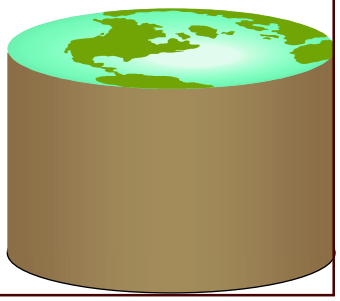
SQL: The Query Language
Part 3

CS186, Fall 2005
R &G - Chapters 5-6

It is not every question
that deserves an answer.

Publius Syrus. 42 B. C.



Null Values

- **Field values in a tuple are sometimes *unknown* (e.g., a rating has not been assigned) or *inapplicable* (e.g., no spouse's name).**
  - SQL provides a special value *null* for such situations.
- **The presence of *null* complicates many issues. E.g.:**
  - Special operators needed to check if value is/is not *null*.
  - Is *rating>8* true or false when *rating* is equal to *null*? What about AND, OR and NOT connectives?
  - We need a 3-valued logic (true, false and *unknown*).
  - Meaning of constructs must be defined carefully. (e.g., WHERE clause eliminates rows that don't evaluate to true.)
  - New operators (in particular, *outer joins*) possible/needed.

Joins

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

Explicit join semantics needed unless it is an INNER join (INNER is default)

Inner Join

Only the rows that match the search conditions are returned.

```
SELECT s.sid, s.name, r.bid
FROM Sailors s INNER JOIN Reserves r
ON s.sid = r.sid
```

Returns only those sailors who have reserved boats

SQL-92 also allows:

```
SELECT s.sid, s.name, r.bid
FROM Sailors s NATURAL JOIN Reserves r
```

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

```
SELECT s.sid, s.name, r.bid
FROM Sailors s INNER JOIN Reserves r
ON s.sid = r.sid
```

sid	sname	rating	age
22	Dustin	7	45.0
31	Lubber	8	55.5
95	Bob	3	63.5

sid	bid	day
22	101	10/10/96
95	103	11/12/96

s.sid	s.name	r.bid
22	Dustin	101
95	Bob	103

Left Outer Join

Left Outer Join returns all matched rows, plus 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.name, r.bid
FROM Sailors s LEFT OUTER JOIN Reserves r
ON s.sid = r.sid
```

Returns all sailors & information on whether they have reserved boats

```
SELECT s.sid, s.name, r.bid
FROM Sailors s LEFT OUTER JOIN Reserves r
ON s.sid = r.sid
```

sid	sname	rating	age
22	Dustin	7	45.0
31	Lubber	8	55.5
95	Bob	3	63.5

sid	bid	day
22	101	10/10/96
95	103	11/12/96

s.sid	s.name	r.bid
22	Dustin	101
95	Bob	103
31	Lubber	

Right Outer Join

Right Outer Join returns all matched rows, plus all unmatched rows from the table on the right of the join clause

```
SELECT r.sid, b.bid, b.name
FROM Reserves r RIGHT OUTER JOIN Boats b
ON r.bid = b.bid
```

Returns all boats & information on which ones are reserved.

```
SELECT r.sid, b.bid, b.name
FROM Reserves r RIGHT OUTER JOIN Boats b
ON r.bid = b.bid
```

sid	bid	day
22	101	10/10/96
95	103	11/12/96

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

r.sid	b.bid	b.name
22	101	Interlake
	102	Interlake
95	103	Clipper
	104	Marine

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.name
FROM Reserves r FULL OUTER JOIN Boats b
ON r.bid = b.bid
```

