Data Science 100
Databases Part 2
(The SQL)

Slides by:
Joseph E. Gonzalez & Joseph Hellerstein,
jegonzal@berkeley.edu
jhellerstein@berkeley.edu

Previously …

Database Management Systems

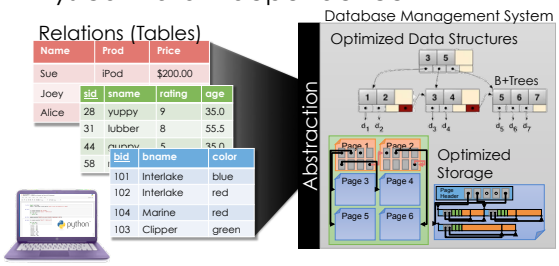
A **database management systems (DBMS)** is a software system that **stores**, **manages**, and **facilitates access** to one or more databases.

- **Relational** database management systems

ORACLE TERADATA Microsoft SQL Server PostgreSQL SQLite

- *Logically* organize data in **relations** (tables)
- Structured Query Language **(SQL)** to define, manipulate and compute on data.

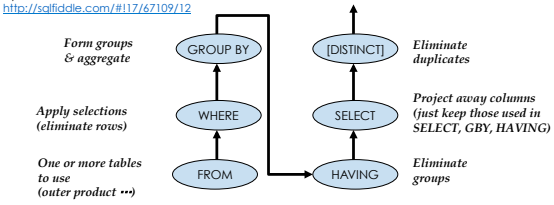
Physical Data Independence



Conceptual SQL Evaluation

```
SELECT    [DISTINCT] target-list
FROM      relation-list
WHERE     qualification
GROUP BY  grouping-list
HAVING    group-qualification
```

Try Queries Here
http://sqlfiddle.com/#!17/67109/12



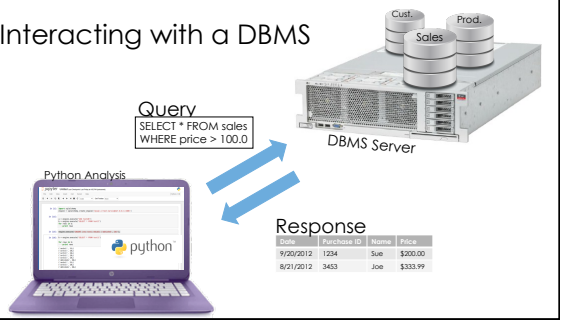
How do you interact with a database?

What is the DBMS?

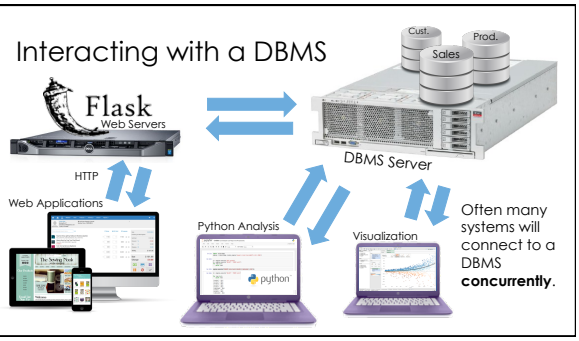
- Server
- Software
- A library

Answer: It can be all of these.

Interacting with a DBMS



Interacting with a DBMS



Data in the Organization

A little bit of buzzword bingo!

