Introduction to Java Database Connectivity API

CSCE 156 - Introduction to Computer Science II

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Java Database Connectivity API

Java Database Connectivity (JDBC)

- General API (using interfaces) for Java client code to connect/interact with a database
- Database providers (IBM, Oracle, etc.) provide *drivers*
- Driver: specific implementation of the API for interacting with a particular database
- Support for
  - `Connection`
  - `PreparedStatement`
  - `ResultSet`
  - Common Java data types (`Integer, Double, String`)

JDBC: basic step-by-step

1. Load the database JDBC driver
   Note: your particular driver (.jar file) must be in the class or build path of your project
2. Make a connection to the database
3. Formulate your query(ies) & prepare your statement (set parameters)
4. Execute your query
5. If its a `SELECT` query:
   5.1 Get your *result set*
   5.2 Process your results
6. Clean up your resources (close resources, close connection)

JDBC

Reflectively loading a driver

- For portability, applications written toward JDBC API, not a particular driver
- Driver is loaded at run time through reflection
- Could be made configurable or delegated by some controller

```
1  try {
2      Class.forName("com.mysql.jdbc.Driver").newInstance();
3  } catch (InstantiationException e) {
4      ...
5  } catch (IllegalAccessException e) {
6      ...
7  } catch (ClassNotFoundException e) {
8      ...
9  }
```

JDBC

Connection

Java provides connectivity through `java.sql.Connection`:

```
1  String url = "jdbc:mysql://cse.unl.edu/cselogin";
2  String u = "cselogin";
3  String p = "mysqlpasswd";
4  Connection conn = null;
5  try {
6    conn = DriverManager.getConnection(url, u, p);
7  } catch (SQLException sqle) {
8    ...
9  }
```

JDBC

Transactions

- By default, all queries are auto-commit
- To change this, use `conn.setAutoCommit(false)`
- No changes committed until `conn.commit()` is called
- Implicitly: new transaction after each commit
- Able to explicitly rollback using `conn.rollback()`
- Some drivers may also support `conn.setReadOnly(true)`

JDBC I

Querying – Prepared Statement

- Always good to use `PreparedStatement`
- Can define *parameters* using `?`
- Parameters indexed by `1..n`
- Can be reused (parameters reset and required)
- Parameters are *safe*!
- Special characters are *escaped*
- Potentially unsafe SQL code is *sanitized*

JDBC II

Querying – Prepared Statement

```
1  String query = "SELECT last_name AS lastName " +
2                 "FROM user WHERE nuid = ?";
3  PreparedStatement ps = null;
4  try {
5    ps = conn.prepareStatement(query);
6    ps.setString(1, "35140602");
7  } catch (SQLException sqle) {
8    ...
9  }
```

JDBC I

Querying – Result Sets

- `executeQuery()` is for read-only (select statements)
- Select statements return *results*: columns and rows
- Results are encapsulated in a Java `ResultSet` object
- Initially a result set "points" just before the first *row*
- Iterating through a `ResultSet`: `rs.next()`
- Returns a boolean: true if the iteration was successful, false otherwise
- If successful, the "current" result row is now pointed to
- Columns can be referenced by name (or alias) using a `String` or
- Columns can be accessed via index $(1, \ldots,)$
- Standard getters provide functionality to get-and-cast columns

JDBC II

Querying – Result Sets

```
1  ResultSet rs = null;
2  try {
3    rs = ps.executeQuery();
4    while(rs.next()) {
5      Integer nuid = rs.getInt("nuid")
6      String firstName = rs.getString("firstName");
7    }
8  } catch (SQLException sqle) {
9    ...
10 }
```

JDBC

Querying – Updates

- *Always* use a prepared statement!
- Same syntax holds for INSERT statements

```
1  String query = "UPDATE user SET email = ?, " +
2                 "last_updated = ? WHERE nuid = ?";
3  PreparedStatement ps = null;
4  try {
5    ps = conn.prepareStatement(query);
6    ps.setString(1, "cmbourke@gmail.com");
7    ps.setString(2, "2011-01-01 00:00:01");
8    ps.setString(3, "35140602");
9    ps.executeUpdate();
10 } catch (SQLException sqle) {
11   ...
12 }
```

JDBC

Good Practices – Rethrow Exceptions

- Most methods explicitly throw `SQLException`
- This is a *checked exception* that *must* be caught and handled
- Occurs with DB errors or program bugs
- Little can be done either way
- Good to catch, log and rethrow
- Even better: use a logging utility like log4j

```
1  ...
2  } catch (SQLException sqle) {
3      System.out.println("SQLException: ");
4      sqle.printStackTrace();
5      throw new RuntimeException(sqle);
6  }
```

JDBC

Cleaning Up

- Objects hold onto valuable external resources
- Network traffic (keep alive), limited connection pool, etc.
- Best practice to release resources as soon as they are no longer needed: `close()` method

```
1  try {
2    if(rs != null && !rs.isClosed())
3      rs.close();
4    if(ps != null && !ps.isClosed())
5      ps.close();
6    if(conn != null && !conn.isClosed())
7      conn.close();
8  } catch (SQLException e) {
9    ...
10 }
```

JDBC

Full Example Demonstration

A full demonstration is available in the `unl.cse.jdbc` package in the SVN.
Demonstration based on the student/course enrollment database.

