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What is J DBC

- JDBC, often known as Java Database Connectivity, provides a Java API for updating and querying relational databases using Structured Query Language (SQL).
- JDBC is now at version 2.0, although many databases don’t as yet support all of the JDBC 2.0 features!
The 4 step approach to JDBC

- Every JDBC program is made up of the following 4 steps:
  - Open a connection to the DB
  - Execute a SQL statement
  - Process the result
  - Close the connection to the DB

We’ll look at each of the four steps in detail!
Example JDBC program

```java
import java.sql.*;

class SelectProducts {
    public static void main(java.lang.String[] args) {
        try {
            Class.forName( "COM.ibm.db2.jdbc.app.DB2Driver" );
            Connection con = DriverManager.getConnection( "jdbc:db2:TEST", "db2admin", " db2admin " );
            Statement statement = con.createStatement();
            ResultSet rs = statement.executeQuery("SELECT NAME, PRICE FROM PRODUCT");
            while ( rs.next() ) {
                String name = rs.getString( "NAME" );
                float price = rs.getFloat( "PRICE" );
                System.out.println("Name: "+name+, price: "+price);
            }
            statement.close();
            con.close();
        } catch( Exception e ) { e.printStackTrace(); } 
    }
}
```

1. open connection to DB
2. execute SQL statement
3. process result
4. close connection to DB
Opening a connection to the DB

- There are two parts to this:
  - loading a driver – we need a driver to allow our Java program to talk to the DB
  - opening the connection itself
Loading a driver

The first step in using JDBC is to load a driver. Here are some examples:

The IBM DB2 driver:

```java
Class.forName("COM.ibm.db2.jdbc.app.DB2Driver");
```

The SUN JDBC/ODBC Bridge driver:

```java
Class.forName("sun.jdbc.JdbcOdbcDriver");
```
There are 4 categories of driver

- **Type 1 JDBC-ODBC Bridge (Native Code)**
  - provides a Java bridge to ODBC
  - implemented in native code and requires some non-Java software on the client

- **Type 2 Native-API (Partly Java)**
  - uses native code to access the DB with a thin Java wrapper
  - can crash the JVM

- **Type 3 Net-protocol (All Java)**
  - defines a generic network protocol that interfaces with some middleware that accesses the DB

- **Type 4 Native-protocol (All Java)**
  - written entirely in Java
Type 1 JDBC-ODBC Bridge

- Provides a Java bridge to ODBC
- Implemented in native code and requires some non-Java software on the client
- Not a mandatory component of the JDK, and is not automatically supported by Java run-time environments
- Only recommended for light use
Type 2 Native API

- Converts JDBC commands into DBMS-specific native calls
- Implemented in native code and requires some non-Java software on the client
- Interfaces directly with the DB, so has performance advantages over Type 1
Type 3 J DBC-Net drivers

- A three tier solution
- Allows pure Java clients
- Can change DBMS without affecting the client

Java application

Type 3 J DBC driver

Middleware

J DBC Driver

SQL command → result set

proprietary protocol

most flexible

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Type 4 Native Protocol drivers

- Native Protocol drivers communicate directly with the DB.
- They convert JDBC commands directly into the DB’s native protocol.
- No additional transformation or middleware layers, therefore has high performance.

Java application

Type 4 Pure Java

SQL command using proprietary protocol

result set using proprietary protocol

best performance

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Making a connection

- Next, the driver must connect to the DBMS:

```java
Connection con = DriverManager.getConnection( "jdbc:db2:TEST", "db2admin", " db2admin " );
```

- The object `con` gives us an open database connection
Creating Statements

- A Statement object is used to send SQL statements to the DB
- First we get a Statement object from our DB connection con

```java
Statement statement = con.createStatement();
```
import java.sql.*;
class CreateProductTable
{
    public static void main(java.lang.String[ ] args)
    {
        try
        {
            Class.forName( "COM.ibm.db2.jdbc.app.DB2Driver" );
            String url = "jdbc:db2:TEST";
            Connection con = DriverManager.getConnection( url, "db2admin", "db2admin" );
            Statement statement = con.createStatement();
            String createProductTable = "CREATE TABLE PRODUCT " +
                "(NAME VARCHAR(64), " +
                "ID VARCHAR(32) NOT NULL, " +
                "PRICE FLOAT, " +
                "DESC VARCHAR(256), " +
                "PRIMARY KEY(ID))";
            statement.executeUpdate( createProductTable );
        } catch( Exception e ) { e.printStackTrace(); }
    }
}
executeUpdate(String sql)

