Java DataBase Connectivity

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Plan for Java DataBase Connectivity (JDBC)

- Motivation
- Architecture
- JDBC Classes and Interfaces
  - JDBC Driver Management
  - Controlling transaction behavior
- Executing SQL statements
- Obtaining result data
- Matching data types
- Exceptions
- Closing a connection

- *Further Reading: The Java™ Tutorial:*

`www.mcs.vuw.ac.nz/technical/java/tutorial/index.html`

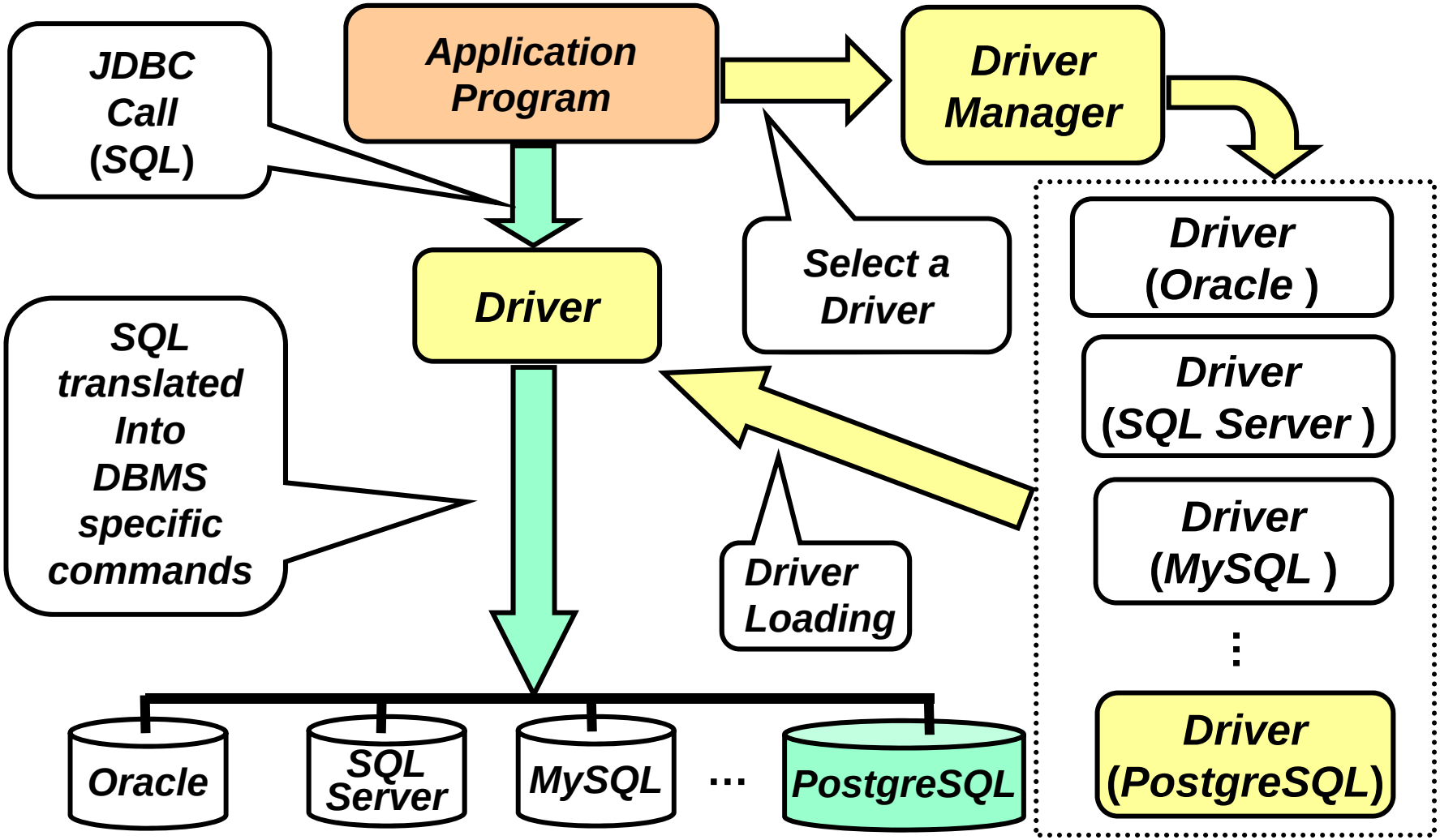
Motivation for Using JDBC

- In practice, databases are not only accessed by human users through the user interface, but also by application programs
- Application programs are written in a general purpose programming language (GPPL)
  - for example, Java, C/C++, Python, ...
- When developing applications, software engineers use SQL for data management from inside their application program
- The application program is written in a GPPL with SQL statement embedded into it
  - therefore, the GPPL is also called the 'host' language

