

Database Application Development

Computer Science Department
Columbia University

Overview

Concepts covered in this lecture:

- ❖ SQL in application code
- ❖ Embedded SQL
- ❖ Cursors
- ❖ Dynamic SQL
- ❖ JDBC
- ❖ SQLJ
- ❖ Stored procedures

SQL in Application Code

- ❖ SQL commands can be called from within a host language (e.g., C++ or Java) program.
 - SQL statements can refer to **host variables** (including special variables used to return status).
 - Must include a statement to *connect* to the right database.
- ❖ Two main integration approaches:
 - Embed SQL in the host language (Embedded SQL, SQLJ)
 - Create special API to call SQL commands (JDBC)

SQL in Application Code (Contd.)

Impedance mismatch:

- ❖ SQL relations are (multi-) sets of records, with no *a priori* bound on the number of records. No such data structure exist traditionally in procedural programming languages such as C++. (Though now: STL)
 - SQL supports a mechanism called a cursor to handle this.

Embedded SQL

- ❖ Approach: Embed SQL in the host language.
 - A preprocessor converts the SQL statements into special API calls.
 - Then a regular compiler is used to compile the code.

- ❖ Language constructs:
 - Connecting to a database:
`EXEC SQL CONNECT`
 - Declaring variables:
`EXEC SQL BEGIN (END) DECLARE SECTION`
 - Statements:
`EXEC SQL Statement;`

Embedded SQL: Variables

```
EXEC SQL BEGIN DECLARE SECTION
```

```
char c_sname[20];
```

```
long c_sid;
```

```
short c_rating;
```

```
float c_age;
```

```
EXEC SQL END DECLARE SECTION
```

❖ Two special “error” variables:

- `SQLCODE` (long, is negative if an error has occurred)
- `SQLSTATE` (char[6], predefined codes for common errors)

EXEC SQL <statement>

EXEC SQL SELECT

SELECT S.sname, S.age INTO :c_sname, :c_age

FROM Sailors S

WHERE S.sid = :c_sid;

This gets into the C variables the values of a single tuple.

Cursors

- ❖ Can declare a cursor on a relation or query statement (which generates a relation).
- ❖ Can *open* a cursor, and repeatedly *fetch* a tuple then *move* the cursor, until all tuples have been retrieved.
 - Can use a special clause, called **ORDER BY [ASC | DESC]**, in queries that are accessed through a cursor, to control the order in which tuples are returned.
 - Fields in ORDER BY clause must also appear in SELECT clause.
 - The **ORDER BY** clause, which orders answer tuples, is *only* allowed in the context of a cursor.
- ❖ Can also modify/delete tuple pointed to by a cursor.

Cursor that gets names of sailors who've reserved a red boat, in alphabetical order

```
EXEC SQL DECLARE sinfo CURSOR FOR  
  SELECT S.sname  
  FROM Sailors S, Boats B, Reserves R  
  WHERE S.sid=R.sid AND R.bid=B.bid AND B.color='red'  
  ORDER BY S.sname
```

- ❖ Note that it is illegal to replace *S.sname* by, say, *S.sid* in the ORDER BY clause!
- ❖ Can we add *S.sid* to the SELECT clause and replace *S.sname* by *S.sid* in the ORDER BY clause?

Embedding SQL in C: An Example

```
char SQLSTATE[6];  
EXEC SQL BEGIN DECLARE SECTION  
char c_sname[20]; short c_minrating; float c_age;  
EXEC SQL END DECLARE SECTION  
c_minrating = random();  
EXEC SQL DECLARE sinfo CURSOR FOR  
    SELECT S.sname, S.age    FROM Sailors S  
    WHERE S.rating > :c_minrating  
    ORDER BY S.sname;  
do {  
    EXEC SQL FETCH sinfo INTO :c_sname, :c_age;  
    printf("%s is %d years old\n", c_sname, c_age);  
} while (SQLSTATE != '02000');  
EXEC SQL CLOSE sinfo;
```

Dynamic SQL

- ❖ SQL query strings are now always known at compile time (e.g., spreadsheet, graphical DBMS frontend):
Allow construction of SQL statements on-the-fly

- ❖ Example:

```
char c_sqlstring[]=
    {"DELETE FROM Sailors WHERE rating>5"};
EXEC SQL PREPARE readytogo FROM :c_sqlstring;
EXEC SQL EXECUTE readytogo;
```

Database APIs: Alternative to embedding

Rather than modify compiler, add library with database calls (API)

- ❖ Special standardized interface: procedures/objects
- ❖ Pass SQL strings from language, presents result sets in a language-friendly way
- ❖ Sun's *JDBC*: Java API
- ❖ Supposedly DBMS-neutral
 - a “driver” traps the calls and translates them into DBMS-specific code
 - database can be across a network

JDBC: Architecture

❖ Four architectural components:

- Application (initiates and terminates connections, submits SQL statements)
- Driver manager (load JDBC driver)
- Driver (connects to data source, transmits requests and returns/translates results and error codes)
- Data source (processes SQL statements)

JDBC Classes and Interfaces

Steps to submit a database query:

1. Load the JDBC driver
2. Connect to the data source
3. Execute SQL statements

JDBC Driver Management

- ❖ All drivers are managed by the DriverManager class
- ❖ Loading a JDBC driver:
 - In the Java code:
`Class.forName("oracle/jdbc.driver.OracleDriver");`
 - When starting the Java application:
`-Djdbc.drivers=oracle/jdbc.driver`

Connections in JDBC

We interact with a data source through sessions. Each connection identifies a logical session.