- Use the executeUpdate() method of the Statement object to execute DDL and SQL commands that update a table (INSERT, UPDATE, DELETE):

```java
String createProductTable = "CREATE TABLE PRODUCT " +
  "(NAME VARCHAR(64), " +
  "ID VARCHAR(32) NOT NULL, " +
  "PRICE FLOAT, " +
  "DESC VARCHAR(256), " +
  "PRIMARY KEY(ID))";

statement.executeUpdate( createProductTable );
```

Be careful to always put spaces in the SQL string at the right places!
Example: inserting rows

```java
import java.sql.*;
class InsertProducts {
    public static void main(java.lang.String[] args) {
        try {
            Class.forName( "COM.ibm.db2.jdbc.app.DB2Driver" );
            String url = "jdbc:db2:TEST";
            Connection con = DriverManager.getConnection( url, "db2admin", "db2admin" );
            Statement statement = con.createStatement();
            statement.executeUpdate( "INSERT INTO PRODUCT " +
                "VALUES ( 'UML User Guide', " +
                "'0-201-57168-4', 47.99, 'The UML user guide')" );
            statement.executeUpdate( "INSERT INTO PRODUCT " +
                "VALUES ( 'Java Enterprise in a Nutshell', " +
                "'1-56592-483-5', 29.95, 'A good introduction to J2EE')" );
            con.close();
            statement.close();
        } catch( Exception e ) { e.printStackTrace(); }
    }
}
```
executeQuery(String sql)

- We use the executeQuery(…) method of the Statement object to execute a SQL statement that returns a single ResultSet:

```
11 ResultSet rs = statement.executeQuery("SELECT NAME, PRICE FROM PRODUCT");
```

- Typically, the SQL statement is a SQL SELECT
- executeQuery(…) always returns a ResultSet, never null. However, the ResultSet may be empty
Example: selecting rows

```java
import java.sql.*;

class SelectProducts {
    public static void main(java.lang.String[] args) {
        try {
            Class.forName( "COM.ibm.db2.jdbc.app.DB2Driver" );
            Connection con = DriverManager.getConnection( "jdbc:db2:TEST", "db2admin", " db2admin " );
            Statement statement = con.createStatement();
            ResultSet rs = statement.executeQuery("SELECT NAME, PRICE FROM PRODUCT");
            while ( rs.next() ) {
                String name = rs.getString( "NAME" );
                float price = rs.getFloat( "PRICE" );
                System.out.println("Name: "+name+", price: "+price);
            }
            statement.close();
            con.close();
        } catch( Exception e ) { e.printStackTrace(); }
    }
}
```
ResultSet

- ResultSet objects provide access to a table
  - usually they provide access to the pseudo table that is the result of a SQL query
- ResultSet objects maintain a cursor pointing to the current row of data
  - this cursor initially points before the first row and is moved to the first row by the next() method

```java
ResultSet rs = statement.executeQuery("SELECT NAME, PRICE FROM PRODUCT");
while ( rs.next( ) )
    {
        String name = rs.getString( "NAME" );
        float price = rs.getFloat( "PRICE" );
        System.out.println("Name: "+name+", price: "+price);
    }
```
Types of ResultSet

Statement statement = con.createStatement( type, concurrency);

- Depending on the parameters passed into the Connection.createStatement(…) method, we can get a total of 6 different types of ResultSet returned!
- Passing no arguments to createStatement() gives a default forward-only read-only ResultSet
- We’ll look at the possible values for type and concurrency next…
<table>
<thead>
<tr>
<th>type</th>
<th>semantics</th>
</tr>
</thead>
<tbody>
<tr>
<td>ResultSet.TYPE_SCROLL_SENSITIVE</td>
<td>Scrollable. Reflects changes made to the underlying data</td>
</tr>
<tr>
<td>ResultSet.TYPE_SCROLL_INSENSITIVE</td>
<td>Scrollable. Does <em>not</em> reflect changes made to the underlying data</td>
</tr>
<tr>
<td>ResultSet.TYPE_FORWARD_ONLY</td>
<td>Not scrollable. Does <em>not</em> reflect changes made to the underlying data</td>
</tr>
</tbody>
</table>

