CS522 Advanced Database Systems

Data Warehouse and OLAP

Chengyu Sun
California State University, Los Angeles

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 – client and employees
  - Access pattern – short, atomic, r/w transactions
  - Design – ER, normalized

Data Warehouse

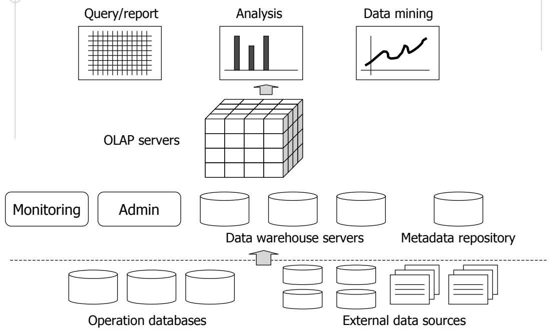
- "A data warehouse is a subject-oriented, integrated, time-variant, and nonvolatile collection of data in support of management's decision making process" – W. H. Inmon

Characteristics of Data Warehouse

- Subject-oriented
- Integrated
- Time-variant
- Nonvolatile

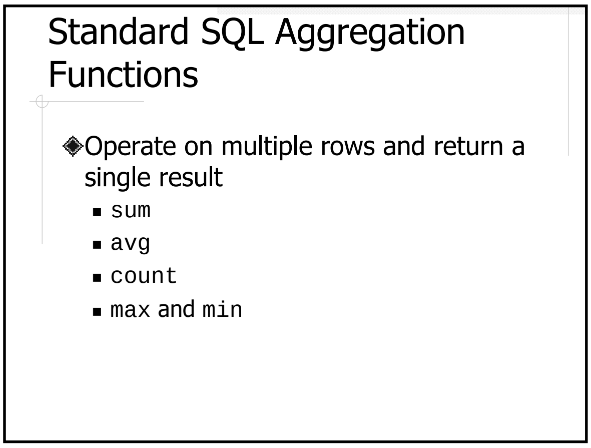
- *To support decision making*

Data Warehouse Architecture



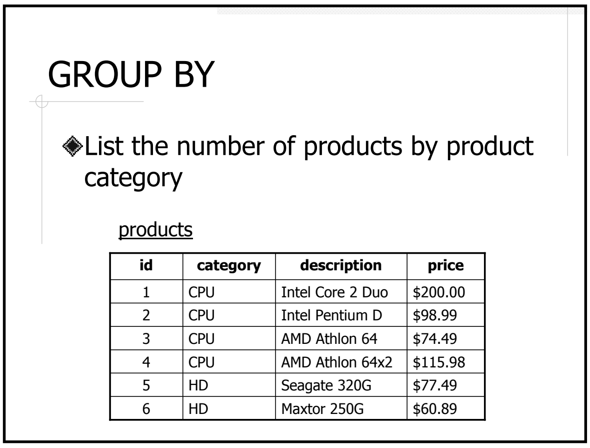
Why The Multidimensional Model

- Decision support applications are dominated by queries involved 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`

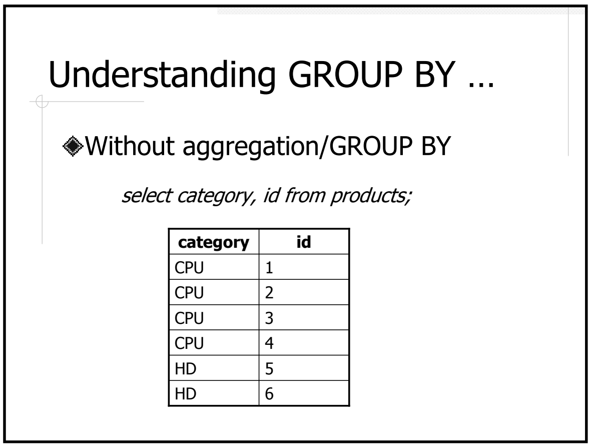


GROUP BY

- List the number of products by product 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

