Data Warehousing and Decision Support

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Introduction to Database Management
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Notes

Outline

Notes

Transaction Processing

The most common use of relational databases is for *operational data*.

- Examples:
  - Students enrolling in courses
  - Customers purchasing products
  - Passengers purchasing airline tickets

On-Line Transactional Processing (OLTP)

Databases that support the basic operations of a business are generally classified as OLTP systems.

- Workload characteristics:
  1. simple queries
  2. many short transactions making small changes
- Systems tuned to maximize throughput of concurrent transactions

Notes

Beyond Transaction Processing

More recent uses of operational data:

Decision Support Summarizing data to support high-level decision making

- Complex queries with much aggregation

Data Mining Searching for trends or patterns in data for a business to exploit

- Simple queries, but very data-intensive

Data Warehousing

A *data warehouse* is a separate copy of the operational data used for executing decision support and/or data mining queries.

Notes

On-Line Analytical Processing

On-Line Analytical Processing (OLAP)

OLAP is a particular type of decision support

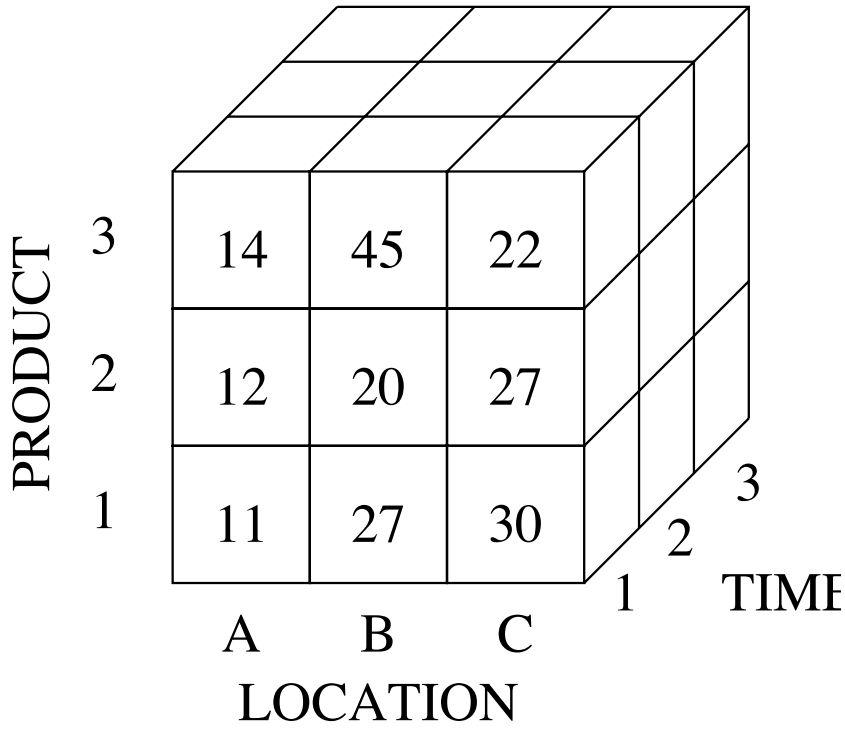
- Data is modeled as multidimensional array
- Queries are usually ad hoc
- Queries select and aggregate cells of the array

- OLAP systems are divided into two categories:
  1. Special-purpose OLAP systems
     - store data as multidimensional arrays ("MOLAP")
     - provide an OLAP-specific query language
  2. Relational databases
     - store data in relations ("ROLAP")
     - queries written in SQL

Notes

Multidimensional Data

- Example: Number of Sales



Notes

Star Schemas

Location

lid	*store*	*city*	*province*	*country*
A	Weber	Waterloo	ON	CA
B	F-H	Kitchener	ON	CA
C	Park	Kitchener	ON	CA

Product

pid	*pname*	*category*	*price*
1	Bolt	Hardware	.10
2	Nut	Hardware	.05
3	Wrench	Tools	1.99

Time

tid	*date*	*week*	*month*	*quarter*	*year*
virtual relation					

Sales

lid	*pid*	*tid*	*sales*
A	1	1	11
A	2	1	12
A	3	1	14
B	1	1	27
B	2	1	20
B	3	1	45
C	1	1	30
C	2	1	27
C	3	1	22
A	1	2	16
A	2	2	20
A	3	2	55
⋮			