Returns all boats & all information on reservations

```
SELECT r.sid, b.bid, b.name
FROM Reserves r FULL OUTER JOIN Boats b
ON r.bid = b.bid
```

sid	bid	day
22	101	10/10/96
95	103	11/12/96

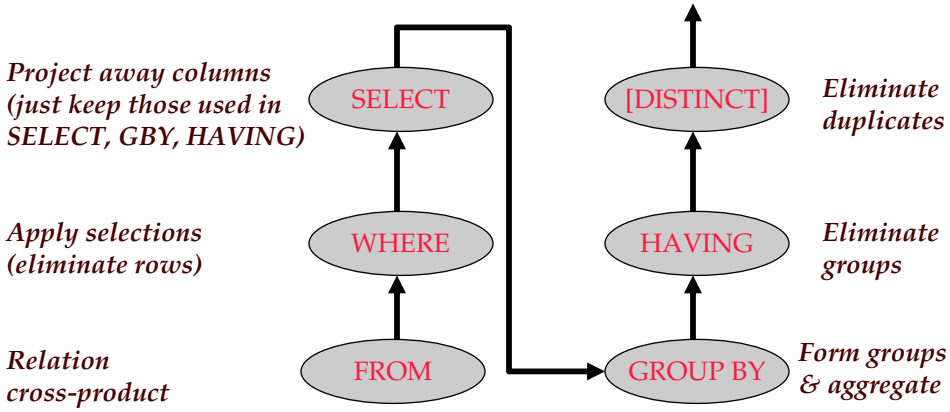
bid	bname	color
101	Interlake	blue
102	Interlake	red
103	Clipper	green
104	Marine	red

r.sid	b.bid	b.name
22	101	Interlake
	102	Interlake
95	103	Clipper
	104	Marine

Note: in this case it is the same as the ROJ because bid is a foreign key in reserves, so all reservations must have a corresponding tuple in boats.

Conceptual SQL Evaluation

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



Sorting the Results of a Query

- **ORDER BY *column* [ASC | DESC] [, ...]**

```
SELECT  S.rating, S.sname, S.age
        FROM  Sailors S, Boats B, Reserves R
        WHERE  S.sid=R.sid
                AND R.bid=B.bid AND B.color='red'
        ORDER BY  S.rating, S.sname;
```

- **Can order by any column in SELECT list, including expressions or aggs:**

```
SELECT  S.sid, COUNT (*) AS redrescnt
        FROM  Sailors S, Boats B, Reserves R
        WHERE  S.sid=R.sid
                AND R.bid=B.bid AND B.color='red'
        GROUP BY S.sid
        ORDER BY  redrescnt DESC;
```

Views: Defining External DB Schemas

```
CREATE VIEW  view_name
AS select_statement
```

Makes development simpler
Often used for security
Not instantiated - makes updates tricky

```
CREATE VIEW Reds
AS SELECT  B.bid,  COUNT (*) AS scount
   FROM Boats B, Reserves R
   WHERE  R.bid=B.bid AND   B.color='red'
   GROUP BY  B.bid
```

Views Instead of Relations in Queries

```
CREATE VIEW Reds
AS SELECT  B.bid,  COUNT (*) AS scount
    FROM Boats B, Reserves R
    WHERE  R.bid=B.bid AND   B.color='red'
     GROUP BY  B.bid
```

bid	scount
102	1

Reds

```
SELECT  bname, scount
    FROM Reds R, Boats B
    WHERE  R.bid=B.bid
        AND scount < 10
```

Discretionary Access Control

GRANT *privileges* ON *object* TO *users*
[WITH GRANT OPTION]

- **Object can be a Table or a View**
- **Privileges can be:**
  - **Select**
  - **Insert**
  - **Delete**
  - **References (cols) – allow to create a foreign key that references the specified column(s)**
  - **All**
- **Can later be REVOKEd**
- **Users can be single users or groups**
- **See Chapter 17 for more details.**

Two more important topics

- **Constraints**
- **SQL embedded in other languages**

Integrity Constraints (Review)

- **An IC describes conditions that every *legal instance* of a relation must satisfy.**
  - Inserts/deletes/updates that violate IC's are disallowed.
  - Can be used to ensure application semantics (e.g., *sid* is a key), or prevent inconsistencies (e.g., *sname* has to be a string, *age* must be < 200)
- ***Types of IC's*: Domain constraints, primary key constraints, foreign key constraints, general constraints.**
  - *Domain constraints*: Field values must be of right type. Always enforced.
  - *Primary key and foreign key constraints*: you know them.