Multidimensional Data Model

Sales **Fact Table**

pid	timeid	locid	sales
11	1	1	25
11	2	1	8
11	3	1	15
12	1	1	30
12	2	1	20
12	3	1	50
12	1	1	8
13	2	1	10
13	3	1	10
11	1	2	35
11	2	2	22
11	3	2	10
12	1	2	26

Locations

locid	city	state	country
1	Omaha	Nebraska	USA
2	Seoul		Korea
5	Richmond	Virginia	USA

Products

pid	pname	category	price
11	Corn	Food	25
12	Galaxy 1	Phones	18
13	Peanuts	Food	2

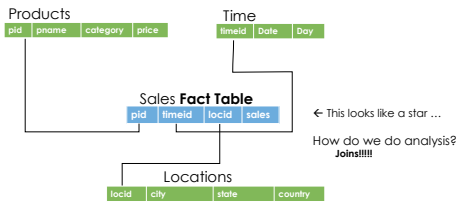
Time

timeid	Date	Day
1	3/30/16	Wed.
2	3/31/16	Thu.
3	4/1/16	Fri.

Dimension Tables

- Normalized Representation
- Fact Table
  - minimizes redundant info.
  - Reduces data errors
- Dimensions
  - easy to manage and summarize
  - Rename: Galaxy1 → Phablet

Connections between table



Joins!

Bringing tables together for decades.

Join Queries

```
SELECT [DISTINCT] <column expression list>
  FROM <table1 [AS t1], ... , tableN [AS tn]>
[WHERE <predicate>]
[GROUP BY <column list>
 [HAVING <predicate>] ]
[ORDER BY <column list>];
```

1. FROM : compute ***outer product*** of tables.
2. WHERE : Check conditions, discard tuples that fail.
3. SELECT : Specify desired fields in output.

- Note: likely a terribly inefficient strategy!
  - Query optimizer will find more efficient plans.

The Outer-Product (×)

R1 × S1: *Each row of **R1** paired with each row of **S1***

R1:

sid	bid	day
22	101	10/10/96
58	103	11/12/96

×

S1:

sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0

=

R1 × S1

sid	bid	day	sid	sname	rating	age
22	101	10/10/96	22	dustin	7	45.0
22	101	10/10/96	31	lubber	8	55.5
22	101	10/10/96	58	rusty	10	35.0
58	103	11/12/96	22	dustin	7	45.0
58	103	11/12/96	31	lubber	8	55.5
58	103	11/12/96	58	rusty	10	35.0

How many rows in the result? | R1 | * | R2 |

Sometimes also called **Cartesian Product:**

Return Sailors (S) and the dates of their Reservations (R)

```
SELECT S.sname, R.day
FROM Reserves AS R, Sailors AS S
WHERE S.sid = R.sid
```

Symbol for join (Rel. Alg.)

R1 ⋈ S1

R:

sid	bid	day
22	101	10/10/96
58	103	11/12/96

S:

sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0

sid	bid	day	sid	sname	rating	age
22	101	10/10/96	22	dustin	7	45.0
22	101	10/10/96	31	lubber	8	55.5
22	101	10/10/96	58	rusty	10	35.0
58	103	11/12/96	22	dustin	7	45.0
58	103	11/12/96	31	lubber	8	55.5
58	103	11/12/96	58	rusty	10	35.0

http://sqlfiddle.com/#!17/53815/1140/0

About Range Variables

- Needed when ambiguity could arise.
  - e.g., same table used multiple times in FROM ("self-join")

```
SELECT  *
FROM    Sailors AS S1, Sailors AS S2
WHERE   S1.age > S2.age
```

S1:

sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0

S1				S2			
sid	sname	rating	age	sid	sname	rating	age
22	dustin	7	45.0	58	rusty	10	35.0
31	lubber	8	55.5	22	dustin	7	45.0
31	lubber	8	55.5	58	rusty	10	35.0

http://sqlfiddle.com/#!17/53815/4

Join Variants

SELECT (column_list)
FROM *table_name*
[INNER | {LEFT | RIGHT | FULL } {OUTER}] JOIN *table_name*
ON *qualification_list*
WHERE …

- INNER is default
- Inner join is akin to what we have seen so far.
- The term Outer is optional for Left, Right, and Full joins
  - For example: LEFT OUTER = LEFT

