Data Warehousing

Introduction to Databases
CompSci 316 Fall 2016

DUKE
COMPUTER SCIENCE

Announcements (Thu., Dec. 8)

- Homework #4 last Gradiance problem due today
  - Sample solution to be posted by this weekend
- Project demos to start tomorrow
  - Check your email for schedule
  - Submit report/code before demo (you have until next Thursday to update it)
- Final exam Thur. Dec. 15 7-10pm
  - **Different room: LSRC B101**
  - Open-book, open-notes
  - Comprehensive, but with strong emphasis on the second half of the course
  - Sample final + solution posted on Sakai

Data integration

- Data resides in many distributed, heterogeneous OLTP (On-Line Transaction Processing) sources
  - Sales, inventory, customer, …
  - NC branch, NY branch, CA branch, …
- Need to support OLAP (On-Line Analytical Processing) over an integrated view of the data
- Possible approaches to integration
  - Eager: integrate in advance and store the integrated data at a central repository called the data warehouse
  - Lazy: integrate on demand; process queries over distributed sources—mediated or federated systems

4

OLTP versus OLAP

OLTP
- Mostly updates
- Short, simple transactions
- Clerical users
- Goal: transaction throughput

OLAP
- Mostly reads
- Long, complex queries
- Analysts, decision makers
- Goal: fast queries

Implications on database design and optimization?

OLAP databases do not care much about redundancy
- "Denormalize" tables
- Many, many indexes
- Precomputed query results

5

Eager versus lazy integration

Eager (warehousing)
- In advance: before queries
- Copy data from sources

☞Answer could be stale

☞Need to maintain consistency

☞Query processing is local to the warehouse
- Faster
- Can operate when sources are unavailable

Lazy
- On demand: at query time
- Leave data at sources

☞Answer is more up-to-date

☞No need to maintain consistency

☞Sources participate in query processing
- Slower
- Interferes with local processing
- Still has consistency issues

6

Maintaining a data warehouse

- The "ETL" process
  - Extract relevant data and/or changes from sources
  - Transform data to match the warehouse schema
  - Load/integrate data/changes into the warehouse
- Approaches
  - Recomputation
    - Easy to implement; just take periodic dumps of the sources, say, every night
    - What if there is no "night," e.g., a global organization?
    - What if recomputation takes more than a day?
  - Incremental maintenance
    - Compute and apply only incremental changes
    - Fast if changes are small
    - Not easy to do for complicated transformations
    - Need to detect incremental changes at the sources

"Star" schema of a data warehouse

Dimension table

Product

PID	name	cost
p1	beer	10
p2	diaper	16
...	...	...

Dimension table

Store

SID	city
s1	Durham
s2	Chapel Hill
s3	RTP
...	...

Sale

OID	Date	CID	PID	SID	qty	price
100	08/23/2015	c3	p1	s1	1	12
102	09/12/2015	c3	p2	s1	2	17
105	09/24/2015	c5	p1	s3	5	13
...	...	...	...	...	...	...

Fact table
- Big
- Constantly growing
- Stores measures (often aggregated in queries)

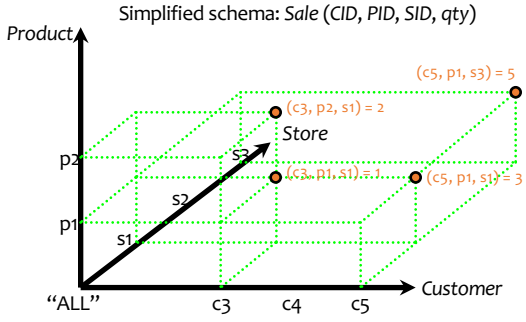
Customer

CID	name	address	city
c3	Amy	100 Main St.	Durham
c4	Ben	102 Main St.	Durham
c5	Coy	800 Eighth St.	Durham
...	...	...	...