General Constraints

- **Useful when more general ICs than keys are involved.**
- **Can use queries to express constraint.**
- **Checked on insert or update.**
- **Constraints can be named.**

```
CREATE TABLE Sailors
        ( sid INTEGER,
        sname CHAR(10),
        rating INTEGER,
        age REAL,
        PRIMARY KEY (sid),
        CHECK ( rating >= 1
                AND rating <= 10 ))
CREATE TABLE Reserves
        ( sname CHAR(10),
        bid INTEGER,
        day DATE,
        PRIMARY KEY (bid,day),
        CONSTRAINT noInterlakeRes
        CHECK (`Interlake' <>
                ( SELECT B.bname
                FROM Boats B
                WHERE B.bid=bid)))
```

Constraints Over Multiple Relations

- **Awkward and wrong!**
- **Only checks sailors!**
- **Only required to hold if the associated table is non-empty.**

Number of boats plus number of sailors is < 100

```
CREATE TABLE Sailors
        ( sid INTEGER,
        sname CHAR(10),
        rating INTEGER,
        age REAL,
        PRIMARY KEY (sid),
        CHECK
        ( (SELECT COUNT (S.sid) FROM Sailors S)
        + (SELECT COUNT (B.bid) FROM
                Boats B) < 100 )
```

- **ASSERTION is the right solution; not associated with either table.**
- **Unfortunately, not supported in many DBMS.**
- ***Triggers* are another solution.**

```
CREATE ASSERTION smallClub
CHECK
( (SELECT COUNT (S.sid) FROM Sailors S)
+ (SELECT COUNT (B.bid)
 FROM Boats B) < 100 )
```

Writing Applications with SQL

- **SQL is not a general purpose programming language.**
  + Tailored for data retrieval and manipulation
  + Relatively easy to optimize and parallelize
  - Can't write entire apps in SQL alone

Options:

Make the query language "Turing complete"

Avoids the "impedance mismatch"

but, loses advantages of relational language simplicity

Allow SQL to be embedded in regular programming languages.

Q: What needs to be solved to make the latter approach work?

Embedded SQL

- **DBMS vendors usually provide "host language bindings"**
  - E.g. for C or COBOL
  - Allow SQL statements to be called from within a program
  - Typically you preprocess your programs
  - Preprocessor generates calls to a proprietary DB connectivity library
- **General pattern**
  - One call to *connect* to the right database (login, etc.)
  - SQL statements can refer to host variables from the language
- **Typically vendor-specific**
  - We won't look at any in detail, we'll look at standard stuff
- **Problem**
  - SQL relations are (multi-)sets, no *a priori* bound on the number of records. No such data structure in C.
  - SQL supports a mechanism called a *cursor* to handle this.

Just to give you a flavor

```
EXEC SQL SELECT S.sname, S.age
  INTO :c_sname,:c_age
  FROM Sailors S
  WHERE S.sid = :c_sid
```

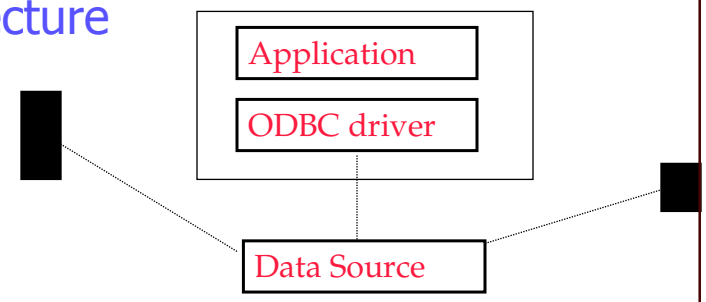
Cursors

- **Can declare a cursor on a relation or query**
- **Can *open* a cursor**
- **Can repeatedly *fetch* a tuple (moving the cursor)**
- **Special return value when all tuples have been retrieved.**
- **ORDER BY allows control over the order in which tuples are returned.**
  - Fields in ORDER BY clause must also appear in SELECT clause.
- **Can also modify/delete tuple pointed to by a cursor**
  - A "non-relational" way to get a handle to a particular tuple
- **There's an Embedded SQL syntax for cursors**
  - DECLARE <cursorname> CURSOR FOR <select stmt>
  - FETCH FROM <cursorname> INTO <variable names>
  - But we'll use JDBC instead

