

Embedded SQL

csc343, Introduction to Databases

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with examples from Ullman and Widom

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Problems with using interactive SQL

- Standard SQL is not “Turing-complete”.
 - E.g., Two profs are “colleagues” if they’ve co-taught a course or share a colleague.
 - We can’t write a query to find all colleagues of a given professor because we have no loops or recursion.
- You can’t control the format of its output.
- And most users shouldn’t be writing SQL queries!
 - You want to run queries that are *based on* user input, not have users writing actual queries.

SQL + a conventional language

- If we can combine SQL with code in a conventional language, we can solve these problems.
- But we have another problem:
 - SQL is based on relations, and conventional languages have no such type.
- It is solved by
 - feeding tuples from SQL to the other language one at a time, and
 - feeding each attribute value into a particular variable.

Approaches

- Three approaches for combining SQL and a general-purpose language:
 - Stored Procedures
 - Statement-level Interface
 - Call-level interface

Three Approaches

I. Stored Procedures

- The SQL standard includes a language for defining “stored procedures”, which can
 - have parameters and a return value,
 - use local variables, ifs, loops, etc.,
 - execute SQL queries.
- Stored procedures can be used in these ways:
 - called from the interpreter,
 - called from SQL queries,
 - called from another stored procedure,
 - be the action that a trigger performs.

Example (just to give you an idea)

- A boolean function `BandW(y INT, s CHAR(15))` that returns true iff
 - movie studio `s` produced no movies in year `y`, or
 - produced at least one comedy.
- (Yes, that's an odd name for this function.)
- Reference: Ullman and Widom textbook, chapter 9

Reference: textbook figure 9.1.3

```
CREATE FUNCTION BandW(y INT, s CHAR(15)) RETURNS BOOLEAN
IF NOT EXISTS
    (SELECT *
      FROM Movies
      WHERE year = y AND studioName = s)
THEN RETURN TRUE;
ELSIF 1 <=
    (SELECT COUNT(*)
      FROM Movies
      WHERE year = y AND studioName = s AND
            genre = 'comedy')
THEN RETURN TRUE;
ELSE RETURN FALSE;
END IF;
```


Calling it

- Now we can say things like this:

```
SELECT StudioName  
FROM Studios  
WHERE BandW(2010, StudioName);
```

Not very standard

- The language is called **SQL/PSM** (Persistent Stored Modules).
 - It came into the SQL standard in SQL3, 1999.
 - Reference: textbook, section 9.4
- By then, commercial DBMSs had defined their own proprietary languages for stored procedures
 - They have generally stuck to them.
- PostgreSQL has defined **PL/pgSQL**.
 - It supports some, but not all, of SQL/PSM.
 - Reference: Chapter 39 of the PostgreSQL documentation.

2. Statement-level interface (SLI)

- Embed SQL statements into code in a conventional language like C or Java.
- Use a preprocessor to replace the SQL with calls written in the host language to functions defined in an SQL library.
- Special syntax indicates which bits of code the preprocessor needs to convert.

Example, in C (just to give you an idea)

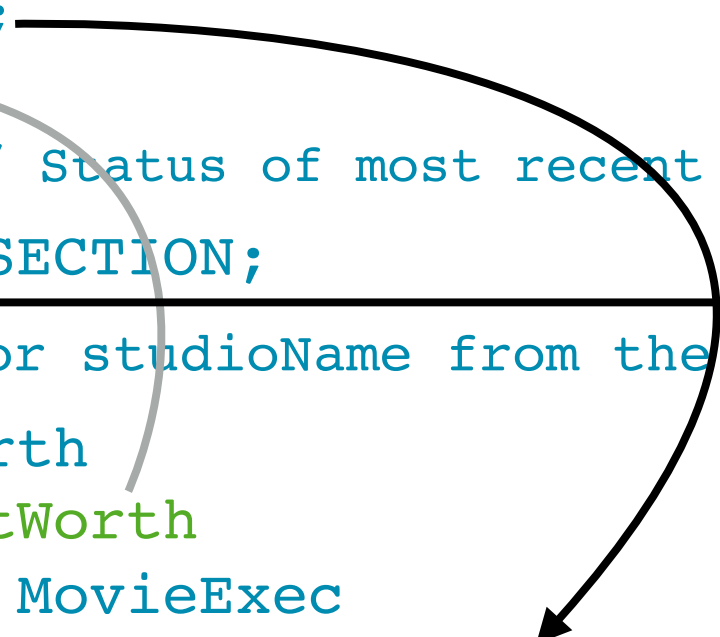
Reference: textbook example 9.7

```
void printNetWorth() {
```