The Java Database Connectivity (JDBC) API

- Java Database Connectivity (JDBC) is the standard application program interface (API) for accessing databases from a Java program
  - it allows us to embed SQL statements into Java code
- JDBC is supported by all relevant DBMS, including all major commercial and open source DBMS
  - Interactions of an application program with a specific DBMS are accomplished through a DBMS-specific JDBC driver
- Application programs using JDBC are independent of the particular DBMS that is used
  - Independence holds on source code & executable code level
  - Independence is a huge advantage when developing applications for multiple DMBS
  - Independence is achieved by an extra level of indirection

Accessing Databases from Application Programs



JDBC Architecture (1)

- When using JDBC the following play a role :
  - Application programs
  - A database system (DBMS plus databases)
  - A DBMS-specific JDBC driver
  - A driver manager

JDBC Architecture (2)

- Application programs ...
  - Dynamically load the JDBC drivers needed,
  - Initiate a connection with a database,
  - Set transaction boundaries (BEGIN,..., {COMMIT | ROLLBACK}),
  - Acquire locks,
  - Submit SQL statements,
  - Receive data,
  - Process data,
  - Process error messages,
  - Decide whether to commit or roll-back a transaction,
  - Disconnect from the database to terminate a session

JDBC Architecture (3)

- The DBMS ...
  - Processes data manipulation commands,
  - Returns results to the application program

- The JDBC driver ...
  - Establishes connection with a database,
  - Submits data manipulation requests,
  - Accepts results returned by the DBMS,
  - Translates DBMS specific data types into Java data types,
  - Translates error messages

- The driver manager ...
  - Loads and supervises available JDBC drivers for various DBMS
  - Calls JDBC drivers to connect to a database

JDBC Classes

- JDBC is a collection of Java classes and interfaces
  - All these are put together in the `java.sql` package

- It contains methods for:
  - Connecting to a remote database,
  - Executing SQL statements,
  - Iterating over a set of tuples from a SQL statement,
  - Transaction management,
  - Exception handling

JDBC DriverManager class

- JDBC provides the `DriverManager` class
- Among others, it defines methods to enable dynamic addition and deletion of JDBC drivers :
  - `registerDriver()`
  - `deregisterDriver()`

- The first step in connecting to a database (managed by some DBMS) is to load a suitable JDBC driver for that particular DBMS

- Any JDBC 4.0 drivers that are found in the class path are automatically loaded

Registering a JDBC Driver

- However, drivers prior to JDBC 4.0 must be loaded manually with the method `Class.forName`

  ```
  public static native Class.forName (String name)
  throws ClassNotFoundException
  ```

  - This creates a `Driver` object for the respective JDBC driver

- Example: to load a JDBC driver for PostgreSQL use
  - `Class.forName("org.postgresql.Driver");`

- If you are unsure which JDBC drivers will be available, load them manually

Establishing a Connection

- To connect to a database in a DBMS, the `getConnection` method of the `DriverManager` object is called
  - `Connection con = DriverManager.getConnection(url, [userId], [password]);`
  - This method requires a URL to the database

- In the application program, the method call starts a session with the database by creating a `Connection` object

Specifying the URL for the Connection

- The URL `url` to the database is of the form

  `jdbc:[drivertype]:[database]`

- Herein,
  - `jdbc` is a constant,
  - `[drivertype]` is the type of the database we want to connect (e.g. `postrgresql`), and
  - `[database]` is the address of the database in form

    `//hostname[:portnumber]/database_name`

- Example:
  - `jdbc:postgresql://db.ecs.vuw.ac.nz/007_jdbc`

Connection Interface

- The interface `java.sql.Connection` has a number of classes and methods that are used:
  - To control transactional behavior of a `Connection` object,
  - To create and execute SQL statements,
  - To iterate over the result returned by a DBMS, and
  - To finish interaction with a database by closing the connection

- After acquiring a connection (with the name say `con`) and before it is closed, the same connection can be used for executing several transactions

Controlling Transaction Behavior-Start

- By default, a Connection **automatically** commits changes after executing each SQL statement
- The method

```
public abstract void setAutoCommit(
boolean autoCommit) throws SQLException
```

  is applied onto a `Connection` object
- To designate the **start** of a transaction (BEGIN point), we assigne a value `false` to `autoCommit`

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

Controlling Transaction Behavior-End

- A transaction is terminated using:
  - Either

```
public abstract void commit() throws
SQLException
```

  or

```
public abstract void rollback() throws
SQLException
```

- And (after any of them)

```
con.setAutoCommit(true)
```

on the `Connection` object

What Next?