Notes

OLAP Queries

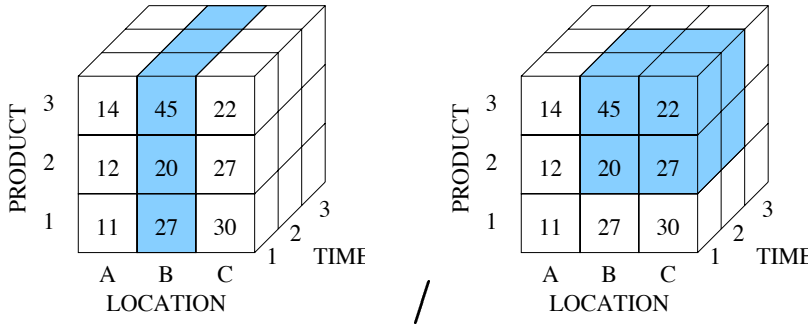
- OLAP queries typically aggregate over one or more dimensions. Examples:
  - Total sales
  - Total sales this year for each product category
  - Total sales for each store per quarter

- OLAP is a tool for *ad hoc* data exploration/visualization
  - Ad hoc queries tend to be iterative
  - Desirable to express queries using operations over previous result

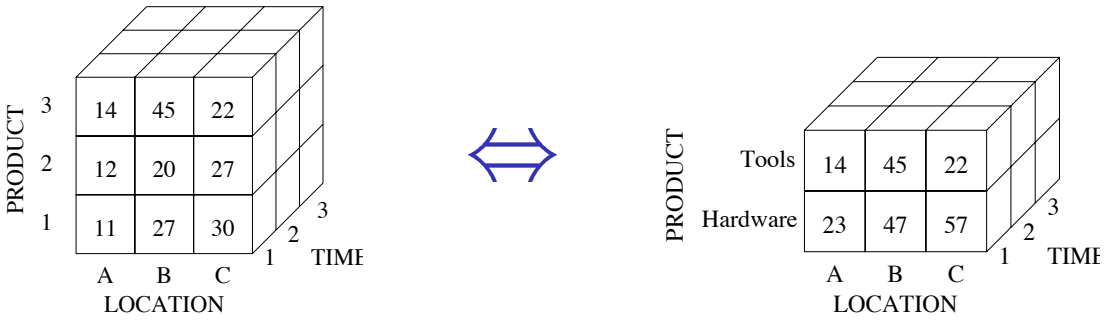
Notes

OLAP Query Operations

- Slicing and Dicing



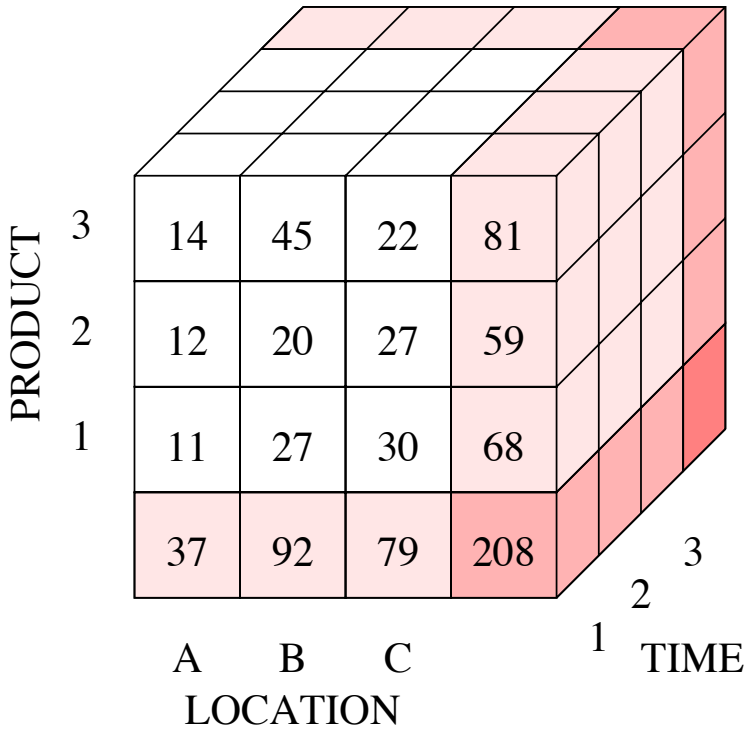
- Roll-up and Drill-down



Notes

Data Cube

- A *data cube* extends a multidimensional array of data to include all possible aggregated totals