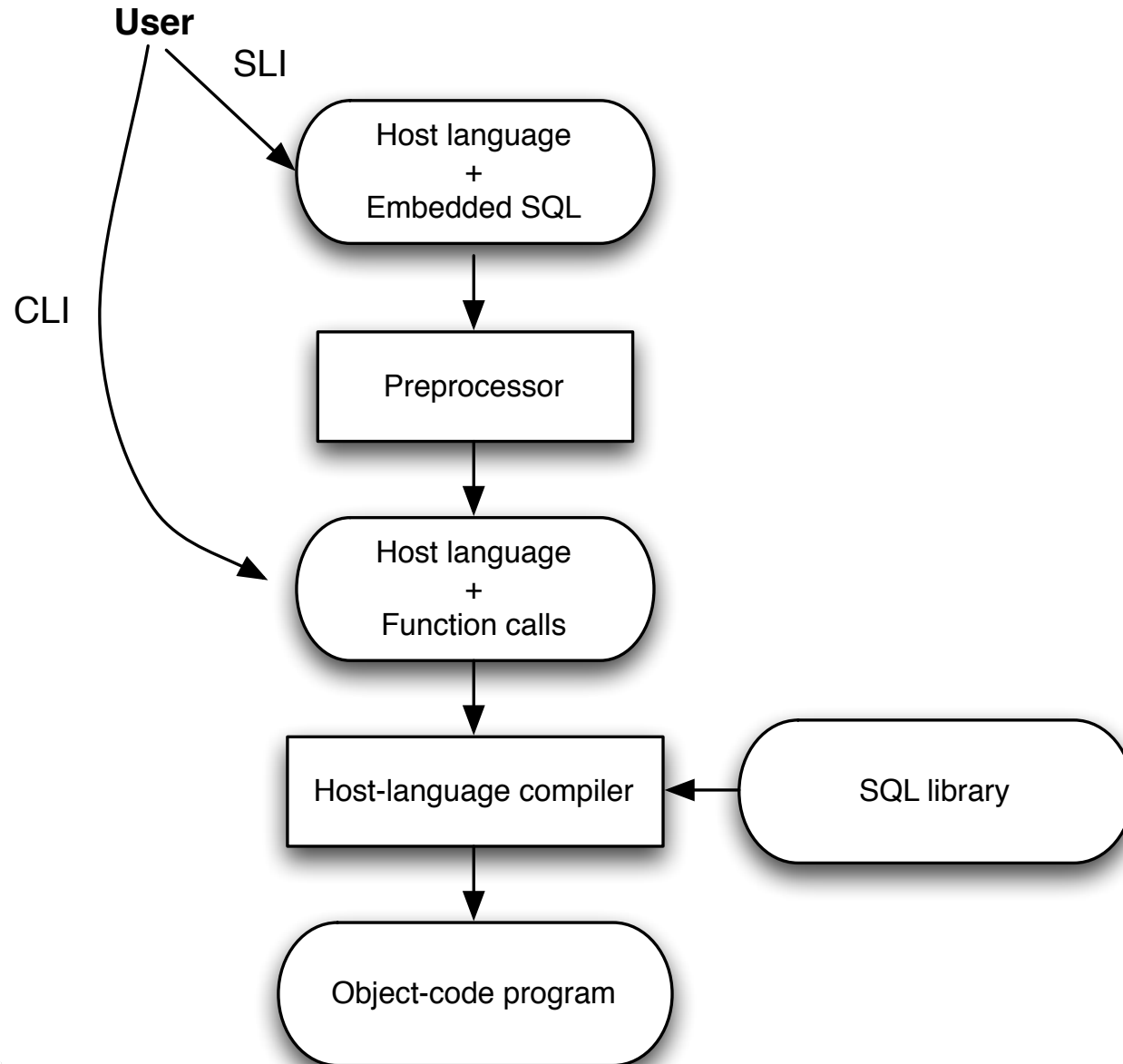
```
EXEC SQL BEGIN DECLARE SECTION;
    char studioName[50];
    int presNetWorth;
    char SQLSTATE[6]; // Status of most recent SQL stmt
EXEC SQL END DECLARE SECTION;

/* OMITTED: Get value for studioName from the user. */
EXEC SQL SELECT netWorth
        INTO :presNetWorth
        FROM Studio, MovieExec
        WHERE Studio.name = :studioName;

/* OMITTED: Report back to the user */
```



Big picture (figure 9.5)



3. Call-level interface (CLI)

- Instead of using a pre-processor to replace embedded SQL with calls to library functions, write those calls yourself.
- Eliminates need to preprocess.
- Each language has its own set of library functions for this.
 - for C, it's called SQL/CLI
 - for Java, it's called JDBC
 - for PHP, it's called PEAR DB
- We'll look at just one: JDBC.

