CS522 Advanced Database Systems
Introduction to Data Warehouse and OLAP

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Operational Databases

- Handles day-to-day operations of an organization
- A.K.A. Online Transaction Processing (OLTP) systems
- Characterized by
  - Content – detailed and current
  - Users – clients, developers, DBA
  - Access pattern – short, atomic, r/w transactions
  - Design – ER, normalized

The Need for Data Warehouse …

- Decision support applications, e.g.
  - Show the sales number by month, by day, region, and/or by product
- Reporting and analysis applications, e.g.
  - Web site analytics
  - Online ad tracking

… The Need for Data Warehouse

- These applications are dominated by queries involving aggregations and group-bys
- And such queries often can't be expressed or executed efficiently by OLTP databases

Standard SQL Aggregation Functions

- Operate on multiple rows and return a single result
  - `sum`
  - `avg`
  - `count`
  - `max` and `min`

More About Aggregation Functions

- Distributive
  - `sum`, `count`, `min`, `max`
- Algebraic
  - `avg = sum / count`
- Holistic
  - `median`

Distributive Aggregation

	Count	Sum	Min	Max
[5,6,2,8,1,9]	6			
[11,12,14,16,18]	5			
[23,20]	2			
All	??			

Holistic Aggregation

	Median
[5,6,2,8,1,9]	??
[11,12,14,16,18]	14
[23,20]	??
All	??

Estimate Median …

	Count	Min	Max
[5,6,2,8,1,9]	6	1	9
[11,12,14,16,18]	5	11	18
[23,20]	2	20	23
All	13	1	23

… Estimate Median

$$median = Min_m + \frac{N/2 - \sum_l Count}{Count_m} \bullet (Max_m - Min_m)$$

`N`: total count
`m`: the median interval
`l`: the intervals lower than the median interval

GROUP BY

```
select category, count(id)
    from products
    group by category;
```

products

id	category	description	price
1	CPU	Intel Core 2 Duo	$200.00
2	CPU	Intel Pentium D	$98.99
3	CPU	AMD Athlon 64	$74.49
4	CPU	AMD Athlon 64x2	$115.98
5	HD	Seagate 320G	$77.49
6	HD	Maxtor 250G	$60.89

Understanding GROUP BY …

- Without aggregation/GROUP BY

select category, id from products;

category	id
CPU	1
CPU	2
CPU	3
CPU	4
HD	5
HD	6

… Understanding GROUP BY

- With aggregation/GROUP BY

select category, count(id) from products group by category;

Grouping attribute

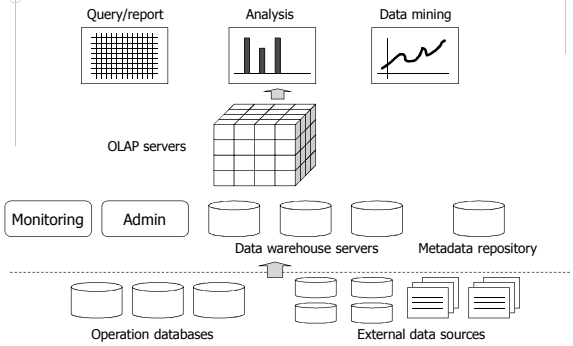
category	id
CPU	1
CPU	2
CPU	3
CPU	4
HD	5
HD	6

Aggregation attribute

count(id) = 4

count(id) = 2

Data Warehouse Architecture



Data Warehouse

- "A data warehouse is a *subject-oriented*, *integrated*, *time-variant*, and *nonvolatile* collection of data in support of management's *decision making* process" – W. H. Inmon
- An Online Analytical Processing (OLAP) system

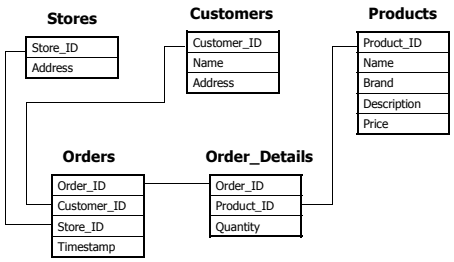
Data Warehouse vs. Operational Database

	Operational Database	Data Warehouse
Content	Detailed and current	??
Users	Clients, developers, DBA	??
Access Patterns	short, atomic, r/w transactions	??
Design	ER, normalized	??

Data

- Customer John Doe, whose address is 123 Main St., LA, CA, bought an Intel CPU for $279 and two Seagate hard drives for $300 at the Best Buy store on Foothill Blvd on 1/9/2012 at 11:01am.

