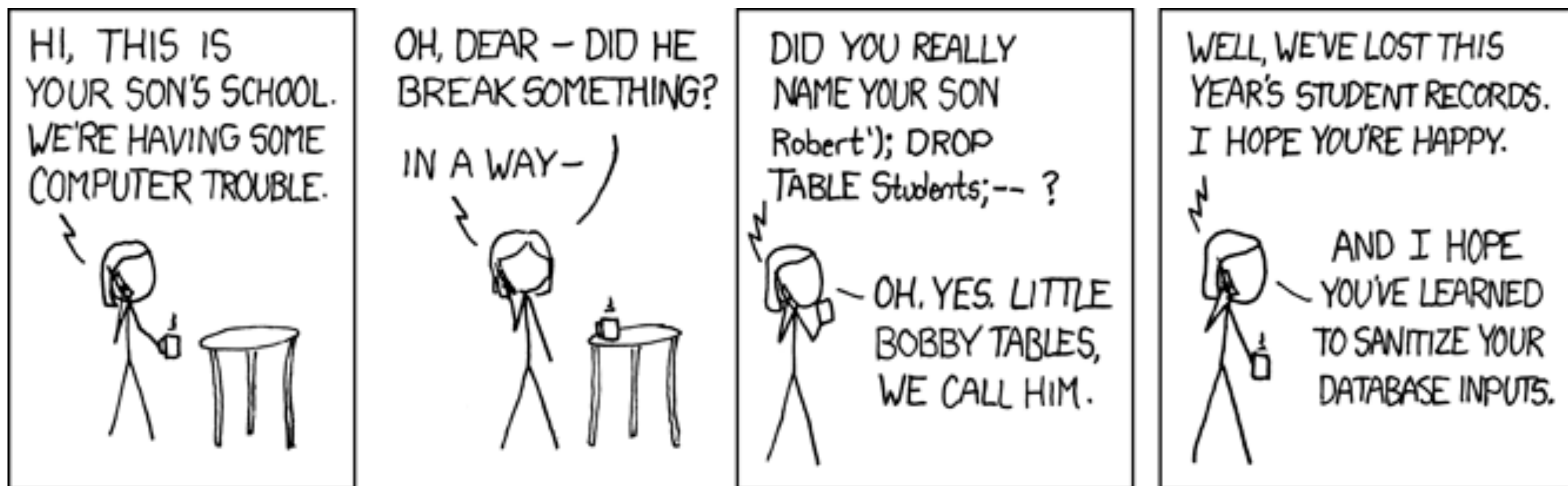
Database Application Development
Part 2 - Chapter 6.3-6.7



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Alternative Approach

- Abstract Database interface layer
- Better dynamic integration into host language
- Somewhat Independent of DBMS
  - Database engine need not even understand SQL
  - Depends on a “Driver” layer to translate generic commands into a DBMS-specific call.
- Two “Network Library” efforts
  - ODBC (Open Database Connectivity)
  - JDBC (Jave DataBase Connectivity)
- We’ ll examine JDBC

JDBC: Architecture

- Four architectural components:
  - *Application* (initiates and terminates connections, submits SQL statements)
  - *Driver Manager* (JDBC initialization, loads JDBC drivers dynamically, delegates calls from the application to the appropriate driver, provides status and logs)
  - *Driver* (connects to data source, transmits requests and returns/translates results and error codes)
  - *Data Sources* (processes SQL statements)

Drivers are like Translators

- Drivers are analogous to translators at the UN
- Person who speaks language X want to communicate with a person who speaks language Y
- Different strategies
  - Hire a translator for every X-Y combination (expensive)
  - Translate X to a Universal language, U, and then translate U to language Y (only needs as many translators as there are languages)
  - Hybrids (Service bureaus provide translators as needed)

Four Driver Types

Bridge:

- Translates SQL commands into non-native API. Example: JDBC-ODBC bridge. Code for ODBC and JDBC driver needs to be available on each client.

Direct translation to native API, non-Java driver:

- Translates SQL commands to native API of data source. Need OS-specific binary on each client.

Network bridge:

- Send commands over the network to a middleware server that talks to the data source. Needs only small JDBC driver at each client.

Direction translation to native API via Java driver:

- Converts JDBC calls directly to network protocol used by DBMS. Needs DBMS-specific Java driver at each client.