JDBC

JDBC Example (see section 9.6)

Do this once in your program:

```
/* Get ready to execute queries. */  
import java.sql.*;  
  
/* A static method of the Class class. It loads the  
   specified driver */  
Class.forName("org.postgresql.jdbc.Driver");  
  
Connection conn = DriverManager.getConnection(  
    jdbc:postgresql://localhost:5432/csc343h-dianeh,  
    dianeh,  
    "" );  
  
/* Continued ... */
```


The arguments to getConnection

- `jdbc:postgresql`

We'll use this, but it could be, e.g., `jdbc:mysql`

- `localhost:5432`

You must use exactly this for the CS Teaching Labs.

- `csc343h-dianeh` and `dianeh`

Substitute your userid on the CS Teaching Labs.

- `""`

Password (unrelated to your password).

Literally use the empty string.

Do this once per query in your program:

```
/* Execute a query and iterate through the resulting
   tuples. */

PreparedStatement execStat = conn.prepareStatement(
    "SELECT netWorth FROM MovieExec");

ResultSet worths = execStat.executeQuery();
while (worths.next()) {
    int worth = worths.getInt(1);
    /* If the tuple also had a float and another int
       attribute, you'd get them by calling
       worths.getFloat(2) and worths.getInt(3).
       Or you can look up values by attribute name.
       Example: worths.getInt(netWorth)
    */
    /* OMITTED: Process this net worth */
}
```

The Java details

- For full details on the Java classes and methods used, see the Java API documentation:

`https://docs.oracle.com/javase/8/docs/api/java/sql/package-summary.html`

Exceptions can occur

- Any of these calls can generate an exception.
- Therefore, they should be inside try/catch blocks.

```
try {  
    /* OMITTED: JDBC code */  
} catch (SQLException ex) {  
    /* OMITTED: Handle the exception */  
}
```

- The class `SQLException` has methods to return the `SQLSTATE`, etc.

What is “preparation”?

- Preparing a statement includes:
 - parsing the SQL
 - compiling
 - optimizing
- The resulting `PreparedStatement` can be executed any number of times without having to repeat these steps.

If the query isn't known until run time

- You may need input and computation to determine exactly what the query should be.
- In that case:
 - Hard-code in the parts you know.
 - Use the character `?` as a placeholder for the values you don't know. (Don't put it in quotes!)
- This is enough to allow a `PreparedStatement` to be constructed.
- Once you know values for the placeholders, use methods `setString`, `setInt`, etc. to fill in those values.

Example (figure 9.22)

```
PreparedStatement studioStat =  
    conn.prepareStatement(  
        "INSERT INTO Studio(name, address)  
        VALUES(?, ?)"  
    );
```

```
/* OMITTED: Get values for studioName and studioAddr */  
studioStat.setString(1, studioName);  
studioStat.setString(2, studioAddr);  
studioStat.executeUpdate();
```

Why not just build the query in a string?

- We constructed an incomplete `PreparedStatement` and filled in the missing values using method calls.
- Instead, we could just build up the query in an ordinary string at run time, and ask to execute that.
- There are classes and methods that will do this in JDBC.

Example that builds the query in a string

- We can just use a `Statement`, and give it a `String` to execute.

```
// stat cannot be compiled & optimized (yet).
Statement stat = conn.createStatement();

String query =
    "SELECT networth
    FROM MovieExec
    WHERE execName like '%Spielberg%';
"

// executeQuery can now compile and optimize, and run
// the query.
ResultSet worths = stat.executeQuery(query);
```

What could possibly go wrong?

Example: Some vulnerable code

Suppose we want the user to provide the string to compare to

You can do this rather than hard-coding Spielberg into the query:

```
Statement stat = conn.createStatement();
String who = /* get a string from the user */
String query =
    "SELECT networth
    FROM MovieExec
    WHERE execName like '%" + who + "%'";
ResultSet worths = stat.executeQuery(query);
```

A gentle user does no harm

If a user enters **Milch**, the SQL code we execute is this:

```
SELECT networth  
FROM MovieExec  
WHERE execName like '%Milch%';
```

Nothing bad happens.

An injection can exploit the vulnerability

What could a malicious user enter?

```
SELECT networth  
FROM MovieExec  
WHERE execName like '%?????????????%';
```

Always use a PreparedStatement

- This was an example of an **injection**.
- The simple approach of giving a String to a Statement is vulnerable to injections.
- Moral of the story:
Always use a PreparedStatement instead.

Queries vs updates in JDBC

- The previous examples used `executeQuery`.
- This method is only for pure queries.
- For SQL statements that change the database (insert, delete or modify tuples, or change the schema), use the analogous method `executeUpdate`.