Operational Database Schema

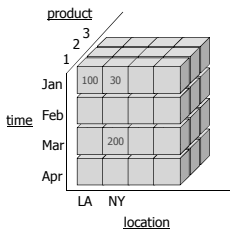


Address could be further split into several tables, e.g. Cities, States_Provinces, Countries, and Regions

Why Not Use Operational Database for OLAP

- Detailed, normalized data is not suitable for efficient OLAP operations
- ER/relational model is good for data storage and access but not for data analysis

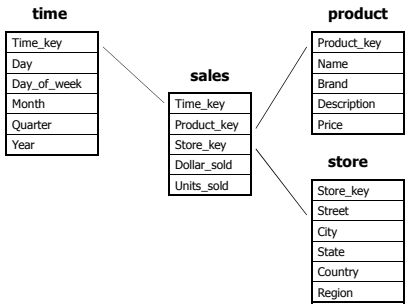
The Multidimensional Model



Terminology

- Dimensions
  - Time, product, location …
- Facts
  - Sales, units sold, expenses …

Star Schema …



… Star Schema

- One Fact Table
  - E.g. `sales`
- One Dimension Table per dimension
  - E.g. `time`, `product`, and `store`

From Operational Database to Star Schema …

- Fact table
  - Data selection
  - Data granularity (i.e. *base facts*)
  - Derived data
  - Pre-aggregated data (i.e. *summary facts*)

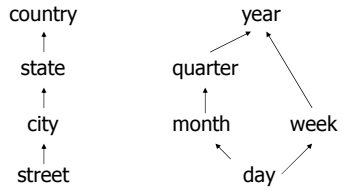
… From Operational Database to Star Schema

- Dimension tables
  - Dimension selection
  - Time dimension
  - De-normalization
  - Surrogate key and natural key

Other Schemas for Multidimensional Databases

- Snowflake schema
  - Some dimensions are normalized
- Fact Constellation schema
  - Dimension tables are shared by more than one fact tables

Concept Hierarchies



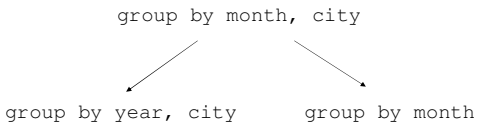
- Total order: `street < city < state < country`
- Partial order: `day < {month < quarter, week} < year`

OLAP Operations

- Roll-up
- Drill-down
- Slice and dice
- Pivot (rotate)

Roll-up

- Aggregation by
  - Going up a concept hierarchy, or
  - Reducing dimension(s)

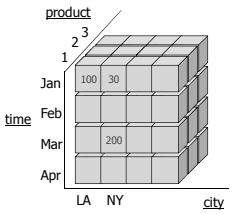


Drill-down

- Reverse of roll-up
  - Going down a concept hierarchy, or
  - Adding dimensions

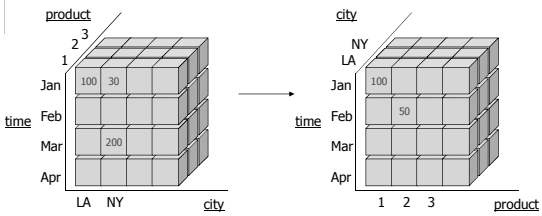
Slice and Dice

- Slice: selection on one dimension
- Dice: selection on more than one dimensions
  - E.g. `(city='LA') and (month='Jan' or month='March')`



Pivot (Rotate)

- Rotate the data axes to provide an alternative presentation of the data



Perform OLAP Operations Efficiently

- Indexing
- Pre-computation
  - Summary fact tables
  - *Data cubes*

Bitmap Indexing …

rid	item	city	month	sales
1001	TV	LA	Jan	100
1002	PC	LA	Jan	200
1003	PC	NY	Jan	150
1004	PC	NY	Feb	100
1005	Phone	NY	Jan	175
1006	TV	NY	Feb	200
1007	Phone	LA	Jan	300
1008	Phone	LA	Feb	120

Item: { TV, PC, Phone }

City: { LA, NY }

… Bitmap Indexing

Bitmap Index on Item: *Bitmap Index on City ??*

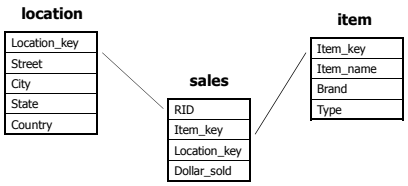
1	0	0
0	1	0
0	1	0
0	1	0
0	0	1
1	0	0
0	0	1
0	0	1
TV	PC	Phone

Using Bitmap Index

- List total sales in LA by item

```
select sum(sales), item
     from sales_table
     where city = 'LA'
     group by item;
```

Join Indexing …



… Join Indexing …

location

Location_key	Street	City	State	Country
1	123 Main St.	LA	CA	USA
2	456 Wall St.	NY	NY	USA
3	789 State St.	LA	CA	USA

item

Item_key	Item_name	Brand	Type
1	Bravia 42in	Sony	TV
2	Bravia 46in	Sony	TV
3	Pavilion A100	HP	PC
4	Pavilion A200	HP	PC
5	iPhone	Apple	Phone

Sales

RID	Item_key	Loc_key	Amount
1001	1	1	100
1002	3	3	120
1003	3	2	150
1004	4	2	110
1005	5	2	130
1006	2	2	170
1007	5	1	200
1008	5	3	100

… Join Indexing

Sales & Item type

rid	item_type
1001	TV
1006	TV
1002	PC
1003	PC
1004	PC
1005	Phone
1007	Phone
1008	Phone

Sales & Item type & City

rid	item	city
1001	TV	LA
1002	PC	LA
1007	Phone	LA
1008	Phone	LA
1006	TV	NY
1003	PC	NY
1004	PC	NY
1005	Phone	NY

Using Join Index

- Find the total sales of TV
- Find the total sales of TV in LA

Readings

- Textbook Chapter 4