What lives where

Application Layer – you write Java here…

JDBC Manager – java.sql.*

JDBC-ODBC Bridge (Type I)	JDBC-Native API (Type II)	JDBC-Network (Type III)	JDBC-Native Protocol (Type IV)
ODBC Driver (*libodbc.so*)	Native Driver (*libdb2jcct2.so*)	Native Driver (*IBM DRDA*)	

Database (almost always on its own server)

JDBC Classes and Interfaces

Steps to submit a database query:

- Load the JDBC driver
- Connect to the data source
- Execute SQL statements

- Part of "`import java.sql.*`" package

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:

```
java -Djdbc.drivers=oracle/jdbc.driver appName
```

Connections in JDBC

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

- JDBC URL:
  jdbc:<subprotocol>:<otherParameters>

<u>Example:</u>

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

Connection con;

try {
   con = DriverManager.getConnection(url,userId,password);
} catch SQLException excpt { …}
```

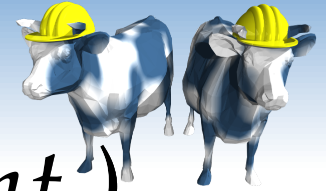
Connection Class Interface

- public boolean getAutoCommit() and
  void setAutoCommit(boolean b)
  If autocommit is set, then each SQL statement is considered its own transaction. Otherwise, a transaction is committed using commit(), or aborted using rollback().
- public int getTransactionIsolation() and
  void setTransactionIsolation(int level)
  Gets/Sets isolation level for the current connection.
- public boolean getReadOnly() and
  void setReadOnly(boolean b)
  Specifies if transactions in this connection are read-only
- public boolean isClosed()
  Checks whether connection is still open.

Executing SQL Statements

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

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



Executing SQL Statements (Cont.)

```
String sql="INSERT INTO Sailors VALUES(?,?,?,?)";
PreparedStatment pstmt=con.prepareStatement(sql);

// instantiate parameters with values
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();
```

ResultSets

- PreparedStatement.executeUpdate returns the number of records modified by the statement
- PreparedStatement.executeQuery returns data, encapsulated in a ResultSet object (a cursor)
- PreparedStatement.execute returns boolean true if at least one ResultSet object is created.

```
ResultSet cursor=pstmt.executeQuery(sql);

while (cursor.next()) {
    // process the data
}
```

ResultSets (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 (positive ints) or backward (negative ints)
- first() and last()

Retrieving Query Results

- Type-specific Accessor methods allow us to retrive the query results
- Two forms
  - By column index
  - By column name

```
ResultSet cursor=pstmt.executeQuery(sql);

while (cursor.next()) {
    sailorname = cursor.getString(2)
    rating = cursor.getFloat(“rating”)
}
```

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()

Examining Database Metadata

DatabaseMetaData object gives information about the database system and the catalog.

```
DatabaseMetaData md = con.getMetaData();
// print information about the driver:
System.out.println(
  "Name:" + md.getDriverName() +
  "version: " + md.getDriverVersion());
```

Database Metadata (Contd.)

```
DatabaseMetaData md=con.getMetaData();
ResultSet trs=md.getTables(null,null,null,null);
String tableName;
While(trs.next()) {
    tableName = trs.getString("TABLE_NAME");
    System.out.println("Table: " + tableName);
    //print all attributes
    ResultSet crs = md.getColumns(null,null,tableName, null);
    while (crs.next()) {
        System.out.println(crs.getString("COLUMN_NAME" + ", ");
    }
}
```

A More Complete Example

```
import java.sql.*;

/**
 * This is a sample program with jdbc odbc  Driver
 **/
public class localdemo {

  public static void main(String[] args) {
    try {
      // Register JDBC/ODBC Driver in jdbc DriverManager
      // On some platforms with some java VMs,
      // newInstance() is necessary...
      Class.forName("sun.jdbc.odbc.JdbcOdbcDriver").newInstance();

      // Test with MS Access database (sailors ODBC data source)
      String url = "jdbc:odbc:mysailors";

      java.sql.Connection c = DriverManager.getConnection(url);
```

A More Complete Example (cont)

```
            String query = "select * from Sailors”;
            java.sql.Statement st = c.createStatement();
            java.sql.ResultSet rs = st.executeQuery(query);

            java.sql.ResultSetMetaData md = rs.getMetaData();
            while(rs.next()) {
              System.out.print("\nTUPLE: | ");
              for(int i=1; i<= md.getColumnCount(); i++) {
                System.out.print(rs.getString(i) + " | ");
              }
            }
            rs.close();
          } catch(Exception e) {
            e.printStackTrace();
          }
        }
    };
```

So, who is Little Bobby Tables?

- When we last saw Bobby's Mom, she had named her son Robert'); DROP TABLE Students; --
- This wasn't very nice of her. *At all*.
- This is a classic SQL Injection Attack

SQL Injection Attacks

Consider this code:

