Database Application Development

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Some of these slides are
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Outline

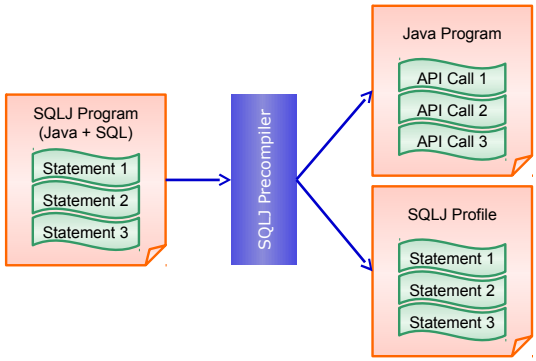
(1) Static SQL
- SQLJ

(2) Dynamic SQL
- JDBC

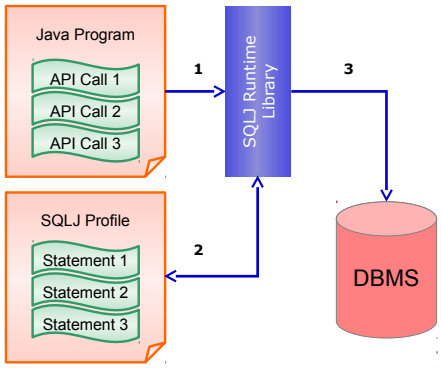
Overview: Static SQL

- General Idea: SQL directly embedded in programming language
  - *Precompiler* converts embedded SQL statements into calls to a special API
  - Then, regular compiler is used to compile the resulting code
- Example for Java: SQLJ

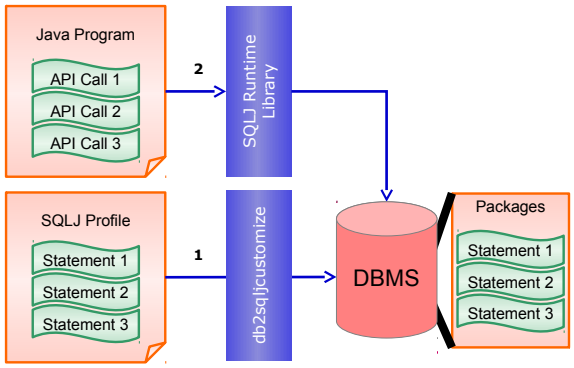
SQLJ Precompiling



SQLJ Execution



SQLJ Execution Using Packages



SQLJ Example

```
public void employee ( String empNo ) {

  String firstName = null;
  String lastName = null;
  ...

  // use the DB2 SAMPLE database
  String url = "jdbc:db2:SAMPLE";

  // Get the connection
  Connection con = DriverManager.getConnection(url);

  // Lookup the employee given the employee number
  // (precompiler will replace this code line)
  #sql { SELECT firstnme, lastnme INTO :fn, :ln
         FROM employee WHERE empno = :empNo } ;

  System.out.println( "Employee " + fn + "  " + ln );

  con.close();
}
```

SQLJ Example (cont'd)

```
public void listStudents( ... ) {

  ...

  // Define iterator
  #sql iterator StudentsIt ( String Name, int Year );

  // Create iterator object
  StudentsIt Stud;

  // Specify SQL query
  #sql Stud = { SELECT name, year FROM students
                WHERE year > 4 };

  // Iterate over the result to generate output
  while ( Stud.next() )
   System.out.println(Stud.Name() + ": " + Stud.Year());

  ...
}
```

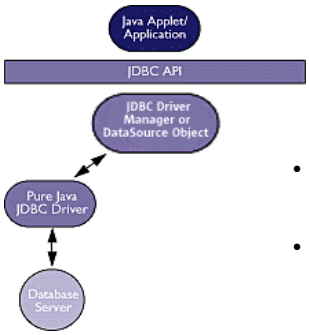
SQLJ Pros and Cons

- Advantages:
  - Straightforward approach for issuing SQL statements
  - SQLJ programs require less lines of code (easier to debug)
  - SQL statements can be validated at compile time
  - Query optimization at run time can be omitted (packages)
- Shortcomings:
  - Build process becomes more complex (due to precompiling)
  - Restricted to fixed, a-priori defined SQL statements
  - Optimizer may not use recent statistics (packages)

Overview: Dynamic SQL

- General Idea: Rather than modify the compiler, let the developer embed API calls in the program code
- Requires a special standardized interface
  - Pass strings that represent SQL statements
  - Present result sets in a language-friendly way
- Allows for generating SQL statements on the fly
- Example for Java: JDBC

