SQL I

R & G Chapter 5

SQL Roots

- Developed @IBM Research in the 1970s
  - System R project
  - Vs. Berkeley's Quel language (Ingres project)
- Commercialized/Popularized in the 1980s
  - "Intergalactic Dataspeak"
  - IBM beaten to market by a startup called Oracle

SQL's Persistence

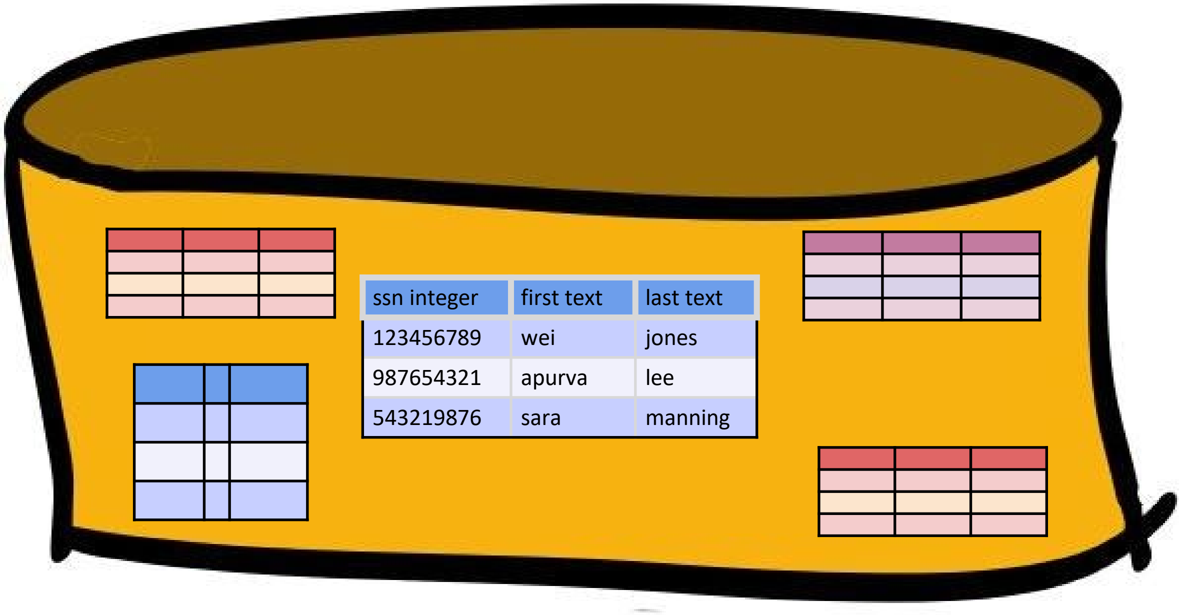
- Over 40 years old!
- Questioned repeatedly
  - 90's: Object-Oriented DBMS (OQL, etc.)
  - 2000's: XML (Xquery, Xpath, XSLT)
  - 2010's: NoSQL & MapReduce
- SQL keeps re-emerging as the standard
  - Even Hadoop, Spark etc. mostly used via SQL
  - May not be perfect, but it is useful

SQL Pros and Cons

- Declarative!
  - Say *what* you want, not *how* to get it
- Implemented widely
  - With varying levels of efficiency, completeness
- Constrained
  - Not targeted at Turing-complete tasks
- General-purpose and feature-rich
  - many years of added features
  - extensible: callouts to other languages, data sources

Relational Terminology

- ***Database***: Set of named Relations



ssn integer	first text	last text
123456789	wei	jones
987654321	apurva	lee
543219876	sara	manning

Relational Terminology, Pt 2.

- ***Database***: Set of named Relations
- ***Relation*** (*Table*):
  - ***Schema****:* description ("metadata")
  - ***Instance****:* set of data satisfying the schema

ssn integer	first text	last text
123456789	wei	jones
987654321	apurva	lee
543219876	sara	manning

Relational Terminology, Pt. 3

- ***Database***: Set of named Relations
- ***Relation*** (*Table*):
  - ***Schema**:* description ("metadata")
  - ***Instance**:* set of data satisfying the schema
- ***Attribute*** (*Column, Field*)

first text
wei
apurva
sara

Relational Terminology, Pt. 4

- ***Database***: Set of named Relations
- ***Relation*** (Table):
  - ***Schema***: description (“metadata”)
  - ***Instance***: set of data satisfying the schema
- ***Attribute*** (Column, Field)
- ***Tuple*** (Record, Row)

543219876	sara	manning

Relational Tables

- *Schema* is fixed:
  - unique attribute names, *atomic* types
  - folks (ssn integer, first text, last text)
- *Instance* can change often
  - a *multi*set of “rows” (“tuples”)