Good Practice Tip 1

ALWAYS use Prepared Statements

When available, in any framework or language, always use prepared statements

- Safer
- Better for batch queries
- Myth: no performance hit
- Protects against *injection attacks*
- Using just one method: more uniform, less of a chance of a mistake
- Unfortunately: some frameworks support *named parameters*, not JDBC

Injection Attack

Example

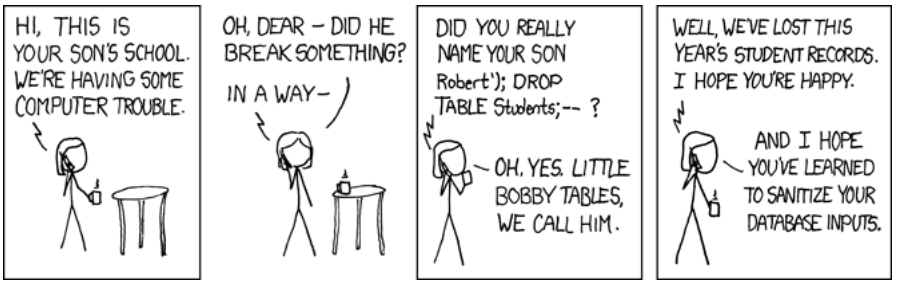
- Say we pull a string value from a web form (`lastName`)
- Not using a prepared statement:

```
1  String query = "SELECT primary_email FROM user " +
2                 "WHERE last_name = '"+lastName+"'";
```

- Without scrubbing the input, say a user enters:
  `a';DROP TABLE user;`
- Actual query run:
  `SELECT primary_email FROM user WHERE last = 'a';DROP TABLE users;`
- Another example: input: `"' OR '1'='1"`
- Actual query:
  `SELECT primary_email FROM user WHERE last_name = '' OR '1'='1'`
- In detail: `https://www.netsparker.com/blog/web-security/sql-injection-cheat-sheet/`

Injection Attack

Example



Good Practice Tip 2

Enumerate fields in SELECT statements

- Using `SELECT * ...` grabs all fields even if you don't use them
- Be intentional about what you want/need, only the minimal set
- Allows the database to optimize, reduces network traffic
- Protects against table changes
- Use aliasing (`first_name AS firstName`) on all fields to reduce affects of changes to field names

Additional Issues

Additional Issues

- Security Issues
  - Where/how should database passwords be stored?
  - Good security policy: *assume* an attacker has your password & take the necessary precautions (secure the server and network)
  - Do not store sensitive data unencrypted
- Efficiency Issues
  - Repeat: **close your resources**
  - Connection Pools
  - Good normalization, design, & practice

Resources

- MySQL 5.1 Reference Manual (`http://dev.mysql.com/doc/refman/5.1/en/index.html`)
- MySQL Community Server (`http://www.mysql.com/downloads/`)
- MySQL Workbench – a MySQL GUI (`http://wb.mysql.com/`)
- Connector/J – MySQL JDBC connector (`http://www.mysql.com/downloads/connector/j/`)
- Stanford's *Introduction to Databases* free online course: `http://db-class.com/`

Log4j I

- Home: `http://logging.apache.org/`
- Standard output is not appropriate for deployed applications (may not exist, certainly no one is "listening" to it)
- Logging provides valuable debugging, metrics, and auditing information
- Provides runtime configuration, formatting, rolling files, etc.

Log4j II

- Supports granularity in different levels of logging (`ERROR` to `DEBUG`)
- Usage: give each loggable class a static logger:

```
1  private static org.apache.log4j.Logger log =
2    Logger.getLogger(MyClass.class);
```

- Then use it: `log.error("SQLException: ", e);`
- Configure using a `log4j.properties` file (must be in the class path)
- Or: call `BasicConfigurator.configure();` in your `main` to have a default setup

Exercise

Write basic CRUD methods for the `Employee` / `Person` *tables by writing static methods to insert, delete, retrieve and update records in both tables.*