# CS 235: Introduction to Databases

Svetlozar Nestorov

*Lecture Notes #23*

## Have You Ever …

- Wondered how products are placed in supermarket aisles?
- Had your application for a no-interest-for-6-months Titanium credit card rejected?
- Puzzled over the two-hour phone call to Belize on your phone bill?
- Gazed at the sky and wondered if that bright star is a white dwarf?
- Data mining has the answers!!!



## What is Data Mining?

- Finding "interesting" patterns in large amounts of data.
- Data mining encompasses several areas:
  - Machine learning (AI)
  - Statistics
  - Databases



## Data Mining Needs Databases

- Machine learning and statistics often make the following assumptions:
  - small amount of data (or sample)
  - data fits in main memory
  - CPU time is crucial
- The reality:
  - huge amounts data
  - data on secondary storage
  - data management (disk I/O) is crucial



## Data Mining Techniques

- Classification (supervised learning)
  - Build and train classifiers (decision trees, neural nets, etc.)
- Clustering (unsupervised learning)
  - Partition the data into groups with similar characteristics.
- Sequence and *stream* analysis
- Association rule-mining



## Association-Rule Mining

- Flagship of data mining with database flavor.
- Find correlations among data *without* building a complete predictive or descriptive model.
- Data-centric approach.

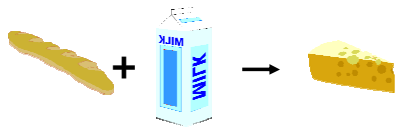
## Market Basket Data

- Consider supermarket customers.
- At the checkout each customer has a basket of items.
- Find correlation among the contents of baskets.
- The model works for many domains:
  - Online/offline shopping
  - Web surfing
  - Text analysis



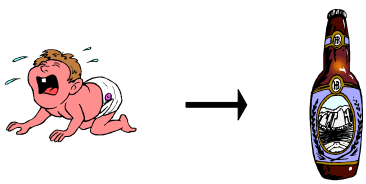
## Association Rules

- Find rules of the form:
  - People who buy X tend to buy Y.






## Mythical Association Rule





## A Lesson in Marketing

- Suppose we know that people buy bread and milk frequently. So what?
  - Stock them together.
  - Stock them apart.
  - Run sales on one and up the price of the other.
- Amazon's recommendations are based on association rules.
  - Order size went up 20% in the first week after recommendations were introduced.



## Schema of Market Basket Data

- Several models possible depending on the application.
- Simplest, most general schema:
  *Baskets(basketID, item)*
- Applicable to many different scenarios, online and offline.



## Market Basket Example

| *basketID* | *item* |
|---|---|
| 11111 | beer |
| 11111 | chips |
| 11111 | salsa |
| 22222 | vodka |
| 22222 | caviar |

## Support and Confidence

- Formally, we associate two numbers with every rule:
  - support
  - confidence
- Example: Diapers → Beers
  - Support is the fraction of all baskets that contain both beer and diapers.
  - Confidence is the fraction of baskets which contain diapers that also contain beers.



## Thresholds

- Find association rules with high support and high confidence.
- Typically, high support means > 0.1% and high confidence means > 50%.
  - Thresholds depend on the application.



## Main Challenge

- Too many item combinations:
  - 100s of thousands of items
  - millions of transactions
- Direct approach too slow:
  - 100 million baskets, 20 items/basket
  - 19 billion pairs, 100+ billion triples,…



## Two-Phase Approach

- Phase 1: Find all itemsets with high support.
  - These itemsets are called frequent.
- Phase 2: Construct rules with high confidence.
- The computational cost of phase 1 dominates the total cost.
- Focus on finding frequent itemsets.



## Find All Frequent Pairs

- Write query in SQL:



## The *A-Priori* Technique

- Key observation: a pair of items is frequent only if each item is frequent.
  - If {bread, cheese} is frequent then {bread} and {cheese} must be frequent.
- Levelwise pruning:
  - Consider {bread, milk, cheese} only if {bread, milk}, {bread, cheese}, {milk, cheese} are frequent

# A-Priori in SQL

```
INSERT INTO Baskets1(bid,  item)
      SELECT * FROM  Baskets
      WHERE item IN (
            SELECT item
             FROM Baskets
             GROUP BY item
             HAVING COUNT(*) >= s
       );
```

- Rewrite join using Basket1 instead of Basket.