{(123456789, ’wei’, ’jones’),
(987654321, ’apurva’, ’lee’),
(543219876, ‘sara’, ‘manning’),
(987654321, ’apurva’, ’lee’)}

Quick Check 1

- Why is this not a relation?

num integer	street text	zip integer	
84	Maple Ave	54704	
22	High	Street	76425
75	Hearst Ave	94720	

Quick Check 2

- Why is this not a relation?

num integer	street text	num integer
84	Maple Ave	54704
22	High Street	76425
75	Hearst Ave	94720

Quick Check 3

- Why is this not a relation?

first text	last text	addr address
wei	jones	(84, ‘Maple’, 54704)
apurva	lee	(22, ‘High’, 76425)
sara	manning	(75, ‘Hearst’, 94720)

SQL Language

- Two sublanguages:
  - DDL – Data Definition Language
    - Define and modify schema
  - DML – Data Manipulation Language
    - Queries can be written intuitively.
- RDBMS responsible for efficient evaluation.
  - Choose and run algorithms for declarative queries
    - Choice of algorithm must not affect query answer.

Example Database

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	9/12/2015
2	102	9/13/2015

The SQL DDL: Sailors

```
CREATE TABLE Sailors (
        sid INTEGER,
        sname CHAR(20),
        rating INTEGER,
        age FLOAT
```

<u>sid</u>	**sname**	**rating**	**age**
1	Fred	7	22
2	Jim	2	39
3	Nancy	8	27

The SQL DDL: Sailors, Pt. 2

```
CREATE TABLE Sailors (
	sid INTEGER,
	sname CHAR(20),
	rating INTEGER,
	age FLOAT
PRIMARY KEY (sid));
```

<u>**sid**</u>	**sname**	**rating**	**age**
1	Fred	7	22
2	Jim	2	39
3	Nancy	8	27

The SQL DDL: Primary Keys

```
CREATE TABLE Sailors (
        sid INTEGER,
        sname CHAR(20),
        rating INTEGER,
        age FLOAT
```

<u>**sid**</u>	**sname**	**rating**	**age**
1	Fred	7	22
2	Jim	2	39
3	Nancy	8	27

- Primary Key column(s)
  - Provides a unique “lookup key” for the relation
  - Cannot have any duplicate values
  - Can be made up of >1 column
    - E.g. (firstname, lastname)

The SQL DDL: Boats

```
CREATE TABLE Sailors (
        sid INTEGER,
        sname CHAR(20),
        rating INTEGER,
        age FLOAT

CREATE TABLE Boats (
    bid INTEGER,
    bname CHAR (20),
    color CHAR(10),
    PRIMARY KEY (bid));
```

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

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

The SQL DDL: Reserves

```
CREATE TABLE Sailors (
        sid INTEGER,
        sname CHAR(20),
        rating INTEGER,
        age FLOAT

CREATE TABLE Boats (
     bid INTEGER,
     bname CHAR (20),
     color CHAR(10),
     PRIMARY KEY (bid));

CREATE TABLE Reserves (
     sid INTEGER,
     bid INTEGER,
     day DATE,
     PRIMARY KEY (sid, bid, day);
```

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

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

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

The SQL DDL: Reserves Pt. 2

```
CREATE TABLE Sailors (
        sid INTEGER,
        sname CHAR(20),
        rating INTEGER,
        age FLOAT

CREATE TABLE Boats (
    bid INTEGER,
    bname CHAR (20),
    color CHAR(10),
    PRIMARY KEY (bid));

CREATE TABLE Reserves (
    sid INTEGER,
    bid INTEGER,
    day DATE,
    PRIMARY KEY (sid, bid, day),
    FOREIGN KEY (sid) REFERENCES Sailors,
```

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

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

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

Slide Deck Title

The SQL DDL: Foreign Keys

```
CREATE TABLE Sailors (
        sid INTEGER,
        sname CHAR(20),
        rating INTEGER,
        age FLOAT

CREATE TABLE Boats (
    bid INTEGER,
    bname CHAR (20),
    color CHAR(10),
    PRIMARY KEY (bid));

CREATE TABLE Reserves (
    sid INTEGER,
    bid INTEGER,
    day DATE,
    PRIMARY KEY (sid, bid, day),
    FOREIGN KEY (sid) REFERENCES Sailors,
        FOREIGN KEY (bid) REFERENCES Boats);
```

<u>sid</u>	sname	rating	age
1	Fred	7	22
2	Jim	2	39
3	Nancy	8	27

<u>bid</u>	bname	color
101	Nina	red
102	Pinta	blue
103	Santa Maria	red

<u>sid</u>	<u>bid</u>	<u>day</u>
1	102	9/12
2	102	9/13

Slide Deck Title

The SQL DDL: Foreign Keys Pt. 2

- Foreign key references a table
  - Via the primary key of that table
- Need not share the name of the referenced primary key

```
CREATE TABLE Reserves (
    sid INTEGER,
    bid INTEGER,
    day DATE,
    PRIMARY KEY (sid, bid, day),
    FOREIGN KEY (sid)
    REFERENCES Sailors,
        FOREIGN KEY (bid)
        REFERENCES Boats);
```