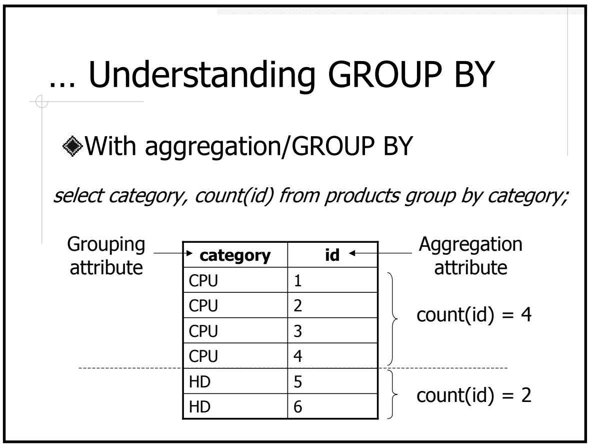


Understanding GROUP BY …

- Without aggregation/GROUP BY

select category, id from products;

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

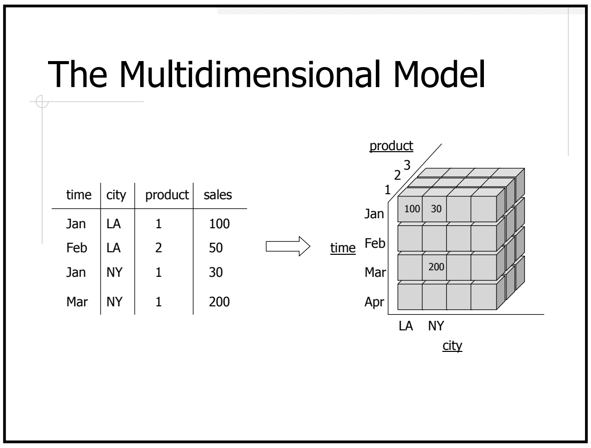


… Understanding GROUP BY

- With aggregation/GROUP BY

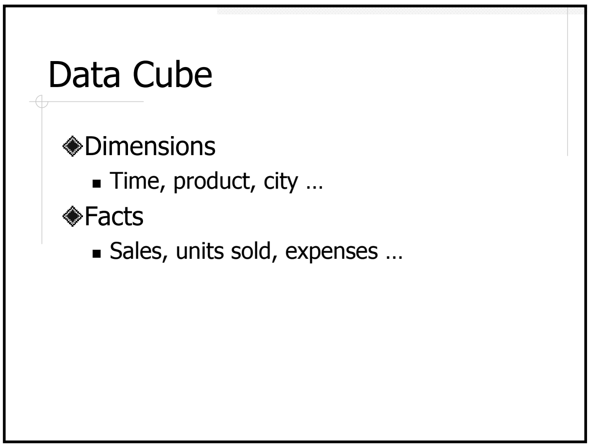
select category, count(id) from products group by category;

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



The Multidimensional Model

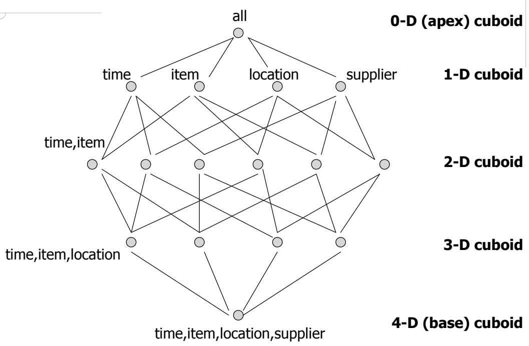
time	city	product	sales
Jan	LA	1	100
Feb	LA	2	50
Jan	NY	1	30
Mar	NY	1	200



Data Cube

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

Data Cube as a Lattice of Cuboids

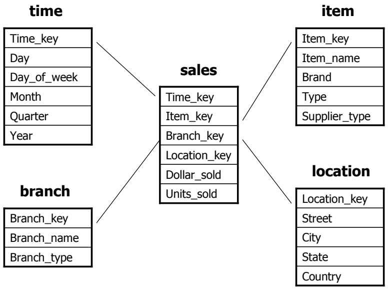


Observations about Data Cubes

◈Given a n-dimensional data cube, with each dimension having m values

- *Number of cuboids??*
- *Number of cells??*

Star Schema …



time

Time_key
Day
Day_of_week
Month
Quarter
Year

sales

Time_key
Item_key
Branch_key
Location_key
Dollar_sold
Units_sold

item

Item_key
Item_name
Brand
Type
Supplier_type

branch

Branch_key
Branch_name
Branch_type

location

Location_key
Street
City
State
Country

… Star Schema

◈One Fact Table

- E.g. *sales*

◈One Dimension Table per dimension

- E.g. *time*, *item*, *branch*, and *location*
- Dimension tables are not normalized (*Why??*)