N.B. Scrollable means that we can navigate forwards *and* backwards through the ResultSet
### concurrency

<table>
<thead>
<tr>
<th>concurrency =</th>
<th>semantics</th>
</tr>
</thead>
<tbody>
<tr>
<td>ResultSet.CONCUR_READ_ONLY</td>
<td>the <strong>Resultset</strong> <em>may not</em> be updated</td>
</tr>
<tr>
<td>ResultSet.CONCUR_UPDATABLE</td>
<td>the <strong>Resultset</strong> <em>may</em> be updated</td>
</tr>
</tbody>
</table>
getXXX(…) methods

The ResultSet has a wide range of methods to return SQL types such as VARCHAR as equivalent Java types.

For example `rs.getString("NAME")` returns the product name as a String.

- In fact, we can get any of the SQL types with `getString(…)` and it will automatically be converted to a String.

The getXXX(…) methods can take a column name or the number of the column.

- Column numbers start at 1 and go from left to right.

See notes!
## ResultSet navigation methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Semantics</th>
</tr>
</thead>
<tbody>
<tr>
<td>first()</td>
<td>Moves cursor to first row</td>
</tr>
<tr>
<td>last()</td>
<td>Moves cursor to last row</td>
</tr>
<tr>
<td>next()</td>
<td>Moves cursor to next row</td>
</tr>
<tr>
<td>previous()</td>
<td>Moves cursor to previous row</td>
</tr>
<tr>
<td>beforeFirst()</td>
<td>Moves cursor to just before the first row</td>
</tr>
<tr>
<td>afterLast()</td>
<td>Moves cursor to just after the last row</td>
</tr>
<tr>
<td>absolute(int)</td>
<td>Moves cursor to a row index. If positive – counting from the front, if negative – from the back</td>
</tr>
<tr>
<td>relative(int)</td>
<td>Moves cursor a relative number of rows, positive or negative from the current position</td>
</tr>
</tbody>
</table>
Working with ResultSets

- We can limit the number of rows that a ResultSet can contain by using:

  ```java
  Statement statement = con.createStatement();
  statement.setMaxRows(100);
  ```

- If a Statement returns multiple ResultSets, then we can move to the next ResultSet as follows:

  ```java
  while ( statement.getMoreResults() )
  {
    rs = statement.getResultset();
    ...
  }
  ```
Updateable ResultSet

- If the statement is created to be of type ResultSet.CONCUR_UPDATABLE, then we may be able to update the database by modifying the ResultSet itself.
  - This may not be supported by all DBMSs as it is not a mandatory requirement for JDBC 2.0 compatibility.
**updateXXX(…)** methods

- Like the getXXX(…) methods, the ResultSet has a wide range of updateXXX(…) methods to change the value of SQL types in the ResultSet.

- For example `rs.updateString("PRICE", 40.0F)` changes the price of a product.
  - We have to be very careful that all the types in an update expression match.

- The updateXXX(…) methods can take a column name or the number of the column.
  - Column numbers start at 1 and go from left to right.
Updating a row

- This is a three step procedure:
  - navigate to the appropriate row using a SELECT and ResultSet navigation methods
  - update the field values in the ResultSet
  - write the change back to the DB

```java
rs.first();
rs.updateFloat("PRICE", 40.0F);
rs.updateRow();
```
Inserting a row

This is a three step procedure:

- navigate to insert row
- update the field values in the ResultSet
- write the row to the DB

```java
rs.moveToInsertRow();
rs.updateString("NAME", "UML Distilled");
rs.updateString("ID", "0-201-32563-2");
rs.updateFloat("PRICE", 40.0F);
rs.insertRow();
```
Deleting a row

- This is a simple two step procedure:
  - navigate to row to be deleted
  - delete the row

```
rs.last();
rs.deleteRow();
```
Prepared statements