Notes

Data Cubes as Relations

Sales

lid	*pid*	*tid*	*sales*
A	1	1	11
A	2	1	12
A	3	1	14
A	-	1	37
B	1	1	27
B	2	1	20
B	3	1	45
B	-	1	92
C	1	1	30
C	2	1	27
C	3	1	22
C	-	1	79
-	1	1	68
-	2	1	59
-	3	1	81
-	-	1	208
A	1	2	16
⋮			

Notes

CUBE operator in SQL:1999

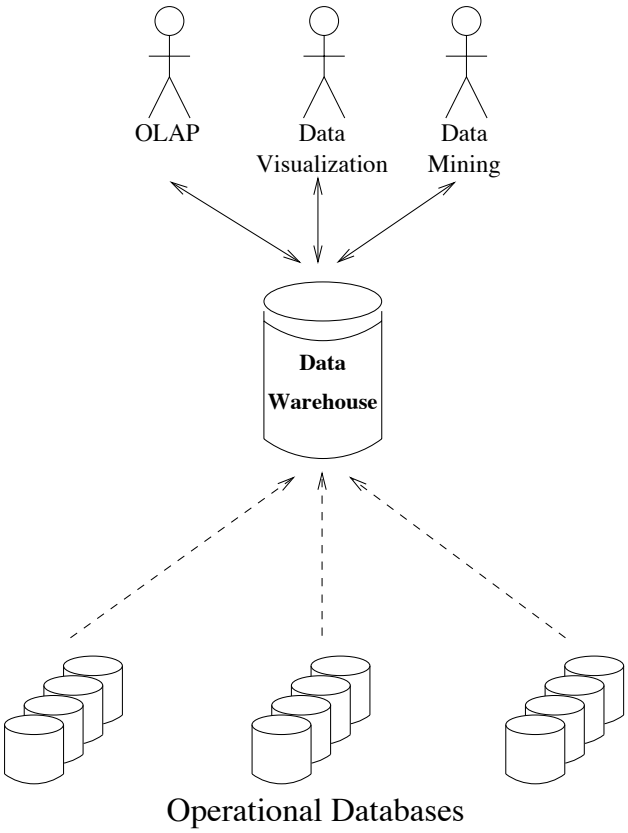
- Generating the data cube:
  1. SUM(sales) GROUP BY location, product, time (raw cells)
  2. SUM(sales) GROUP BY location, time
  3. SUM(sales) GROUP BY product, time
  4. SUM(sales) GROUP BY product, location
  5. SUM(sales) GROUP BY product
  6. SUM(sales) GROUP BY location
  7. SUM(sales) GROUP BY time
  8. SUM(sales)

- CUBE operator in SQL:1999 groups by all combinations

```
SELECT lid, pid, tid, SUM(sales)
FROM Sales
GROUP BY CUBE(lid, pid, tid)
```


Notes

Data Warehousing



Notes

Creating and Maintaining a Warehouse

Necessary steps when creating a warehouse:

Extract Run queries against the operational databases to retrieve necessary data

Clean Delete or repair tuples with missing or invalid information

Transform Reorganize the data to fit the conceptual schema of the warehouse

Load Populate the warehouse tables; build indexes and/or materialized views

Note

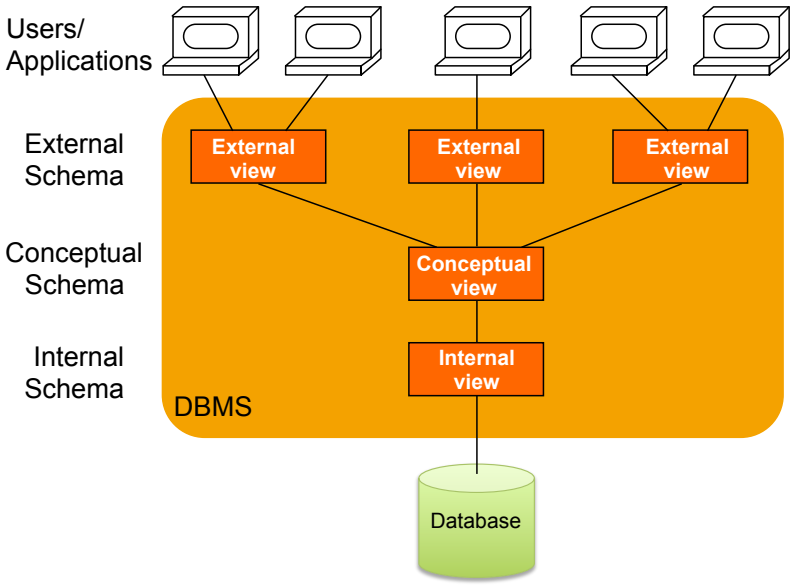
The data in the warehouse needs to be refreshed periodically (typically nightly or weekly). To make this process efficient, the above steps need to be executed *incrementally*.

