Database Programming Approaches

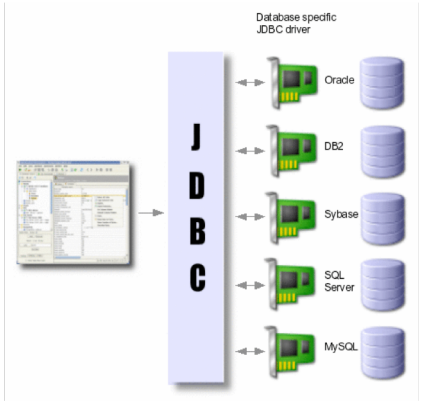
- Embedded commands:
  - Database commands are **embedded** in a general-purpose programming language
- Library of database functions:
  - Available to the host language for database calls; known as an **API** (Application Program Interface)
  - *e.g., JDBC, ODBC, PHP*
- A brand new, full-fledged language
  - e.g., Oracle PL/SQL
  - **P**rocedural **L**anguage extensions to SQL

JDBC: An example of SQL API

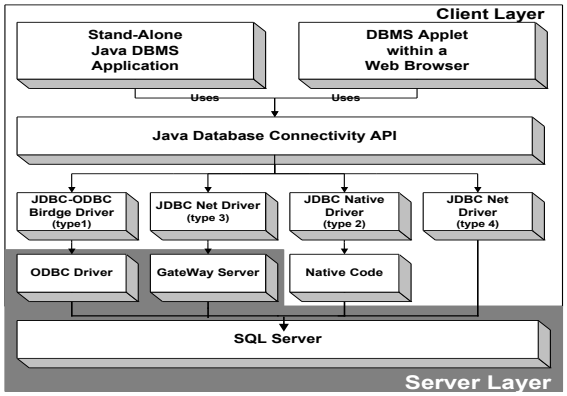
- JDBC resembles dynamic SQL, in which SQL statements are passed in the form of strings
- JDBC supports its own dialect of SQL
- An application program (Java applet) executes an SQL statement by submitting it to the JDBC driver manager
- Any database using can be accessed as long as an appropriate DBMS-specific driver exists, is loaded, and is registered with the driver manager:

```
import java.sql.*;
Class.forName("jdbc.driver_name");
```


JDBC Configuration



JDBC Drivers



JDBC Drivers

- Type 1: JDBC-ODBC bridge.
  This driver translates JDBC calls into ODBC calls.
- Type 2: JDBC-Gateway.
  This pure Java driver connects to a database middleware server that in turn interconnects multiple databases and performs any necessary translations.
- Type 3:
  Java JDBC Native Code. This partial Java driver converts JDBC calls into client API for the DBMS.
- Type 4:
  Pure Java JDBC. This driver connects directly to the DBMS.

Useful Links

- JDBC DRIVER
  - https://jdbc.postgresql.org/download.html
- JDBC API
  - https://docs.oracle.com/javase/8/docs/technotes/guides/jdbc/

Accessing a Database

- Open Connection:

```
Connection dbcon;
dbcon=
    DriverManager.getConnection(<"URL">,<"userId">,<"pwd">);
```

- E.g.,

```
import java.sql.*;
public class JavaDemo  {
private Connection dbcon;  private String username = "PittID", password = "PSNum";
  public JavaDemo() {
   DriverManager.registerDriver (new oracle.jdbc.driver.OracleDriver());
   String url = "jdbc:oracle:thin:@class3.cs.pitt.edu:1521:dbclass";
  dbcon = DriverManager.getConnection(url, username, password);
  …
```

- Close connection: dbcon.close();

Executing an SQL Statement

- Statement class: Execute SQL statements without parameters
  - Create statement object

```
Statement st;
 st = dbcon.createStatement();
```

  - Directly execute: Select, Update, Insert, Delete, DDL

```
st.executeQuery(<"sql-query">);
st.executeUpdate(<"sql-modification">);
```

- Example of an SQL modification

```
int numberrows = st.executeUpdate
("INSERT INTO STUDENT VALUES (123, 'J.J. Kay', 'CS' )");
```