- If we want to execute the same SQL statement several times, we can create a PreparedStatement object:
  - at the point of creation of a PreparedStatement object the SQL code is sent to the DB and compiled. Subsequent executions may therefore be more efficient than normal statements
  - PreparedStatements can take parameters
import java.sql.*;

class PreparedStatementTest {
    public static void main(java.lang.String[] args) {
        try {
            Class.forName( "COM.ibm.db2.jdbc.app.DB2Driver" );
            Connection con = DriverManager.getConnection( "jdbc:db2:TEST", "db2admin", "db2admin" );
            PreparedStatement findBooks = con.prepareStatement("SELECT NAME FROM PRODUCT WHERE NAME LIKE ?");
            findBooks.setString( 1, "%Java%" );
            ResultSet rs = findBooks.executeQuery();
            while ( rs.next() ) { System.out.println( "Name: "+ rs.getString( "NAME" ) ); }
            findBooks.setString( 1, "%UML%" );
            rs = findBooks.executeQuery();
            while ( rs.next() ) { System.out.println( "Name: "+ rs.getString( "NAME" ) ); }
            findBooks.close();
            con.close();
        } catch( Exception e ) { e.printStackTrace(); }
    }
}
Transactions

- Normally each SQL statement will be committed automatically when it has completed executing (auto commit is *on*).
- A group of statements can be committed together by turning auto commit *off*, and explicitly committing the statements ourselves.
- This ensures that if *any* of the statements fail, they *all* fail. We can then *roll back* the transaction.
JDBC transaction modes

```
con.setTransactionIsolation( mode )
```

- **TRANSACTION_NONE**
  - transactions are disabled or not supported

- **TRANSACTION_READ_UNCOMMITTED**
  - other transactions may see the results *before* the transaction is committed
  - “dirty read” - uncommitted rows might be rolled back if the transaction fails.

- **TRANSACTION_READ_COMMITTED**
  - dirty reads are not allowed.

- **TRANSACTION_REPEATABLE_READ**
  - if a transaction performs multiple reads on a row that is being changed by another transaction, then it does not see the changes

- **TRANSACTION_SERIALIZABLE**
  - same as TRANSACTION_REPEATABLE_READ but also protects against row insertions
  - if a transaction does a read, another transaction inserts a row, and the first transaction does another read, the first transaction does *not* see the new row.
import java.sql.*;

class TransactionTest
{
    public static void main(java.lang.String[ ] args)
    {
        try
        {
            Class.forName( "COM.ibm.db2.jdbc.app.DB2Driver" );
            String url = "jdbc:db2:TEST";
            Connection con = DriverManager.getConnection( url, "db2admin", "db2admin" );
            Statement s = con.createStatement();
            try
            {
                con.setAutoCommit( false );
                s.executeUpdate("UPDATE PRODUCT SET PRICE = 40.00 WHERE ID = '0-201-57168-4' ");
                s.executeUpdate("UPDATE REVIEW SET COMMENT = 'Now on sale!' WHERE BOOKID = '0-201-57168-4' ");
                con.commit();
            } catch( SQLException e ) { con.rollback(); }
            finally{ con.close(); s.close(); }
            catch( Exception e ){ e.printStackTrace(); }
        }
    }
}
Batch updates

- JDBC 1.0 was very inefficient for loading a lot of data into a DB - a separate SQL command had to be executed for each record changed.
- JDBC 2.0 allows batch updates:
  - multiple statements can be executed as a single batch
  - we can roll back the whole batch if a single statement fails.
- We simply add statements to be batched to a Statement or PreparedStatement object using addBatch()!
- We can remove the statements using clearBatch()!
import java.sql.*;

class BatchInsertProducts
{
    public static void main(java.lang.String[] args) throws SQLException, ClassNotFoundException
    {
        Class.forName( "COM.ibm.db2.jdbc.app.DB2Driver" );
        String url = "jdbc:db2:TEST";
        Connection con = DriverManager.getConnection( url, "db2admin", "db2admin" );
        Statement s = con.createStatement();
        try
        {
            con.setAutoCommit( false );
            s.addBatch("INSERT INTO PRODUCT " + "VALUES ( 'The Object Constraint Language', " +
            "'0-201-37940-4', 29.95, 'All about constraints')" );
            s.addBatch("INSERT INTO PRODUCT " + "VALUES ( 'The Rational Unified Process', " +
            "'0-201-60459-0', 29.95, 'A good introduction to RUP')" );
            int[] count = s.executeBatch();
            con.commit();
        }catch( SQLException e ) { con.rollback( ); }
        finally{ con.close( ); s.close( ); }
    }
}
Stored procedures