Database APIs: Alternative to embedding

- **Rather than modify compiler, add a library with database calls (API)**
  - special procedures/objects
  - passes SQL strings from language, presents result sets in a language-friendly way
  - *ODBC* a C/C++ standard started on Windows
  - *JDBC* a Java equivalent
  - Most scripting languages have similar things
    - E.g. For Perl there is DBI, "oraPerl", other packages
- **Mostly DBMS-neutral**
  - at least try to hide distinctions across different DBMSs

Architecture



- A lookup service maps "data source names" ("DSNs") to drivers
  - Typically handled by OS
- Based on the DSN used, a "driver" is linked into the app at runtime
- The driver traps calls, translates them into DBMS-specific code
- Database can be across a network
- ODBC is standard, so the same program can be used (in principle) to access multiple database systems
- Data source may not even be an SQL database!

ODBC/JDBC

- **Various vendors provide drivers**
  - MS bundles a bunch into Windows
  - Vendors like DataDirect and OpenLink sell drivers for multiple OSes
- **Drivers for various data sources**
  - Relational DBMSs (Oracle, DB2, SQL Server, Informix, etc.)
  - "Desktop" DBMSs (Access, Dbase, Paradox, FoxPro, etc.)
  - Spreadsheets (MS Excel, Lotus 1-2-3, etc.)
  - Delimited text files (.CSV, .TXT, etc.)
- **You can use JDBC/ODBC *client*s over many data sources**
  - E.g. MS Query comes with many versions of MS Office (msqry32.exe)
- **Can write your own Java or C++ programs against xDBC**

JDBC

- **Part of Java, very easy to use**
- **Java comes with a JDBC-to-ODBC bridge**
  - So JDBC code can talk to any ODBC data source
  - E.g. look in your Windows Control Panel for JDBC/ODBC drivers!
- **JDBC tutorial online**
  - http://developer.java.sun.com/developer/Books/JDBCTutorial/

JDBC Basics: Connections

- **A Connection is an object representing a login to a database**

```
// GET CONNECTION
Connection con;
try {
    con = DriverManager.getConnection(
         "jdbc:odbc:sailorsDB",
         userName,password);
} catch(Exception e){ System.out.println(e);  }
```

- **Eventually you close the connection**

```
// CLOSE CONNECTION
try { con.close(); }
catch (Exception e) { System.out.println(e); }
```

JDBC Basics: Statements

- **You need a Statement object for each SQL statement**

```
// CREATE STATEMENT
Statement stmt;
try {
   stmt = con.createStatement();
} catch (Exception e){
   System.out.println(e);
}
```

Soon we'll say stmt.executeQuery("select …");

CreateStatement cursor behavior

- **Two optional args to createStatement:**
  - `createStatement(ResultSet.<TYPE>, ResultSet.<CONCUR>)`
  - Corresponds to SQL cursor features
- **<TYPE> is one of**
  - TYPE_FORWARD_ONLY: can't move cursor backward
  - TYPE_SCROLL_INSENSITIVE: can move backward, but doesn't show results of any updates
  - TYPE_SCROLL_SENSITIVE: can move backward, will show updates made while result set is open
- **<CONCUR> is one of**
  - CONCUR_READ_ONLY: this statement doesn't allow updates
  - CONCUR_UPDATABLE: this statement allows updates
- **Defaults:**
  - TYPE_FORWARD_ONLY and CONCUR_READ_ONLY