Other Schemas for Multidimensional Databases

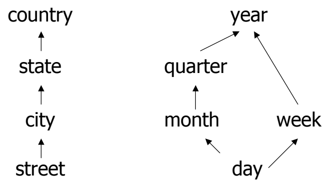
◈Snowflake schema

- Star schema with normalized dimension tables

◈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 Storage Strategies

- ◈Relational OLAP (ROLAP)
- ◈Multidimensional OLAP (MOLAP)
- ◈Hybrid OLAP (HOLAP)

A ROLAP Data Store

- ◈Summary fact tables

RID	Item	◦◦◦	Day	Month	Quarter	Year	Sales
1001	TV		15	10	Q4	2003	250
1002	TV		23	10	Q4	2003	175
◦◦◦				◦◦◦		◦◦◦	
5001	TV		all	10	Q4	2003	45,786

Aggregation Functions

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

More About Aggregation Functions

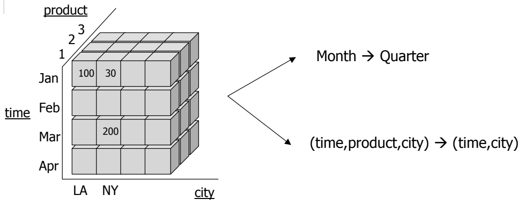
- ◈Variance: $\frac{1}{N}\sum_{i=1}^{N}(x-\overline{x_i})^2$
- ◈`Min`, `average`, `median` with *incremental delete*

OLAP Operations

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

Roll-up

- ◈Aggregation on a data cube by
  - Going up a concept hierarchy, or
  - Reducing dimension(s)



Month → Quarter

(time,product,city) → (time,city)

Drill-down

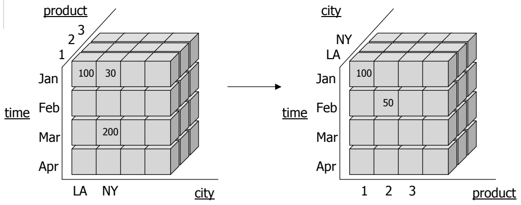
- Reverse of roll-up
  - Going down a concept hierarchy, or
  - Adding dimensions

Slice and Dice

- Slice: selection on one dimension
- Dice: selection on more than one dimensions
- For example:
  - `(city = "LA") and (month = "Jan" or "Feb")`

Pivot (Rotate)

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



Perform OLAP Operations Efficiently

- Indexing
- Cube pre-computation

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

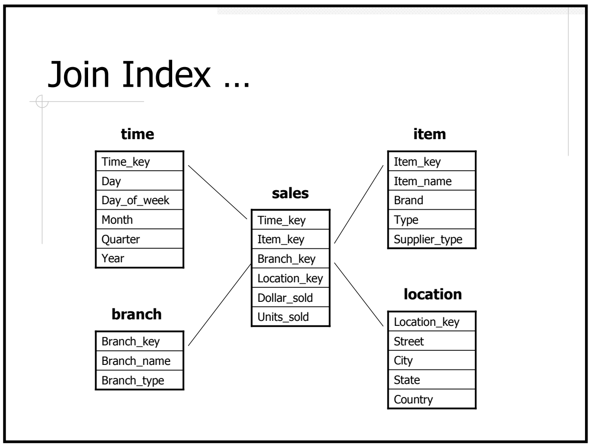
Item: { TV, PC, Phone }

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



Join Index …

time

- Time_key
- Day
- Day_of_week
- Month
- Quarter
- Year

sales

- Time_key
- Item_key
- Branch_key
- Location_key
- Dollar_sold
- Units_sold

item

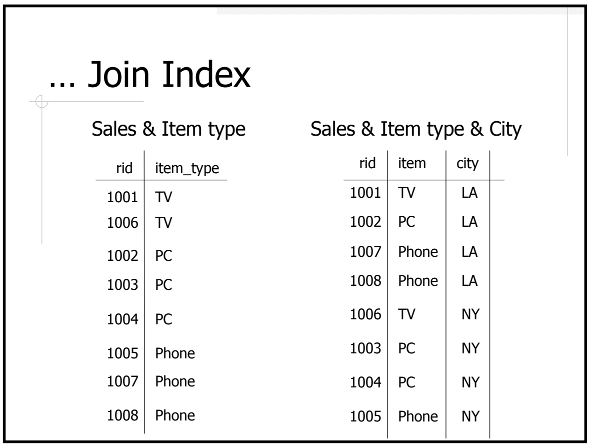
- Item_key
- Item_name
- Brand
- Type
- Supplier_type