- The syntax for defining a stored procedure is different for each DBMS
  - use the stored procedure tools that come with the RDBMS

- The syntax for calling a stored procedure is different for each DBMS
  - JDBC defines a special *escape sequence syntax* that allows stored procedures to be called in the same way on any RDBMS
Escape sequences

{?= call <procedure-name>(<arg1>,<arg2>, ...)}
{call <procedure-name>(<arg1>,<arg2>, ...)}

- The ? represents a return value
- <procedure-name> is the name of the stored procedure
- <arg1> etc. are the arguments passed into and out of the stored procedure
import java.sql.*;

class StoredProcedureExample
{
    public static void main(java.lang.String[] args)
    {
        try
        {
            Class.forName( "COM.ibm.db2.jdbc.app.DB2Driver" );
            Connection con = DriverManager.getConnection( "jdbc:db2:TEST", "db2admin", "db2admin" );
            CallableStatement cs = con.prepareCall("call DB2ADMIN.ALLPRODUCTS");
            cs.execute();
            ResultSet rs = cs.getResultSet();
            while ( rs.next() )
            {
                String name = rs.getString( "NAME" );
                float price = rs.getFloat( "PRICE" );
                System.out.println( "Name: "+name+, price: "+price);
            }
            con.close();
            cs.close();
        }
        catch( Exception e ){ e.printStackTrace(); }
    }
}
Using input parameters

```java
import java.sql.*;

class StoredProcedureParameterExample
{
    public static void main(java.lang.String[ ] args)
    {
        try
        {
            Class.forName( "COM.ibm.db2.jdbc.app.DB2Driver" );
            Connection con = DriverManager.getConnection( "jdbc:db2:TEST", "db2admin", "db2admin" );
            CallableStatement cs = con.prepareCall("{call DB2ADMIN.FINDPROD2(?)}");
            cs.setString( 1, "%UML%" );
            cs.execute();
            ResultSet rs = cs.getResultSet();
            while ( rs.next() )
            {
                String name = rs.getString( "NAME" );
                float price = rs.getFloat( "PRICE" );
                System.out.println("Name: "+name+, price: "+price);
            }
            con.close();
            cs.close();
        }catch( Exception e ){ e.printStackTrace(); }
    }
}
```

we specify a single parameter

set the parameter value
Metadata

- JDBC has facilities to get information about a ResultSet or DB
  - for a ResultSet, this information may include the number and names of the columns, the types of the columns etc.
  - for a DB this information may include the name of the driver, the DB URL etc.
- This information about a ResultSet or DB is known as metadata
- See the following classes for details:
  - ResultSet – see ResultSetMetadata
  - Database – see DatabaseMetadata
Getting metadata

- Getting database metadata:

  ```java
  Connection con = DriverManager.getConnection( "jdbc:db2:TEST", "db2admin", "db2admin" );
  DatabaseMetaData dmd = con.getMetaData( );
  ```

- Getting ResultSet metadata:

  ```java
  Statement statement = con.createStatement();
  ResultSet rs = statement.executeQuery("SELECT NAME, PRICE FROM PRODUCT");
  ResultSetMetaData rsmd = rs.getMetaData( );
  ```
Summary

- We have looked at:
  - 4 step approach to JDBC
    - Connection
    - drivers
  - Statement
    - PreparedStatement
    - batch update
    - transactions
    - CallableStatement (stored procedures)
  - ResultSet handling
  - Metadata
Appendix: IBM DB2 (v6)
Installing the JDBC 2.0 driver

- To install JDBC 2.0:
  - go to the directory sqllib\java12
  - run the command usejdbc2

- To switch back to 1.2.2:
  - go to the directory sqllib\java12
  - run the command usejdbc1