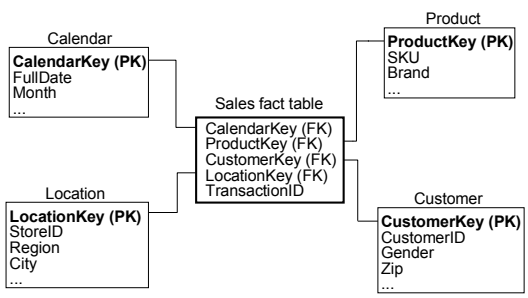


# Extending Association Rules

- Causality vs. association
  - much trickier
  - hidden variables outside the domain
- More detailed associations:
  - Find items that are bought together frequently, in a particular region, in a particular month.
  - Additional information is already available at the data warehouse.



# Example Data Warehouse






# Need for Data Warehousing

- Integrated, company-wide view of high-quality information.
- Separation of operational and analytical systems and data.



# Operational vs. Analytical Data

**Data Differences**

| | |
|---|---|
| Typical Time-Horizon: Days/Months | Typical Time-Horizon: Years |
| Detailed | Summarized (and/or Detailed) |
| Current | Values over time (Snapshots) |

**Technical Differences**

| | |
|---|---|
| Can be Updated | Read (and Append) Only |
| Control of Update: Major Issue | Control of Update: No Issue |
| Small Amounts used in a Process | Large Amounts used in a Process |
| Non-Redundant | Redundancy not an Issue |
| High frequency of Access | Low/Modest frequency of Access |

**Purpose Differences**

| | |
|---|---|
| For "Clerical Community" | For "Managerial Community" |
| Supports Day-to-Day Operations | Supports Managerial Needs |
| Application Oriented | Subject Oriented |



# Application vs. Subject Oriented

**Application:**
*Health Club Members-Visit Database*

HEALTHCLUBMEMEBRS

| MembId | Name | MembLevel | DatePayed |
|---|---|---|---|
| 111 | Joe | A | 01/01/2000 |
| 222 | Sue | B | 01/01/2000 |
| 333 | Pat | A | 01/01/2000 |
| … | … | … | … |

DAILYVISITSFROMNONMEMBERS

| Trid | VisitType | VisitDate |
|---|---|---|
| 11xx22 | YP | 01/01/2000 |
| 11xx23 | NP | 02/01/2000 |
| 11xx24 | YP | 02/01/2000 |
| … | … | … |

MEMBRSHPLEVELS

| ID | Type | Fee |
|---|---|---|
| A | Gold | $100 |
| B | Basic | $50 |

VISITLEVELS

| ID | Type | Fee |
|---|---|---|
| YP | With Pool Usage | $15 |
| NP | Without Pool Usage | $10 |

**Subject**:
*Health Club Revenue*

REVENUE

| Rid | Date | GeneratedBy | Amount |
|---|---|---|---|
| 7235 | 01/01/2000 | NonMember | $15 |
| 7236 | 01/01/2000 | Member | $100 |
| 7237 | 01/01/2000 | Member | $50 |
| 7238 | 01/01/2000 | Member | $100 |
| 7239 | 02/01/2000 | NonMember | $10 |
| 7240 | 02/01/2000 | NonMember | $15 |
| … | … | … | … |

# Application vs. Subject Oriented

**Application:**
*Health Club Members-Visit Database*

HEALTHCLUBMEMEBRS

| MembId | Name | MembLevel | DatePayed |
|---|---|---|---|
| 111 | Joe | A | 01/01/2000 |
| 222 | Sue | B | 01/01/2000 |
| 333 | Pat | A | 01/01/2000 |
| … | … | … | … |