  - Table can be prefixed by its schema, e.g., cs1555.STUDENT

Querying a database & Cursors

```
String fname = readString("Enter First Name: ");
String query1 = "SELECT SID, Name, Major FROM  STUDENT
                 WHERE Name  LIKE  '" + fname + "  '"   ;
ResultSet res1 = st.executeQuery(query1);
int rsid; String rname, rmajor;
while (res1.next()) {
    rsid = res1.get Int("SID");
    rname = res1.getString("Name");
    rmajor = res1.getString(3);
    if wasNULL {
      System.out.print(rsid+" "+rname+" NULL"); }
    else { System.out.print(rsid+" "+rname+" "+rmajor); }
};
```

getXXX(param)
XXX: valid SQL Type
param: name or index

wasNULL() returns True if the last getXXX() value should be read as NULL

JDBC Example in PostgreSQL

```
package edu.pitt.cs;

import java.util.Properties;
import java.sql.*;

public class JavaDemo {
   public static void main(String args[]) throws
         SQLException, ClassNotFoundException {
      Class.forName("org.postgresql.Driver");
      String url = "jdbc:postgresql://localhost/postgres";
      Properties props = new Properties();
      props.setProperty("user", "postgres");
      props.setProperty("password", "password");
      Connection conn =
            DriverManager.getConnection(url, props);
```


JDBC Example in PostgreSQL

```
Statement st = conn.createStatement();
String query1 = "SELECT SID, Name, Major FROM
          CS1555.STUDENT WHERE Major='CS'";
ResultSet res1 = st.executeQuery(query1);
int rid; String rname, rmajor;
while (res1.next()) {
   rid = res1.getInt("SID");
   rname = res1.getString("Name");
   rmajor = res1.getString(3);
   if wasNULL(){
      System.out.println(rid + " " + rname + " " + "NULL");
   } else {
      System.out.println(rid + " " + rname + " " + rmajor);
   }
 }
}}
```


Moving Cursors

```
Statement stC = dbcon.createStatemen
                (ResultSet.TYPE_SCROLL_INSENSITIVE,
                 ResultSet.CONCUR_READ_ONLY);
ResultSet resultSet = stC.executeQuery("SELECT * FROM STUDENT");

int pos = resultSet.getRow();          // Get cursor position, pos =  0
boolean b = resultSet.isBeforeFirst(); // true

resultSet.next();                      // Move cursor to the first row
pos = resultSet.getRow();              // Get cursor position, pos = 1
b = resultSet.isFirst();               // true

resultSet.last();                      // Move cursor to the last row
pos = resultSet.getRow();              // If table has 10 rows, pos = 10
b = resultSet.isLast();                // true

resultSet.afterLast();                 // Move cursor past last row
pos = resultSet.getRow();              // If table has 10 rows, value would be 11
b = resultSet.isAfterLast();           // true
```

Cursor Navigation Types

- Statement stC = dbcon.createStatement ({ResultSet.TYPE_XXXX});
- TYPE_XXXX
  - TYPE_FORWARD_ONLY: ResultSet can only be navigated forward.
  - SCROLL_INSENSITIVE: ResultSet can be navigated forward, backwards and jump. Concurrent db changes are not visible.
  - SCROLL_SENSITIVE: ResultSet can be navigated forward, backwards and jump. Concurrent db changes are visible.

Cursor Concurrency Types

- Statement stC = dbcon.createStatement (ResultSet.TYPE_XXXX);
- TYPE_XXXX
  - CONCUR_READ_ONLY: ResultSet can only be read
  - CONCUR_UPDATABLE: ResultSet can be updated

The PreparedStatement Class

- Create and pre-compile parameterized queries using parameters markers, indicated by question marks (?)

```
PreparedStatement st2 = dbcon.prepareStatement
    ( "SELECT * FROM STUDENT WHERE Name LIKE ?");
```

- Specify the values of parameters using *setXXX(i,v)* where XXX: SQL type in including NULL,
  i: argument-index,
  v: value

```
String fname = readString("Enter First Name: ");
st2.setString(1, fname);
ResultSet res2 = st2.executeQuery();
```


Error Handling

- JDBC provides the SQLException class to deal with errors

```
try { ResultSet res3 =
    st.executeQuery("SELECT * FROM STUDENT"); }
catch (SQLException e1) {
    System.out.println("SQL Error");
    while (e1 != null) {
    System.out.println("Message = "+ e1.getMessage());
    System.out.println("SQLState = "+ e1.getSQLstate());
    System.out.println("SQLState = "+ e1.getErrorCode());
    e1 = e1.getNextException();
  }; };
```

Error Handling

- JDBC provides the SQLException class to deal with errors

```
try { ResultSet res3 =
     st.executeQuery("SELECT * FROM STUDENT"); }
 catch (SQLException e1) {
      System.out.println("SQL Error");
       while (e1 != null) {
       System.out.println("Message = "+ e1.toString());
       System.out.println("SQLState = "+ e1.getSQLstate());
       System.out.println("SQLState = "+ e1.getErrorCode());
       e1 = e1.getNextException();
      }; };
```