```
String query = "select id_num from
  students where name = ‘” +
  userInputName + “’”;

      java.sql.Statement st =
  c.createStatement();

      java.sql.ResultSet rs =
  st.executeQuery(query);
```

SQL Injection (2)

"Normal Execution" – user enters "Bob":

```
String query = "select id_num from
  students where name = '" +
  userInputName + "'"
```

Query starts as:

```
select id_num from students where name = '
```

Then:

```
select id_num from students where name = 'Bob
```

Then:

```
select id_num from students where name = 'Bob'
```

And finally we execute that string. Cool.

SQL Injection (3)

Instead, user enters *Robert'); DROP TABLE Students; --*

Query starts as:

```
select id_num from students where name = ‘
```

Then:

```
select id_num from students where name =
   ‘Robert’) ; DROP TABLE Students; --
```

Then:

```
select id_num from students where name =
   ‘Robert’) ; DROP TABLE Students; --’
```

And finally we execute that tampered-with string. Not cool.

SQL Injection (4)

What Happens?

It’s actually three queries, separated by semicolons.

1. **A legitimate query:**

```
select id_num from students where name =
   ‘Robert’)
```

2. Some (at best) mischief:

```
DROP TABLE Students
```

3. And a harmless comment to burn off the excess quotation mark:

```
--’
```

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 x = {
    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)

SQLJ Code

```
Int sid;
String name;
Int rating;
// named iterator
#sql iterator Sailors(Int sid, String name);
Sailors sailors;
rating = 7;
// assume that the application sets rating
#sailors = {
    SELECT sid, sname INTO :sid, :name
    FROM Sailors WHERE rating = :rating
};

// retrieve results
while (sailors.next()) {
    System.out.println(sailors.sid + " " + sailors.sname));
}
sailors.close();
```

SQLJ Iterators

Two types of iterators ("cursors"):

- Named iterator
  - Need both variable type and name, and then allows retrieval of columns by name.
  - See example on previous slide.
- Positional iterator
  - Needs only variable type; uses FETCH .. INTO construct:

```
#sql iterator Sailors(Int, String, Int);
Sailors sailors;
#sailors = …
while (true) {
    #sql {FETCH :sailors INTO :sid, :name} ;
    if (sailors.endFetch()) { break; }
    // process the sailor
}
```

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:

- Three different modes: IN, OUT, INOUT

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

Stored Procedure Languages

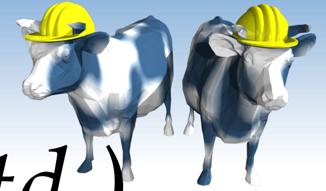
Stored procedures don't have to be written in SQL:

```
CREATE PROCEDURE TopSailors(IN num INTEGER)
LANGUAGE JAVA
EXTERNAL NAME "file:///c:/storedProcs/rank.jar"
```

Calling Stored Procedures

```
EXEC SQL BEGIN DECLARE SECTION
Int sid;
Int rating;
EXEC SQL END DECLARE SECTION

// now increase the rating of this sailor
EXEC CALL IncreaseRating(:sid,:rating);
```



Calling Stored Procedures (Contd.)

JDBC:

```
CallableStatement cstmt=
   con.prepareCall("{call
   ShowSailors});
ResultSet rs =
   cstmt.executeQuery();
while (rs.next()) {
    …
}
```

SQLJ:

```
#sql iterator ShowSailors(…);
ShowSailors showsailors;
#sql showsailors={CALL
   ShowSailors};
while (showsailors.next()) {
    …
}
```

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:

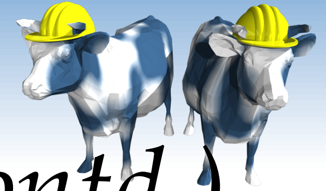
```
CREATE PROCEDURE name(p1, p2, …, pn)
    local variable declarations
    procedure code;
```

Declare a function:

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

Simple SQL/PSM Example

```
CREATE FUNCTION rateSailor(IN sailorId INTEGER)
      RETURNS INTEGER
DECLARE rating INTEGER
DECLARE numRes INTEGER
SET numRes = (SELECT COUNT(*)
              FROM Reserves R
              WHERE R.sid=sailorId)
IF (numRes > 10) THEN rating=1;
ELSE rating=0;
END IF;
RETURN rating;
```



Main SQL/PSM Constructs (Contd.)

- Local variables (DECLARE)
- RETURN values for FUNCTION
- Assign variables with SET
- Branches and loops:
  - IF (condition) THEN statements;
    ELSEIF (condition) statements;
    … ELSE statements; END IF;
  - LOOP statements; END LOOP
- Queries can be parts of expressions
- Can use cursors naturally without "EXEC SQL"

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 a compile-time.
- Stored procedures execute application logic directly at the server

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