- Executing SQL statements
  - Statement object
  - PreparedStatement object
- Obtaining result data
- Matching data types
- Exceptions
- Closing a connection

Executing SQL Statements

- JDBC supports three different ways of executing SQL statements:
  - **`Statement`**,
  - **`PreparedStatement`**, and
  - `CollableStatement`

Statement Class and It's Subclasses

- The **`Statement`** class is the base class of the three classes used to submit queries to a DBMS
  - Its objects are used to send such SQL queries to a DBMS that are executed with no repetition within a transaction and that have no parameters

- **`PreparedStatement`** objects are used for SQL statements with parameters or for those that are executed multiple times (in a loop)
  - SQL statements of PreparedStatement objects may be precompiled yielding better performance

- `CollableStatement` objects are used with stored procedures and are out of the scope of the course

Submitting a SQL Query to a DBMS

- The following steps should be performed in order to submit a SQL statement to a DBMS either using a `Statement` (S) or `PreparedStatement` (PS) object:
  1. Define a SQL query as a string
  2. Create a S or PS object

  If the SQL statement is one of `CREATE`, `INSERT`, `DELETE`, `UPDATE`, or `SET` type:
  3. Apply **`executeUpdate()`** method onto the S or PS object

  Else (the SQL statement is of the **`SELECT`** type):
  3. Create a **`ResultSet`** object
  4. Feed into the `ResultSet` object the return value of applying **`executeQuery()`** method onto the S or PS object

Statement Objects With `executeUpdate`

```
String insert="INSERT INTO Grades " +
"VALUES (007007,'C305','A+')";

Statement stmt=con.createStatement();

int return_value =
stmt.exectuteUpdate(insert);
```

- For `INSERT`, `DELETE`, and `UPDATE` queries, the return value will be the number of tuples affected
- For `CREATE` or `SET`, the return value should be 0

ResultSet Object

- The `executeQuery()` method returns an object of the type set (or superset)
- This set object should be assigned to an object of the **`ResultSet`** class

- The `ResultSet` class has the `next()` method that allows traversing the set in a tuple at a time fashion
- Initially, the `ResultSet` object is positioned before the first tuple of the result
- The method `next()` returns `true` if there is a next tuple in the result, otherwise `false`
- After executing `next()`, the `ResultSet` object contains a pointer to the current tuple

Statement Objects With `executeQuery`

```
String select="SELECT * FROM Grades"
+ "WHERE StudentId=007007";

Statement stmt =
con.createStatement();

ResultSet rs =
stmt.exectuteQuery(select);

while (rs.next()){

// extracting data from rs tuples

// data processing

}
```

Extracting Data from the Result

- To match Java and database data types, JDBC specifies mappings and provides accessor methods in the `ResultSet` class

```
int j_studId;
String j_courseId;
String j_grade;
while (rs.next()){
j_studId=rs.getInt("StudentId");
j_courseId=rs.getString("CourseId");
j_grade=rs.getString(3)
// 3 is the column number in the result
}
```

PreparedStatement With executeUpdate

```
String insert="INSERT INTO Grades VALUES (?,?,?)";
PreparedStatement prstmt =
     con.prepareStatement(insert);
boolean end=false;
while(!end){
// suppose j_studId, j_courseId, j_grade, and end
are
// dynamically initialized to desired values
  prstmt.setInt(1, j_studId);
  prstmt.setString(2, j_courseId);
  prstmt.setString(3, j_grade);
  int return_value = prstmt.exectuteUpdate();
…
}
```

PreparedStatement with executeQuery

```
String select= "SELECT * FROM Grades
WHERE StudentId = ?";

PreparedStatement prstmt =
  con.prepareStatement(select);

// suppose j_studId is initialized on the

// desired value

prstmt.setInt(1, j_studId);

ResultSet rs =
prstmt.exectuteQuery();

while(rs.next()){

}
```

Closing a Connection

- Before exiting from an application program all connections acquired should be closed by applying

  ```
  public abstract void close() throws SQLException
  ```

  method on each of them

Exceptions

- Most of the methods in `java.sql` can throw an exception of the type `SQLException` if an error occurs
- In addition to inhereted `getMessage()` method, SQLException class has two additional methods for providing error information:
  - `public String getSQLState()` that returns an SQL state identifier according to SQL:1999 standard, and
  - `public int getErrorCode()` that retrieves a vendor specific error code
- Each JDBC method that throws an exception has to be placed inside a **`try`** block followed by a **`catch`** block

Code to See Exceptions

```
try{
/* Code that could generate an
                exception goes here. If an
          exception is generated, the
catch   block below will print out
   information about it*/
}
catch (SQLException ex){
  System.println(ex.getMessage());
  System.println(ex.getSQLState());
  System.println(ex.getErrorCode());
}
```

Summary

- JDBC Transactions are executed by:
  - Acquiring a Driver,
  - Constructing a connection object,
  - Establishing transaction boundaries
  - Submitting SQL statements,
  - Retrieving results,
  - Processing either results returned or exception errors,
  - Committing or roll-backing transactions, and
  - Disconnecting from databases to terminate interaction
- `Statement` objects - SQL statements have no parameters,
- `PreparedStatement` objects - SQL statements have parameters