f</td>
<td>30</td>
<td>Oberlin</td>
<td>Trainspotting</td>
</tr>
<tr>
<td>Ansje</td>
<td>f</td>
<td>25</td>
<td>Oberlin</td>
<td>I Shot Andy Warhol</td>
</tr>
<tr>
<td>Beth</td>
<td>f</td>
<td>30</td>
<td>Oberlin</td>
<td>Chain Reaction</td>
</tr>
<tr>
<td>Bob</td>
<td>m</td>
<td>51</td>
<td>Pinewoods</td>
<td>Schindler's List</td>
</tr>
<tr>
<td>Brian</td>
<td>m</td>
<td>23</td>
<td>Oberlin</td>
<td>Super Cop</td>
</tr>
<tr>
<td>Candy</td>
<td>f</td>
<td>29</td>
<td>Oberlin</td>
<td>Eddie</td>
</tr>
<tr>
<td>Cara</td>
<td>f</td>
<td>25</td>
<td>Oberlin</td>
<td>Phenomenon</td>
</tr>
<tr>
<td>Cathy</td>
<td>f</td>
<td>39</td>
<td>Mt. Auburn</td>
<td>The Birdcage</td>
</tr>
<tr>
<td>Charles</td>
<td>m</td>
<td>25</td>
<td>Oberlin</td>
<td>Kingpin</td>
</tr>
<tr>
<td>Curt</td>
<td>m</td>
<td>30</td>
<td>MRJ</td>
<td>T2 Judgment Day</td>
</tr>
<tr>
<td>David</td>
<td>m</td>
<td>40</td>
<td>MRJ</td>
<td>Independence Day</td>
</tr>
<tr>
<td>Erica</td>
<td>f</td>
<td>23</td>
<td>Mt. Auburn</td>
<td>Trainspotting</td>
</tr>
</tbody>
</table>
Example: Moviegoer Database

- **Classification**
  - determine sex based on age, source, and movies seen
  - determine source based on sex, age, and movies seen
  - determine most recent movie based on past movies, age, sex, and source

- **Estimation**
  - for predict, need a continuous variable (e.g., “age”)
  - predict age as a function of source, sex, and past movies
  - if we had a “rating” field for each moviegoer, we could predict the rating a new moviegoer gives to a movie based on age, sex, past movies, etc.
Example: Moviegoer Database

- Clustering
  - find groupings of movies that are often seen by the same people
  - find groupings of people that tend to see the same movies
  - clustering might reveal relationships that are not necessarily recorded in the data (e.g., we may find a cluster that is dominated by people with young children; or a cluster of movies that correspond to a particular genre)
Example: Moviegoer Database

Association Rules

- market basket analysis (MBA): “which movies go together?”
- need to create “transactions” for each moviegoer containing movies seen by that moviegoer:

<table>
<thead>
<tr>
<th>name</th>
<th>TID</th>
<th>Transaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amy</td>
<td>001</td>
<td>{Independence Day, Trainspotting}</td>
</tr>
<tr>
<td>Andrew</td>
<td>002</td>
<td>{12 Monkeys, The Birdcage, Trainspotting, Phenomenon}</td>
</tr>
<tr>
<td>Andy</td>
<td>003</td>
<td>{Super Cop, Independence Day, Kingpin}</td>
</tr>
<tr>
<td>Anne</td>
<td>004</td>
<td>{Trainspotting, Schindler's List}</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

- may result in association rules such as:

  {“Phenomenon”, “The Birdcage”} ==> {“Trainspotting”}
  {“Trainspotting”, “The Birdcage”} ==> {sex = “f”}
Example: Moviegoer Database

- **Sequence Analysis**
  - similar to MBA, but order in which items appear in the pattern is important
  - e.g., people who rent “The Birdcage” during a visit tend to rent “Trainspotting” in the next visit.


- Barry Linoff Data Mining Techniques for Marketing Sales and Customer Support, John Wiles & Sons, 2002