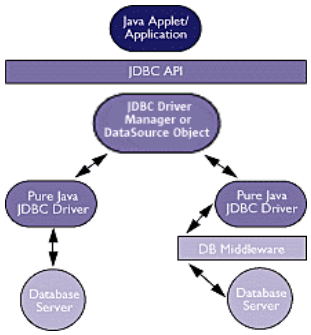
JDBC Architectural Components



Picture source: http://java.sun.com/products/jdbc/overview.html

- Application
  - Initiates and terminates connections to data sources
  - Submits SQL statements
- Data source (usually a DBMS)
  - Processes SQL statements
- Driver
  - Connects to data source
  - Transmits requests
  - Returns results and error codes
- Driver manager

Types of JDBC Drivers



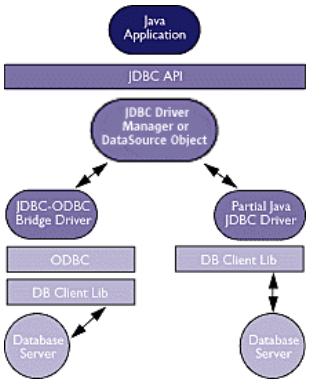
Type (1) Type (2)

Picture source: http://java.sun.com/products/jdbc/overview.html

(1) Direct Translation via Java Driver
- Converts JDBC calls directly to network protocol used by the DBMS
- Requires DBMS-specific JDBC driver at the client

(2) Network Bridge
- Send JDBC calls to a middleware server that talks to the data source
- Only small JDBC driver at the client

Types of JDBC Drivers (cont'd)



Type (3) Type (4)

(3) Bridge
- Translation of JDBC calls to a non-native API, usually ODBC
- Requires code for JDBC and ODBC at the client

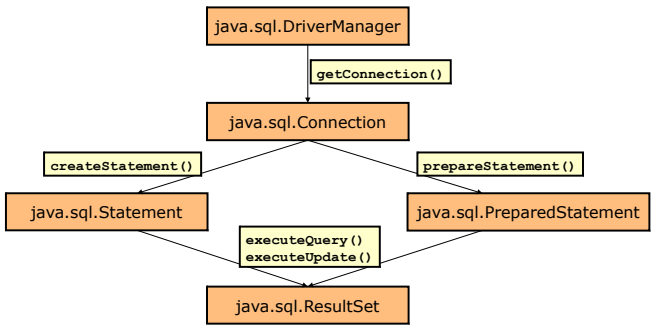
(4) Direct Translation via Non-Java Driver
- Converts JDBC calls to native API of data source

Picture source: http://java.sun.com/products/jdbc/overview.html

Using JDBC in an Application

1. Load and register JDBC driver
2. Connect to database via driver
3. Generate SQL statement
4. Submit SQL statement
5. Process result set
6. Close connection

Important JDBC Java Interfaces



The Driver Manager

- Singleton class (i.e., static methods only)
- Manages drivers
  - Loading and registering drivers via:
    `Class.forName( className ).newInstance();`
- Establishes connections via drivers
  - Call: `DriverManager.getConnection( url, … );`
  - URL: `jdbc:<sub-protocol>:<further parameters>`
  - Selects a driver based on the URL
  - Connects to the corresponding database
  - Result: a `Connection` object

JDBC Connection URLs

- General form:
  `jdbc:<sub-protocol>:<further parameters>`
- Example: Native JDBC driver for DB2 (Type 1)
  - URL: `jdbc:db2://<server>:<port>/<dbname>`
  - Default port: 50004
  - Class: `COM.ibm.db2.jcc.DB2Driver`
- Example: Type 4 driver for DB2
  - URL: `jdbc:db2:<dbname>`
  - Class: `COM.ibm.db2.jdbc.app.DB2Driver`

The Connection Interface

- Represents a logical session for interacting with a database
- Can be used to:
  - Set transaction specific options
  - Generate SQL statements (i.e., `Statement` objects)
  - Close the session (via the `close()` method)

The Statement Interface

- Represents a SQL statement that is meant to be executed
- Use the **`createStatement(...)`** method of a **`Connection`** object to create a **`Statement`** object
- Execution via **`executeQuery( String sql )`**
  - For SELECT statements; returns a **`ResultSet`** object
- Execution via **`executeUpdate( String sql )`**
  - For INSERT, UPDATE, DELETE, or DDL statements
- Execution via **`execute( String sql )`**
  - For any type of SQL statement; may return multiple result sets (use **`getResultSet()`** and **`getMoreResults()`**)
- Close via **`close()`**

Examples for the Statement Interface

```
Connection con = ...
Statement stmt = con.createStatement();
ResultSet rs = stmt.executeQuery("SELECT * FROM person");
```

```
Connection con = ...
Statement stmt = con.createStatement();
stmt.executeUpdate("DELETE FROM person WHERE id = 2");
```

```
Connection con = ...
Statement stmt = con.createStatement();
String s = "\'Smith\'";
ResultSet rs = stmt.executeQuery("SELECT * FROM person " +
                                 "WHERE name = " + s);
```

- What happens if: `String s = "\'Smith\' OR \'Jones\'";` ?
- And if `String s = "\'Smith\'; UPDATE USER SET TYPE = \'admin\' WHERE ID=23";` ?
- And if we use `stmt.execute("SELECT ...` ?