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

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

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

Slide Deck Title

The SQL DML

- Find all 27-year-old sailors:

```
SELECT *
FROM  Sailors AS S
WHERE S.age=27;
```

- To find just names and rating, replace the first line to:

```
SELECT S.sname,
S.rating
```

Sailors

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

Basic Single-Table Queries

- **SELECT** [*DISTINCT*] <*column expression list*>
  FROM <*single table*>
  [**WHERE** <*predicate*>]

- Simplest version is straightforward
  - Produce all tuples in the table that satisfy the predicate
  - Output the expressions in the SELECT list
  - Expression can be a column reference, or an arithmetic expression over column refs

SELECT DISTINCT

SELECT DISTINCT S.name, S.gpa
FROM students S
WHERE S.dept = 'CS'

- DISTINCT specifies removal of duplicate rows before output
- Can refer to the students table as “S”, this is called an alias

ORDER BY

- **SELECT** S.name, S.gpa, S.age*2 AS a2
  FROM Students S
  WHERE S.dept = 'CS'
  ORDER BY S.gpa, S.name, a2;

- ORDER BY clause specifies output to be sorted
  - ***Lexicographic*** ordering
- Obviously must refer to columns in the output
  - Note the AS clause for naming output columns!

ORDER BY, Pt. 2

- **SELECT** S.name, S.gpa, S.age*2 AS a2
  FROM Students S
  WHERE S.dept = 'CS'
  ORDER BY S.gpa DESC, S.name **ASC**, a2;

- Ascending order by default, but can be overridden
  - DESC flag for descending, ASC for ascending
  - Can mix and match, lexicographically

LIMIT

```
SELECT  S.name, S.gpa, S.age*2 AS a2
FROM Students S
WHERE S.dept = 'CS'
ORDER BY S.gpa DESC, S.name ASC, a2;
LIMIT 3 ;
```

- Only produces the first <integer> output rows
- Typically used with ORDER BY
  - Otherwise the output is *non-deterministic*
  - Not a “pure” declarative construct in that case – output set depends on algorithm for query processing

Aggregates

- **SELECT** [DISTINCT] **AVG**(S.gpa)
  FROM Students S
  WHERE S.dept = 'CS'

- Before producing output, compute a summary (a.k.a. an *aggregate*) of some arithmetic expression
- Produces 1 row of output
  - with one column in this case
- Other aggregates: SUM, COUNT, MAX, MIN

GROUP BY

SELECT [DISTINCT] **AVG**(S.gpa), S.dept
FROM Students S
GROUP BY S.dept

- Partition table into groups with same GROUP BY column values
  - Can group by a list of columns
- Produce an aggregate result per group
  - Cardinality of output = # of distinct group values
- Note: can put grouping columns in SELECT list

HAVING

SELECT [DISTINCT] **AVG**(S.gpa), S.dept
FROM Students S
GROUP BY S.dept
HAVING COUNT(*) > 2

- The HAVING predicate filters groups
- HAVING is applied *after* grouping and aggregation
  - Hence can contain anything that could go in the SELECT list
  - I.e. aggs or GROUP BY columns
- HAVING can only be used in aggregate queries
- It’s an optional clause

Putting it all together

```
SELECT S.dept, AVG(S.gpa), COUNT(*)
FROM Students S
WHERE S.gender = 'F'
GROUP BY S.dept
HAVING COUNT(*) >= 2
ORDER BY S.dept;
```

DISTINCT Aggregates

Are these the same or different?

```
SELECT COUNT(DISTINCT S.name)
FROM Students S
WHERE S.dept = 'CS';
```

```
SELECT DISTINCT COUNT(S.name)
FROM Students S
WHERE S.dept = 'CS';
```

What Is This Asking For?

```
SELECT S.name, AVG(S.gpa)
FROM Students S
GROUP BY S.dept;
```

SQL DML:
General Single-Table Queries

- **SELECT [DISTINCT]** *<column expression list>*
  FROM *<single table>*
  [**WHERE** *<predicate>*]
  [**GROUP BY** *<column list>*
  [**HAVING** *<predicate>*]]
  [**ORDER BY** *<column list>*]
  [**LIMIT** <integer>];

Summary

- Relational model has **well-defined query semantics**
- Modern SQL extends "pure" relational model

  (some extra goodies for duplicate row, non-atomic types… more in next lecture)
- Typically, many ways to write a query
  - DBMS figures out a fast way to execute a query, regardless of how it is written.