Executing Transactions

- Each JDBC statement is treated as a separate transaction that is autocommitted by default

  dbcon.setAutoCommit(false);

- A new transaction automatically is set after either

  dbcon.commit; or dbcon.rollback;

- Set Constraint Mode

  ResultSet res1 = st.executeQuery("SET CONSTRAINTS ALL DEFERRED");

- Five transaction isolation levels (to be discussed later)
  - setTransactionIsolation(int level);
- No global transactions, transactions across many db
  - No atomicity or "all or nothing property"

Not Deferred Constraints

- Transaction atomicity is enforced in a flexible way by the developer (with the support of the DBMS), e.g.:

```
try {
      dbcon.setAutoCommit(false);
     st.executeUpdate("insert into student values (23, 'John', 'CS')");
     st.executeUpdate("insert into Dept values (15, 'Joanne', 'CoE')");
     dbcon.commit();
  }
  catch (SQLException e1) {
     try {
       dbcon.rollback();
         }
      catch(SQLException e2) { System.out.println(e2.toString()); }
  }
```


Querying the Catalog & Native SQL

- Metadata about about results

  ResultSet res3 = st.executeQuery("SELECT * FROM STUDENT");

  ResultSetMetaData resmetadata = res3.getMetaData();

  int num_columns = resmetadata.getColumnCount();

  string column_name = resmetadata.getColumnName(3);

- Metadata about database

  DatabaseMetaData dbmd = dbcon.getMetaData();

- Native SQL

  nativeSQL(String sql);
  - Converts SQL stmt into the system's native SQL grammar

SQL injection vulnerabilities

- Allow an attacker to inject (or execute) SQL commands within an application
- Typical example:

```
Connection dbcon  = db.getConnection( );
String sql = "SELECT * FROM user  WHERE
      username= '" + username  +"' and password='" + password + "'";
Statement stmt = dbcon.createStatement();
int rs = stmt.executeQuery(sql);
if (rs.next())  { loggedIn = true; out.println("Successfully logged in"); }
   else { out.println("Username and/or password not recognized"); }
```


What is the problem?

- Accepting user input without performing adequate input validation or escaping meta-characters
- String sql = "SELECT * FROM user WHERE
  username= '" + username +"' and password='" + password + "'";
- Example inputs:

  admin' (for username)
  '1' OR '1'='1. (for password)
- Result:

```
SELECT * FROM user
WHERE username='admin' and password='1' OR '1'='1' ;
```

- Effect: ?

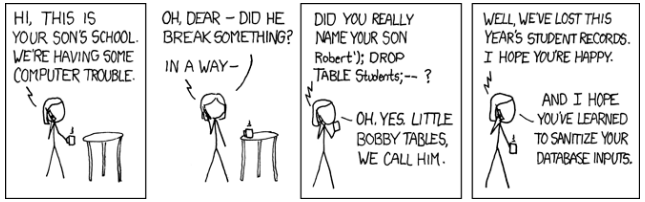
What is the problem?

- String sql = "SELECT * FROM user WHERE
  username= '" + username +"' and password='" + password + "'";
- Example inputs:

  panos'
  password = '3113'; DELETE FROM user WHERE '1
- Result:

```
SELECT * FROM user
WHERE username='panos' and password='3113';
DELETE FROM user WHERE '1';
```

- Effect: ?



Avoiding SQL Injection

- In the same way attackers can inject other SQL commands
  - extract, update or delete data within the database
- Solution: Good programming practice; use prepareStatement()
  - All queries should be parameterized
  - All dynamic data should be explicitly bound to parameterized queries
  - String concatenation should never be used to create dynamic SQL (in general)
- Example:

```
PreparedStatement st3 = dbcon.prepareStatement
 ( "SELECT * FROM user  WHERE  username= ? AND password = ?");
```


Fix SQL Injection

```
Connection dbcon =
      DriverManager.getConnection(url, props);
String username = "admin";
String password = "1' OR '1'='1";
PreparedStatement st = dbcon.prepareStatement(
      "SELECT * FROM users WHERE username=? AND password=?");
st.setString(1, username);
st.setString(2, password);
ResultSet rs = st.executeQuery();
if (rs.next()) {
  loggedIn = true;
  System.out.println("Successfully logged in");
} else {
  System.out.println("Username / password not recognized");
}
```