Dimension table
- Small
- Updated infrequently

Data cube

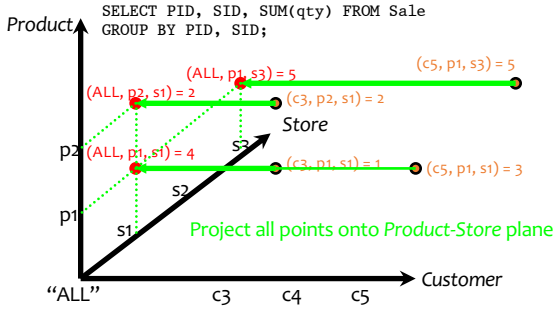
Simplified schema: *Sale* (*CID*, *PID*, *SID*, *qty*)



Completing the cube—plane

Total quantity of sales for each product in each store

```
SELECT PID, SID, SUM(qty) FROM Sale
GROUP BY PID, SID;
```

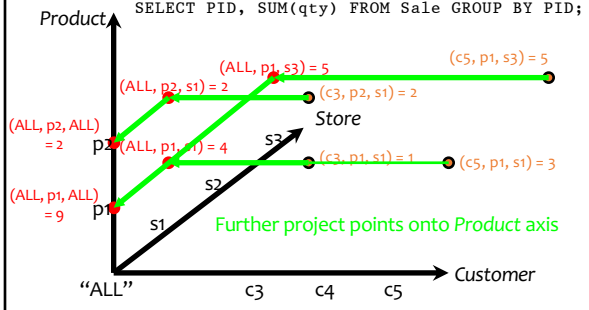


10

Completing the cube—axis

Total quantity of sales for each product

```
SELECT PID, SUM(qty) FROM Sale GROUP BY PID;
```

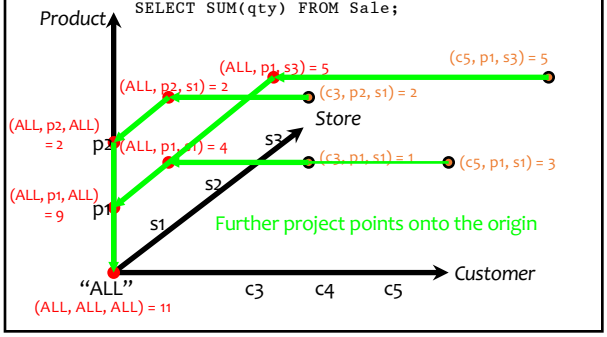


11

Completing the cube—origin

Total quantity of sales

```
SELECT SUM(qty) FROM Sale;
```



12

CUBE operator

- *Sale* (*CID*, *PID*, *SID*, *qty*)
- Proposed SQL extension:

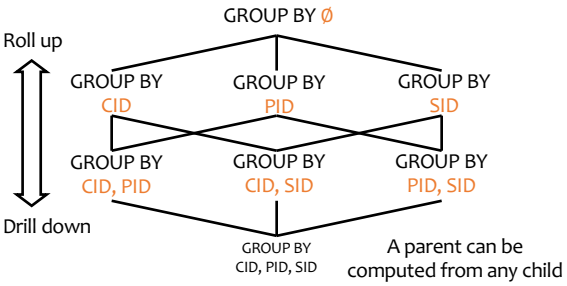
```
SELECT SUM(qty) FROM Sale
GROUP BY CUBE CID, PID, SID;
```

- Output contains:
  - Normal groups produced by GROUP BY
    - (c1, p1, s1, sum), (c1, p2, s3, sum), etc.
  - Groups with one or more ALL's
    - (ALL, p1, s1, sum), (c2, ALL, ALL, sum), (ALL, ALL, ALL, sum), etc.
- Can you write a CUBE query using only GROUP BY's?