The PreparedStatement Interface

- Extends the **`Statement`** interface
- Create a **`PreparedStatement`** object via the **`prepareStatement(...)`** method of a **`Connection`** object
- The DBMS prepares such a statement for execution
- Prepared statements may contain *parameter makers:*
  - Represented by placeholder: ?
  - A value needs to be bound to each parameter prior to execution
- Prepared statements may be executed multiple times (with different bindings for the parameters)

Examples for Prepared Statements

```
Connection con = ...
Statement stmt = con.prepareStatement(
        "SELECT * FROM empl WHERE sal = ? AND name = ?" );
stmt.setInt( 1, 20000 );
stmt.setString( 2, "Smith" );
ResultSet rs = stmt.executeQuery();
```

```
Connection con = ...
PreparedStatement stmt = con.prepareStatement(
        "UPDATE empl SET address = ? WHERE address = ?" );
stmt.setString( 1, "103 Bridge St" );
stmt.setString( 2, "200 University Ave" );
stmt.executeUpdate();
stmt.setString( 2, "504 Bridge St" );
stmt.executeUpdate();
```

- `stmt.setString( 1, "103 Bridge St AND sal = 20000" );`

The ResultSet Interface

- Represents the result of a SQL query
- Using **`ResultSet`** objects is similar to using Java iterators
- Navigate to the next element of the result via **`next()`**
  - Initially, a **`ResultSet`** points *before* the first element
- Access values of the current result element via **`getInt(...)`**, **`getString(...)`**, etc.
  - Use name or number of the column as parameter (column numbering starts with 1)
  - Following a **`getXXX(...)`** call you may check for NULL via **`wasNull()`**
- Close via **`close()`**

Examples for Accessing Result Sets

```
Connection con = ...
Statement stmt = con.createStatement();
ResultSet rs = stmt.executeQuery(
                        "SELECT id, no FROM data" );
while ( rs.next() ) {
   System.out.println( rs.getString(1) );
   System.out.println( rs.getString(2) );
}
```

```
...
while ( rs.next() ) {
   System.out.println( rs.getString("id") );
   System.out.println( rs.getString("no") );
}
```

```
...
while ( rs.next() ) {
   System.out.println( rs.getInt("id") );
   System.out.println( rs.getInt("no") );
}
```

Metadata about Result Sets

- Represents by **`ResultSetMetaData`** objects
  - Can be obtained by calling method **`getMetaData()`** of the **`ResultSet`** object
- Methods:
  - **`getColumnCount()`**
  - **`getColumnName( int col )`**
  - **`isNullable( int col )`**
  - **`getColumnClassName( int col )`**
  - etc.

Exception Handling

- Almost all JDBC methods may throw a **`SQLException`**
- Handling those exceptions is important for building *robust* applications!

Complete JDBC Example

```
Connection con = null;
try {
   Class.forName("COM.ibm.db2.jdbc.app.DB2Driver").
                                              newInstance();
   con = DriverManager.getConnection("jdbc:db2:MyDB");
   PreparedStatement stmt = con.prepareStatement(
                  "SELECT name FROM person WHERE id = ?");
   stmt.setInt( 1, 25 );
   ResultSet rs = stmt.executeQuery();
   while ( rs.next() ) {
     System.out.println( rs.getString(1) );
   }
   rs.close();
   stmt.close();
}
catch (SQLException se) {
   System.out.println( "Error:" + se );
}                  // better: also catch ClassNotFoundException
finally {
   if ( con != null ) con.close();
}                  // better: wrap close by another try/catch
```


Transactions in JDBC

- By default, each SQL statement presents a separate transaction (auto commit)
- Disable auto commit to combine multiple statements into a single transaction
  - **`setAutoCommit( boolean ac )`**
  - Commit or abort such a transaction via **`commit()`** or **`rollback()`**

```
Connection con = ... ;
con.setAutoCommit( false );

... // execute statements

if ( everythingOK )
  con.commit();
else
  con.rollback();
```


JDBC Pros and Cons

- Advantages:
  - Allows for dynamically generated SQL statements
  - Easier for accessing multiple, heterogeneous DBMSs
- Shortcomings:
  - Validation of queries only at run time
  - Compiling and optimizing the same SQL query over and over again (can be avoided by using prepared statements)

Summary

- Static SQL:
  - SQL directly embedded in programming language
  - SQL statements in the code identified by prefix
  - 2-pass compilation required
  - Example for a Java extension: SQLJ
- Dynamic SQL:
  - SQL-based DB access via function calls
  - SQL statement strings generated at runtime
  - Uses access privileges of the application user
  - Example for a Java extension: JDBC