branch

- Branch_key
- Branch_name
- Branch_type

location

- Location_key
- Street
- City
- State
- Country



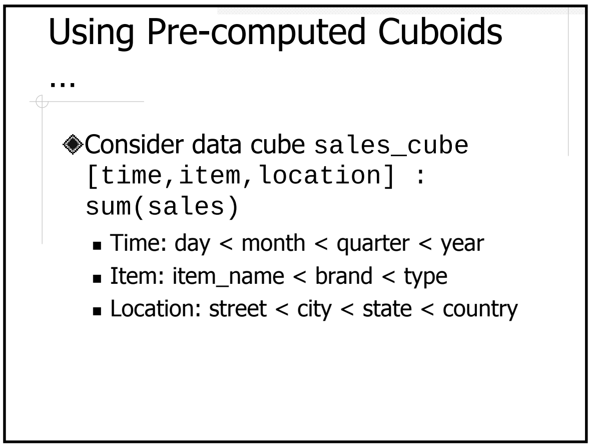
… Join Index

Sales & Item type

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

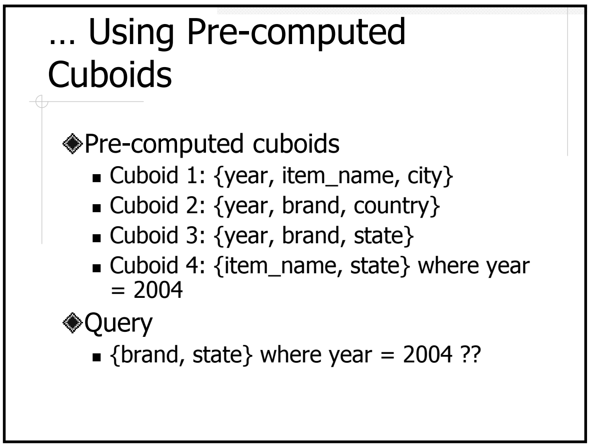
Sales & Item type & City

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



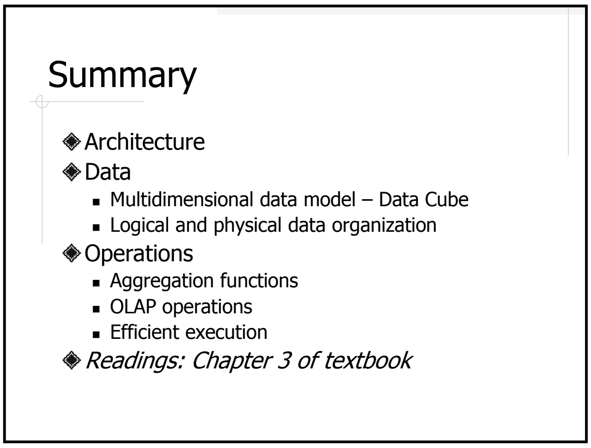
Using Pre-computed Cuboids …

- Consider data cube `sales_cube [time,item,location] : sum(sales)`
  - Time: day < month < quarter < year
  - Item: item_name < brand < type
  - Location: street < city < state < country



… Using Pre-computed Cuboids

- Pre-computed cuboids
  - Cuboid 1: {year, item_name, city}
  - Cuboid 2: {year, brand, country}
  - Cuboid 3: {year, brand, state}
  - Cuboid 4: {item_name, state} where year = 2004
- Query
  - {brand, state} where year = 2004 ??



Summary

- Architecture
- Data
  - Multidimensional data model – Data Cube
  - Logical and physical data organization
- Operations
  - Aggregation functions
  - OLAP operations
  - Efficient execution
- *Readings: Chapter 3 of textbook*