Gray et al., "Data Cube: A Relational Aggregation Operator Generalizing Group-By, Cross-Tab, and Sub-Total." *ICDE* 1996

13

Aggregation lattice



A parent can be computed from any child

14

Materialized views

- Computing `GROUP BY` and `CUBE` aggregates is expensive
- OLAP queries perform these operations over and over again

☞Idea: precompute and store the aggregates as materialized views
- Maintained automatically as base data changes
- No. 1 user-requested feature in PostgreSQL!

15

Selecting views to materialize

- Factors in deciding what to materialize
  - What is its storage cost?
  - What is its update cost?
  - Which queries can benefit from it?
  - How much can a query benefit from it?
- Example
  - GROUP BY ∅ is small, but not useful to most queries
  - GROUP BY CID, PID, SID is useful to any query, but too large to be beneficial

16

Other OLAP extensions

- Besides extended grouping capabilities (e.g., CUBE), window operations have also been added to SQL
- A "window" specifies an ordered list of rows related to the "current row"
- A window function computes a value from this list and the "current row"
  - Standard aggregates: COUNT, SUM, AVG, MIN, MAX
  - New functions: RANK, PERCENT_RANK, LAG, LEAD, …

17

RANK window function example

sid	pid	cid	qty
Durham	beer	Alice	10
Durham	beer	Bob	2
Durham	chips	Bob	3
Durham	diaper	Alice	5
Raleigh	beer	Alice	2
Raleigh	diaper	Bob	100

```
SELECT SID, PID, SUM(qty),
       RANK() OVER w
FROM Sale GROUP BY SID, PID
WINDOW w AS
(PARTITION BY SID
 ORDER BY SUM(qty) DESC);
```

⇩ GROUP BY

sid	pid	cid	qty
Durham	beer	Alice	10
		Bob	2
Durham	chips	Bob	3
Durham	diaper	Alice	5
Raleigh	beer	Alice	2
Raleigh	diaper	Bob	100

Apply WINDOW after processing FROM, WHERE, GROUP BY, HAVING

- PARTITION defines the related set and ORDER BY orders it

E.g., for the following "row,"

Durham	beer	Alice	10
		Bob	2

the related list is:

Durham	beer	Alice	10
		Bob	2
Durham	diaper	Alice	5
Durham	chips	Bob	3

18

RANK example (cont'd)

sid	pid	cid	qty
Durham	beer	Alice	10
		Bob	2
Durham	chips	Bob	3
Durham	diaper	Alice	5
Raleigh	beer	Alice	2
Raleigh	diaper	Bob	100

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SELECT SID, PID, SUM(qty),
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E.g., for the following "row,"

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the related list is:

Durham	beer	Alice	10
		Bob	2
Durham	diaper	Alice	5
Durham	chips	Bob	3

Then, for each "row" and its related list, evaluate SELECT and return:

sid	pid	sum	rank
Durham	beer	12	1
Durham	diaper	5	2
Durham	chips	3	3
Raleigh	diaper	100	1
Raleigh	beer	2	2

19

Multiple windows

sid	pid	cid	qty
Durham	beer	Alice	10
		Bob	2
Durham	chips	Bob	3
Durham	diaper	Alice	5
Raleigh	beer	Alice	2
Raleigh	diaper	Bob	100

```
SELECT SID, PID, SUM(qty),
  RANK() OVER w,
  RANK() OVER w1 AS rank1
FROM Sale GROUP BY SID, PID
WINDOW w AS
  (PARTITION BY SID
   ORDER BY SUM(qty) DESC),
w1 AS
  (ORDER BY SUM(qty) DESC)
ORDER BY SID, rank;
```

No `PARTITION` means all "rows" are related to the current one

So `rank1` is the "global" rank:

sid	pid	sum	rank	rank1
Durham	beer	12	1	2
Durham	diaper	5	2	3
Durham	chips	3	3	4
Raleigh	diaper	100	1	1
Raleigh	beer	2	2	5

20

Summary

- Eagerly integrate data from operational sources and store a redundant copy to support OLAP
- OLAP vs. OLTP: different workload → different degree of redundancy
- SQL extensions: grouping and windowing