Inner/Natural Joins

Sailors

sid	sname	rating	age
1	Fred	7	22
2	Jim	2	39
3	Nancy	8	27

Boats

bid	bname	color
101	Nina	red
102	Pinta	blue
103	Santa Maria	red

Reserves

sid	bid	day
1	102	9/12
2	102	9/13

```
SELECT s.sid, s.sname, r.bid
    FROM Sailors s, Reserves r
   WHERE s.sid = r.sid
     AND s.age > 20;

SELECT s.sid, s.sname, r.bid
    FROM Sailors s INNER JOIN Reserves r
      ON s.sid = r.sid
   WHERE s.age > 20;

  SELECT s.sid, s.sname, r.bid
    FROM Sailors s NATURAL JOIN Reserves r
   WHERE s.age > 20;
```

all 3 are equivalent!

- "NATURAL" means equi-join for each pair of attributes with the same name

http://sqlfiddle.com/#!17/4215a/10

Left Join

Returns all matched rows, and *preserves* all unmatched rows from the table on the left of the join clause
(use nulls in fields of non-matching tuples)

```
SELECT s.sid, s.sname, r.bid
FROM Sailors2 s LEFT JOIN Reserves2 r
ON s.sid = r.sid;
```

Returns all sailors & bid for boat in any of their reservations

Note: If there is a sailor without a boat reservation then the sailor is matched with the NULL bid.

```
SELECT s.sid, s.sname, r.bid
FROM Sailors2 s LEFT JOIN Reserves2 r
ON s.sid = r.sid;
```

Sailors2

sid	sname	rating	age
22	Dustin	7	45
31	Lubber	8	55.5
95	Bob	3	63.5

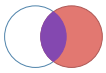
Reserves2

sid	bid	day
22	101	1996-10-10
95	103	1996-11-12

sid	sname	bid
22	Dustin	101
95	Bob	103
31	Lubber	**(null)**

http://sqlfiddle.com/#!17/54a88/2

Right Join



- Right join returns all matched rows, **and *preserves* all unmatched rows from the table on the right** of the join clause

```
SELECT r.sid, b.bid, b.bname
FROM Reserves2 r RIGHT JOIN Boats2 b
ON r.bid = b.bid;
```

- Returns all boats & information on which ones are reserved.
- No match for b.bid? r.sid IS NULL!

```
SELECT r.sid, b.bid, b.bname
FROM Reserves2 r RIGHT JOIN Boats2 b
ON r.bid = b.bid;
```

Reserves2

sid	bid	day
22	101	1996-10-10
95	103	1996-11-12

Boats2

bid	bname	color
101	Interlake	blue
102	Interlake	red
103	Clipper	green
104	Marine	red

Result:

sid	bid	bname
22	101	Interlake
95	103	Clipper
(null)	104	Marine
(null)	102	Interlake

http://sqlfiddle.com/#!17/a7b2f/1

Full Outer Join

- Full Outer Join returns all (matched or unmatched) rows from the tables on both sides of the join clause

```
SELECT r.sid, b.bid, b.bname
FROM Reserves2 r FULL JOIN Boats2 b
ON r.bid = b.bid
```

- If no boat for a sailor? → b.bid IS NULL AND b.bname IS NULL!
- If no sailor for a boat? → r.sid IS NULL!

```
SELECT r.sid, b.bid, b.bname
FROM Reserves3 r FULL JOIN Boats2 b
ON r.bid = b.bid
```

Reserves3

sid	bid	day
22	101	1996-10-10
95	103	1996-11-12
38	42	2010-08-21

Boats2

bid	bname	color
101	Interlake	blue
102	Interlake	red
103	Clipper	green
104	Marine	red

Result:

sid	bid	bname
22	101	Interlake
95	103	Clipper
38	**(null)**	**(null)**
(null)	104	Marine
(null)	102	Interlake

http://sqlfiddle.com/#!17/e1f3a/3/0

Brief Detour: Null Values

- Field values are sometimes unknown
  - SQL provides a special value NULL for such situations.
  - Every data type can be NULL
- The presence of null complicates many issues. E.g.:
  - Selection predicates (WHERE)
  - Aggregation
- But NULLs are common after outer joins