Notes

Views

Recall the three-level schema architecture:

1. External schema
2. Conceptual schema
3. Physical schema



Notes

Views

Definition (View)

A *view* is a relation in the external schema whose instance is determined by the instances of the relations in the conceptual schema.

A view has many of the same properties as a base relation in the conceptual schema:

- its schema information appears in the database schema
- access controls can be applied to it
- other views can be defined in terms of it

Notes

Types of Views

- Virtual: Views are used only for querying; they are not stored in the database
- Materialized: The query that makes up the view is executed, the view constructed and stored in the database.

Notes

SQL DDL: Views

- General form:

```
create [materialized] view <name>
    as <query>
```

- Example

```
create view ManufacturingProjects as
    ( select projno, projname, firstnme, lastname
      from project, employee
      where respemp = empno and deptno = 'D21' )
```


Notes

Accessing a View

Query a view as if it were a base relation.

```
select projname
from ManufacturingProjects
```

What happens when you query a virtual view?

- At compile time, the view definition is found
- The query over the view is modified with the query definition
- The resulting query is optimized and executed

Notes

Updating Views

- Modifications to a view's instance must be propagated back to instances of relations in conceptual schema.
- Some views cannot be updated unambiguously.

Conceptual Schema

Persons

NAME	CITIZENSHIP
Ed	Canadian
Dave	Canadian
Wes	American

NationalPastimes

CITIZENSHIP	PASTIME
Canadian	Hockey
Canadian	Curling
American	Hockey
American	Baseball

$\Leftrightarrow$

External Schema

PersonalPastimes

NAME	PASTIME
Ed	Hockey
Ed	Curling
Dave	Hockey
Dave	Curling
Wes	Hockey
Wes	Baseball

1. What does it mean to insert (Darryl, Hockey)?
2. What does it mean to delete (Dave, Curling)?

Notes

View Updates in SQL

According to SQL-92, a view is updatable only if its definition satisfies a variety of conditions:

- The query references exactly one table
- The query only outputs simple attributes (no expressions)
- There is no grouping/aggregation/**distinct**
- There are no nested queries
- There are no set operations

These rules are more restrictive than necessary.

Notes

Materialized Views

Problem

When a base table changes, the materialized view may also change.

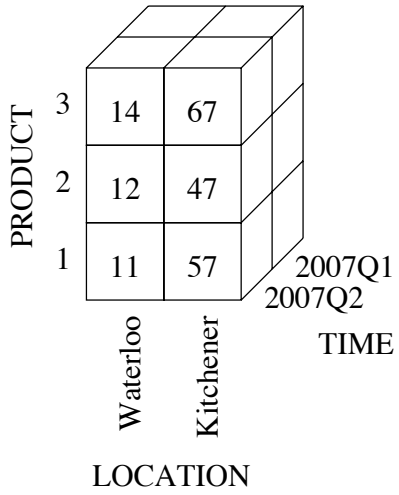
- Solution?
  - Periodically reconstruct the materialized view.
  - Incrementally update the materialized view.
- Example: Data warehouses

Notes

Materializing Views

- Consider the following view of the Sales data:

```
CREATE VIEW
ByCityQuarter(city, pid, quarter, sales) AS
 SELECT city, pid, QUARTER(tid), SUM(sales)
 FROM Sales s, Location l
 WHERE s.lid = l.lid
 GROUP BY city, pid, QUARTER(tid)
```



- View `ByCityQuarter` is useful for any query that
  1. Rolls-up the Location dimension to *at least* City; and
  2. Rolls-up the Time dimension to *at least* Quarter

Notes

Materializing Views (cont'd)

- Issues related to using materialized views:
  1. Which views to materialize (*view selection*)
  2. Which views are useful to answer a query (*view matching*)
  3. Which indexes to build on the views
  4. How to refresh the data in the view. Options:
     - Synchronous incremental maintenance
     - Asynchronous incremental maintenance
     - No synchronization (periodic re-creation)

Observation

These are the very same issues that apply to the entire data warehouse, relative to the data in the operational databases.

Notes