❖ JDBC URL:

`jdbc:<subprotocol>:<otherParameters>`

Example:

```
String url="jdbc:oracle:www.bookstore.com:3083";
```

```
Connection con;
```

```
try{
```

```
    con = DriverManager.getConnection(url,userId,password);
```

```
} catch SQLException excpt { ...}
```


Executing SQL Statements

- ❖ Three different ways of executing SQL statements:
 - Statement (both static and dynamic SQL statements)
 - PreparedStatement (semi-static SQL statements)
 - CallableStatement (stored procedures)

- ❖ PreparedStatement class:
Precompiled, parametrized SQL statements:
 - Structure is fixed
 - Values of parameters are determined at run-time

Executing SQL Statements (Contd.)

```
String sql="INSERT INTO Sailors VALUES(?,?,?,?)";  
PreparedStatement pstmt=con.prepareStatement(sql);  
pstmt.clearParameters();  
pstmt.setInt(1,sid);  
pstmt.setString(2,sname);  
pstmt.setInt(3, rating);  
pstmt.setFloat(4,age);  
  
// we know that no rows are returned, thus we use  
    executeUpdate()  
int numRows = pstmt.executeUpdate();
```

ResultSet

- ❖ `PreparedStatement.executeUpdate` only returns the number of affected records
- ❖ `PreparedStatement.executeQuery` returns data, encapsulated in a `ResultSet` object (a cursor)

```
ResultSet rs=pstmt.executeQuery(sql);  
// rs is now a cursor  
While (rs.next()) {  
    // process the data  
}
```

ResultSet (Contd.)

A ResultSet is a very powerful cursor:

- ❖ `previous()`: moves one row back
- ❖ `absolute(int num)`: moves to the row with the specified number
- ❖ `relative (int num)`: moves forward or backward
- ❖ `first()` and `last()`

Matching Java and SQL Data Types

SQL Type	Java class	ResultSet get method
BIT	Boolean	getBoolean()
CHAR	String	getString()
VARCHAR	String	getString()
DOUBLE	Double	getDouble()
FLOAT	Double	getDouble()
INTEGER	Integer	getInt()
REAL	Double	getFloat()
DATE	java.sql.Date	getDate()
TIME	java.sql.Time	getTime()
TIMESTAMP	java.sql.TimeStamp	getTimestamp()

A (Semi-)Complete Example

```
Connection con = // connect
    DriverManager.getConnection(url, "login", "pass");
Statement stmt = con.createStatement(); // set up stmt
String query = "SELECT name, rating FROM Sailors";
ResultSet rs = stmt.executeQuery(query);
try { // handle exceptions
    // loop through result tuples
    while (rs.next()) {
        String s = rs.getString("name");
        Int n = rs.getFloat("rating");
        System.out.println(s + " " + n);
    }
} catch(SQLException ex) {
    System.out.println(ex.getMessage ()
        + ex.getSQLState () + ex.getErrorCode ());
}
```

SQLJ

Complements JDBC with a (semi-)static query model:
Compiler can perform syntax checks, strong type checks, consistency of the query with the schema

- All arguments always bound to the same variable:

```
#sql = {  
    SELECT name, rating INTO :name, :rating  
    FROM Books WHERE sid = :sid;
```

- Compare to JDBC:

```
sid=rs.getInt(1);  
if (sid==1) {sname=rs.getString(2);}  
else { sname2=rs.getString(2);}
```

❖ SQLJ (part of the SQL standard) versus embedded SQL (vendor-specific)

Stored Procedures

- ❖ What is a stored procedure:
 - Program executed through a single SQL statement
 - Executed in the process space of the server
- ❖ Advantages:
 - Can encapsulate application logic while staying “close” to the data
 - Reuse of application logic by different users
 - Avoid tuple-at-a-time return of records through cursors

Stored Procedures: Examples

```
CREATE PROCEDURE ShowNumReservations
  SELECT S.sid, S.sname, COUNT(*)
  FROM Sailors S, Reserves R
  WHERE S.sid = R.sid
  GROUP BY S.sid, S.sname
```

- ❖ Stored procedures can have parameters with mode IN, OUT, INOUT
- ❖ They do not have to be written in SQL

```
CREATE PROCEDURE IncreaseRating(
  IN sailor_sid INTEGER, IN increase INTEGER)
UPDATE Sailors
  SET rating = rating + increase
  WHERE sid = sailor_sid
```

SQL/PSM

Most DBMSs allow users to write stored procedures in a simple, general-purpose language (close to SQL) → SQL/PSM standard is a representative

Declare a stored procedure:

```
CREATE PROCEDURE name(p1, p2, ..., pn)  
    local variable declarations  
    procedure code;
```

Declare a function:

```
CREATE FUNCTION name (p1, ..., pn) RETURNS  
    sqlDataType  
    local variable declarations  
    function code;
```

Summary

- ❖ Embedded SQL allows execution of parametrized static queries within a host language
- ❖ Dynamic SQL allows execution of completely ad-hoc queries within a host language
- ❖ Cursor mechanism allows retrieval of one record at a time and bridges impedance mismatch between host language and SQL
- ❖ APIs such as JDBC introduce a layer of abstraction between application and DBMS

Summary (Contd.)

- ❖ SQLJ: Static model, queries checked at compile-time.
- ❖ Stored procedures execute application logic directly at the server
- ❖ SQL/PSM standard for writing stored procedures