NULL in the WHERE clause

- Consider a tuple where `rating` IS NULL.

```
INSERT INTO sailors VALUES
 (11, 'Jack Sparrow', NULL, 35);
```

- If we run the following query

```
SELECT * FROM sailors
WHERE rating > 8;
```

- Jack Sparrow will not be included in the output.

http://sqlfiddle.com/#!17/36ca9/2

NULL in comparators

What entries are in the output of all these queries?

```
SELECT rating = NULL FROM sailors;
SELECT rating < NULL FROM sailors;
SELECT rating >= NULL FROM sailors;
```

All of these queries evaluate to null!

Even this one!

```
SELECT * FROM sailors WHERE rating = NULL;
```

Rule: (x *op* NULL) evaluates to … NULL!

http://sqlfiddle.com/#!17/f35aa/6

Explicit NULL Checks

- To check if a value is NULL you must use explicit NULL checks

```
SELECT * FROM sailors WHERE rating IS NULL;

SELECT * FROM sailors WHERE rating IS NOT NULL;
```

http://sqlfiddle.com/#!17/f35aa/4

NULL in Boolean Logic

Three-valued logic:

Not

T	F
F	T
N	N

And

	T	F	N
T	T	F	N
F	F	F	F
N	N	F	N

Or

	T	F	N
T	T	T	T
F	T	F	N
N	T	N	N

```
SELECT * FROM sailors WHERE rating > 8 AND TRUE;
SELECT * FROM sailors WHERE rating > 8 OR TRUE;
SELECT * FROM sailors WHERE NOT (rating > 8);
```

http://sqlfiddle.com/#!17/f35aa/2

NULL and Aggregation

```
SELECT count(rating) FROM sailors;
```
- 4

```
SELECT sum(rating) FROM sailors;
```
- 27

```
SELECT avg(rating) FROM sailors;
```
- ??

```
SELECT count(*) FROM sailors;
```
- ??

sid	sname	rating	age
1	Popeye	10	22
2	OliveOyl	11	39
3	Garfield	1	27
4	Bob	5	19
11	Jack Sparrow	(null)	35

http://bit.ly/ds100-sp18-null

http://sqlfiddle.com/#!17/f35aa/7

NULL and Aggregation

```
SELECT count(rating) FROM sailors;
```
- 4

```
SELECT sum(rating) FROM sailors;
```
- 27

```
SELECT avg(rating) FROM sailors;
```
- (10+11+1+5) / **4** = 6.75

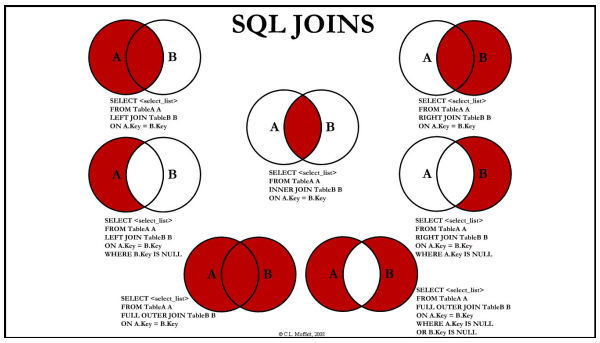
```
SELECT count(*) FROM sailors;
```
- 5

sid	sname	rating	age
1	Popeye	10	22
2	OliveOyl	11	39
3	Garfield	1	27
4	Bob	5	19
11	Jack Sparrow	(null)	35

http://sqlfiddle.com/#!17/f35aa/7

NULLs: Summary

- NULL *op* NULL is NULL
- WHERE NULL: do not send to output
- Boolean connectives: 3-valued logic
- Aggregates ignore NULL-valued inputs



SQL Query Demo

Returning to Notebook