On-Line Application Processing

Warehousing
Data Cubes
Data Mining

Overview

- Traditional database systems are tuned to many, small, simple queries.
- Some new applications use fewer, more time-consuming, complex queries.
- New architectures have been developed to handle complex “analytic” queries efficiently.

The Data Warehouse

- The most common form of data integration.
  - Copy sources into a single DB (warehouse) and try to keep it up-to-date.
  - Usual method: periodic reconstruction of the warehouse, perhaps overnight.
  - Frequently essential for analytic queries.

OLTP

- Most database operations involve On-Line Transaction Processing (OTLP).
  - Short, simple, frequent queries and/or modifications, each involving a small number of tuples.
  - Examples: Answering queries from a Web interface, sales at cash registers, selling airline tickets.

OLAP

- Of increasing importance are On-Line Application Processing (OLAP) queries.
  - Few, but complex queries --- may run for hours.
  - Queries do not depend on having an absolutely up-to-date database.
  - [Sometimes called Data Mining.]

OLAP Examples

1. Amazon analyzes purchases by its customers to come up with an individual screen with products of likely interest to the customer.
2. Analysts at Wal-Mart look for items with increasing sales in some region.
Common Architecture
◆ Databases at store branches handle OLTP.
◆ Local store databases copied to a central warehouse overnight.
◆ Analysts use the warehouse for OLAP.

Star Schemas
◆ A star schema is a common organization for data at a warehouse. It consists of:
  1. Fact table: a very large accumulation of facts such as sales.
     - Often "insert-only."
  2. Dimension tables: smaller, generally static information about the entities involved in the facts.

Example: Star Schema
◆ Suppose we want to record in a warehouse information about every beer sale: the bar, the brand of beer, the drinker who bought the beer, the day, the time, and the price charged.
◆ The fact table is a relation: Sales(bar, beer, drinker, day, time, price)

Example, Continued
◆ The dimension tables include information about the bar, beer, and drinker "dimensions":
  Bars(bar, addr, license)
  Beers(beer, manf)
  Drinkers(drinker, addr, phone)

Dimensions and Dependent Attributes
◆ Two classes of fact-table attributes:
  1. Dimension attributes: the key of a dimension table.
  2. Dependent attributes: a value determined by the dimension attributes of the tuple.

Example: Dependent Attribute
◆ price is the dependent attribute of our example Sales relation.
◆ It is determined by the combination of dimension attributes: bar, beer, drinker, and the time (combination of day and time attributes).
Approaches to Building Warehouses

1. **ROLAP** = “relational OLAP”: Tune a relational DBMS to support star schemas.
2. **MOLAP** = “multidimensional OLAP”: Use a specialized DBMS with a model such as the “data cube.”

ROLAP Techniques

1. **Bitmap indexes**: For each key value of a dimension table (e.g., each beer for relation Beers) create a bit-vector telling which tuples of the fact table have that value.
2. **Materialized views**: Store the answers to several useful queries (views) in the warehouse itself.

Typical OLAP Queries

- Often, OLAP queries begin with a “star join”: the natural join of the fact table with all or most of the dimension tables.
- **Example:**
  ```sql
  SELECT *
  FROM Sales, Bars, Beers, Drinkers
  WHERE Sales.bar = Bars.bar AND
        Sales.beer = Beers.beer AND
        Sales.drinker = Drinkers.drinker;
  ```

Typical OLAP Queries --- 2

- The typical OLAP query will:
  1. Start with a star join.
  2. Select for interesting tuples, based on dimension data.
  3. Group by one or more dimensions.
  4. Aggregate certain attributes of the result.

Example: OLAP Query

- For each bar in Palo Alto, find the total sale of each beer manufactured by Anheuser-Busch.
- **Filter**: `addr = "Palo Alto" and manf = "Anheuser-Busch"`.
- **Grouping**: by bar and beer.
- **Aggregation**: `Sum of price`.

Example: In SQL

```sql
SELECT bar, beer, SUM(price)
FROM Sales NATURAL JOIN Bars
     NATURAL JOIN Beers
WHERE addr = 'Palo Alto' AND
     manf = 'Anheuser-Busch'
GROUP BY bar, beer;
```
Using Materialized Views

- A direct execution of this query from Sales and the dimension tables could take too long.
- If we create a materialized view that contains enough information, we may be able to answer our query much faster.

Example: Materialized View

- Which views could help with our query?
- Key issues:
  1. It must join Sales, Bars, and Beers, at least.
  2. It must group by at least bar and beer.
  3. It must not select out Palo-Alto bars or Anheuser-Busch beers.
  4. It must not project out addr or manf.