DAILYVISITSFROMNONMEMBERS

| Trid | VisitType | VisitDate |
|---|---|---|
| 11xx22 | YP | 01/01/2000 |
| 11xx23 | NP | 02/01/2000 |
| 11xx24 | YP | 02/01/2000 |
| … | … | … |

MEMBRSHPLEVELS

| ID | Type | Fee |
|---|---|---|
| A | Gold | $100 |
| B | Basic | $50 |

VISITLEVELS

| ID | Type | Fee |
|---|---|---|
| YP | With Pool Usage | $15 |
| NP | Without Pool Usage | $10 |

**Subject:**
*Health Club Revenue*

REVENUE

| Rid | Date | GeneratedBy | Amount |
|---|---|---|---|
| 7235 | 01/01/2000 | NonMember | $15 |
| 7236 | 01/01/2000 | Member | $100 |
| 7237 | 01/01/2000 | Member | $50 |
| 7238 | 01/01/2000 | Member | $100 |
| 7239 | 02/01/2000 | NonMember | $10 |
| 7240 | 02/01/2000 | NonMember | $15 |
| … | … | … | … |



# Application vs. Subject Oriented

**Application:**
*Health Club Members-Visit Database*

HEALTHCLUBMEMEBRS

| MembId | Name | MembLevel | DatePayed |
|---|---|---|---|
| 111 | Joe | A | 01/01/2000 |
| 222 | Sue | B | 01/01/2000 |
| 333 | Pat | A | 01/01/2000 |
| … | … | … | … |

DAILYVISITSFROMNONMEMBERS

| Trid | VisitType | VisitDate |
|---|---|---|
| 11xx22 | YP | 01/01/2000 |
| 11xx23 | NP | 02/01/2000 |
| 11xx24 | YP | 02/01/2000 |
| … | … | … |

MEMBRSHPLEVELS

| ID | Type | Fee |
|---|---|---|
| A | Gold | $100 |
| B | Basic | $50 |

VISITLEVELS

| ID | Type | Fee |
|---|---|---|
| YP | With Pool Usage | $15 |
| NP | Without Pool Usage | $10 |

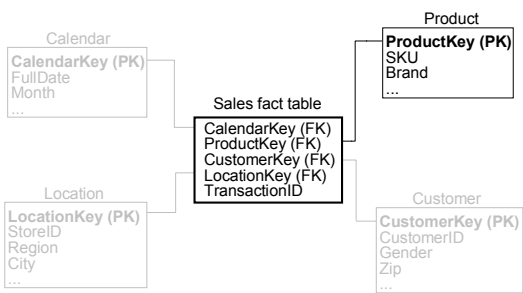
**Subject:**
*Health Club Revenue*

REVENUE

| Rid | Date | GeneratedBy | Amount |
|---|---|---|---|
| 7235 | 01/01/2000 | NonMember | $15 |
| 7236 | 01/01/2000 | Member | $100 |
| 7237 | 01/01/2000 | Member | $50 |
| 7238 | 01/01/2000 | Member | $100 |
| 7239 | 02/01/2000 | NonMember | $10 |
| 7240 | 02/01/2000 | NonMember | $15 |
| … | … | … | … |

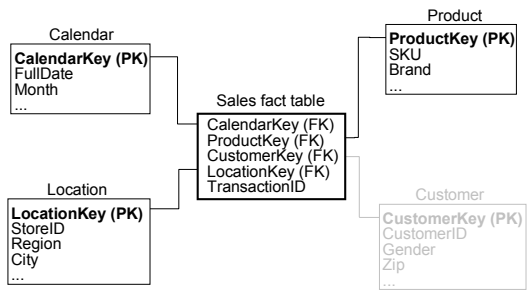


Standard ARM Question:
*What products are frequently bought together?*






Analyst may want to know:
*What products are frequently bought together **in a particular region and in a particular month?***






# New Challenges

- Interactive mining
- Collaborative/distributed mining
  - Peer to peer systems
- Beyond relational data:
  - Text
  - XML
  - Audio
  - Video