JDBC Basics: ResultSet

- **A ResultSet object serves as a *cursor* for the statement's results (stmt.executeQuery())**

```
// EXECUTE QUERY
ResultSet results;
try {
    results = stmt.executeQuery(
           "select * from Sailors")
} catch (Exception e){
    System.out.println(e);  }
```

- **Obvious handy methods:**
  - results.next() advances cursor to next tuple
    - Returns "false" when the cursor slides off the table (beginning or end)
  - "scrollable" cursors:
    - results.previous(), results.relative(int), results.absolute(int), results.first(), results.last(), results.beforeFirst(), results.afterLast()

ResultSet Metadata

- **Can find out stuff about the ResultSet schema via ResultSetMetaData**

```
ResultSetMetaData rsmd = results.getMetaData();
int numCols = rsmd.getColumnCount();
int i, rowcount = 0;

// get column header info
for (i=1; i <= numCols; i++){
    if (i > 1) buf.append(",");
    buf.append(rsmd.getColumnLabel(i));
}
buf.append("\n");
```

- **Other ResultSetMetaData methods:**
  - getColumnType(i), isNullable(i), etc.

Getting Values in Current of Cursor

- **getString**

```
// break it off at 100 rows max
   while (results.next() && rowcount < 100){
       // Loop through each column, getting the
       // column data and displaying

       for (i=1; i <= numCols; i++) {
           if (i > 1) buf.append(",");
           buf.append(results.getString(i));
       }
       buf.append("\n");
       rowcount++;
   }
```

- **Similarly, getFloat, getInt, etc.**

Updating Current of Cursor

- **Update fields in current of cursor:**

```
result.next();
result.updateInt("Rating", 10);
```

- **Also updateString, updateFloat, etc.**
- **Or can always submit a full SQL UPDATE statement**
  - Via executeQuery()
- **The original statement must have been CONCUR_UPDATABLE in either case!**

Cleaning up Neatly

```
try {
  // CLOSE RESULT SET
  results.close();
  // CLOSE STATEMENT
  stmt.close();
  // CLOSE CONNECTION
  con.close();
} catch (Exception e) {
    System.out.println(e);
}
```

Putting it Together (w/o try/catch)

```
Connection con =
   DriverManager.getConnection("jdbc:odbc:weblog",userNa
   me,password);
Statement stmt = con.createStatement();
ResultSet results =
    stmt.executeQuery("select * from Sailors")
ResultSetMetaData rsmd = results.getMetaData();
int numCols = rsmd.getColumnCount(), i;
StringBuffer buf = new StringBuffer();

while (results.next() && rowcount < 100){
  for (i=1; i <= numCols; i++) {
     if (i > 1) buf.append(",");
     buf.append(results.getString(i));
  }
  buf.append("\n");
}
results.close(); stmt.close();  con.close();
```

Similar deal for web scripting languages

- **Common scenario today is to have a web client**
  - A web form issues a query to the DB
  - Results formatted as HTML
- **Many web scripting languages used**
  - jsp, asp, PHP, etc.
  - most of these are similar, look a lot like JDBC with HTML mixed in

E.g. PHP/Postgres

```
<?php   $conn = pg_pconnect("dbname=cowbook user=jmh\
                    password=secret");
 if (!$conn) {
   echo "An error occured.\n";
   exit;
 }
 $result = pg_query ($conn, "SELECT * FROM Sailors");
 if (!$result) {
   echo "An error occured.\n";  exit;
 }
 $num = pg_num_rows($result);
 for ($i=0; $i < $num; $i++) {
   $r = pg_fetch_row($result, $i);
   for ($j=0; $j < count($r); $j++) {
          echo "$r[$j] ";
   }
   echo "<BR>";
 }
?>
```

API Summary

APIs are needed to interface DBMSs to programming languages

- Embedded SQL uses "native drivers" and is usually faster but less standard
- ODBC (used to be Microsoft-specific) for C/C++
- JDBC the standard for Java
- Scripting languages (PHP, Perl, JSP) are becoming the preferred technique for web-based systems