Example --- Continued

- Here is a materialized view that could help:
  ```sql
  CREATE VIEW BABMS(bar, addr, beer, manf, sales) AS
  SELECT bar, addr, beer, manf,
  SUM(price) sales
  FROM Sales NATURAL JOIN Bars
  NATURAL JOIN Beers
  GROUP BY bar, addr, beer, manf
  ```
  Since bar -> addr and beer -> manf, there is no real grouping. We need addr and manf in the SELECT.

Example --- Concluded

- Here’s our query using the materialized view BABMS:
  ```sql
  SELECT bar, beer, sales
  FROM BABMS
  WHERE addr = 'Palo Alto' AND manf = 'Anheuser-Busch';
  ```

MOLAP and Data Cubes

- Keys of dimension tables are the dimensions of a hypercube.
  - Example: for the Sales data, the four dimensions are bars, beers, drinkers, and time.
  - Dependent attributes (e.g., price) appear at the points of the cube.

Marginals

- The data cube also includes aggregation (typically SUM) along the margins of the cube.
- The marginals include aggregations over one dimension, two dimensions...
Example: Marginals

- Our 4-dimensional Sales cube includes the sum of price over each bar, each beer, each drinker, and each time unit (perhaps days).
- It would also have the sum of price over all bar-beer pairs, all bar-drinker-day triples,…

Structure of the Cube

- Think of each dimension as having an additional value *.
- A point with one or more *’s in its coordinates aggregates over the dimensions with the *’s.
- Example: Sales("Joe’s Bar", "Bud", *, *) holds the sum over all drinkers and all time of the Bud consumed at Joe’s.

Drill-Down

- Drill-down = “de-aggregate” = break an aggregate into its constituents.
- Example: having determined that Joe’s Bar sells very few Anheuser-Busch beers, break down his sales by particular A.-B. beer.

Roll-Up

- Roll-up = aggregate along one or more dimensions.
- Example: given a table of how much Bud each drinker consumes at each bar, roll it up into a table giving total amount of Bud consumed for each drinker.

Materialized Data-Cube Views

- Data cubes invite materialized views that are aggregations in one or more dimensions.
- Dimensions may not be completely aggregated --- an option is to group by an attribute of the dimension table.

Example

- A materialized view for our Sales data cube might:
  1. Aggregate by drinker completely.
  2. Not aggregate at all by beer.
  3. Aggregate by time according to the week.
  4. Aggregate according to the city of the bar.
**Data Mining**

*Data mining* is a popular term for queries that summarize big data sets in useful ways.

**Examples:**
1. Clustering all Web pages by topic.
2. Finding characteristics of fraudulent credit-card use.

**Market-Basket Data**

An important form of mining from relational data involves *market baskets* = sets of "items" that are purchased together as a customer leaves a store.

Summary of basket data is *frequent item sets* = sets of items that often appear together in baskets.

**Example: Market Baskets**

- If people often buy hamburger and ketchup together, the store can:
  1. Put hamburger and ketchup near each other and put potato chips between.
  2. Run a sale on hamburger and raise the price of ketchup.

**Finding Frequent Pairs**

- The simplest case is when we only want to find "frequent pairs" of items.
- Assume data is in a relation Baskets(basket, item).
- The **support threshold** $s$ is the minimum number of baskets in which a pair appears before we are interested.

**Frequent Pairs in SQL**

```sql
SELECT b1.item, b2.item
FROM Baskets b1, Baskets b2
WHERE b1.basket = b2.basket
    AND b1.item < b2.item
GROUP BY b1.item, b2.item
HAVING COUNT(*) >= s;
```

Look for two Basket tuples with the same basket and different items. First item must precede second, so we don't count the same pair twice.

Create a group for each pair of items that appears in at least one basket.

- Throw away pairs of items that do not appear at least $s$ times.

**A-Priori Trick --- 1**

- Straightforward implementation involves a join of a huge Baskets relation with itself.
- The *a-priori algorithm* speeds the query by recognizing that a pair of items $\{i,j\}$ cannot have support $s$ unless both $\{i\}$ and $\{j\}$ do.
A-Priori Trick --- 2

- Use a materialized view to hold only information about frequent items.

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

Items that appear in at least `s` baskets.

A-Priori Algorithm

1. Materialize the view Baskets1.
2. Run the obvious query, but on Baskets1 instead of Baskets.

- Baskets1 is cheap, since it doesn’t involve a join.
- Baskets1 probably has many fewer tuples than Baskets.

- Running time shrinks with the square of the number of tuples involved in the join.

Example: A-Priori

- Suppose:
  1. A supermarket sells 10,000 items.
  2. The average basket has 10 items.
  3. The support threshold is 1% of the baskets.

- At most 1/10 of the items can be frequent.

- Probably, the minority of items in one basket are frequent -> factor 4 speedup.