Real SQL Programming

Embedded SQL

Call-Level Interface

Java Database Connectivity

SQL in Real Programs

- We have seen only how SQL is used at the generic query interface --- an environment where we sit at a terminal and ask queries of a database.
- Reality is almost always different.
  - Programs in a conventional language like C are written to access a database by “calls” to SQL statements.

Host Languages

- Any conventional language can be a *host language*, that is, a language in which SQL calls are embedded.
- The use of a host/SQL combination allows us to do anything computable, yet still get the very-high-level SQL interface to the database.

Connecting SQL to the Host Language

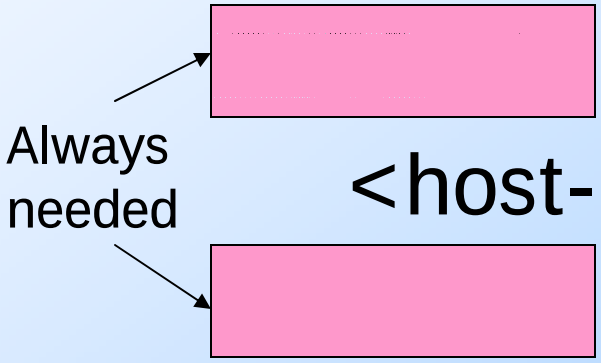
1. *Embedded SQL* is a standard for combining SQL with seven languages.
2. CLI (*Call-Level Interface*) is a different approach to connecting C to an SQL database.
3. JDBC (*Java Database Connectivity*) is a way to connect Java with an SQL database.

Embedded SQL

- Key idea: Use a preprocessor to turn SQL statements into procedure calls that fit with the host-language code surrounding.
- All embedded SQL statements begin with EXEC SQL, so the preprocessor can find them easily.

Shared Variables

- To connect SQL and the host-language program, the two parts must share some variables.
- Declarations of shared variables are bracketed by:



BEGIN DECLARE SECTION;

<host-language declarations>

END DECLARE SECTION;

Use of Shared Variables

- In SQL, the shared variables must be preceded by a colon.
  - They may be used as constants provided by the host-language program.
  - They may get values from SQL statements and pass those values to the host-language program.
- In the host language, shared variables behave like any other variable.

Example: Looking Up Prices

- We'll use C with embedded SQL to sketch the important parts of a function that obtains a beer and a bar, and looks up the price of that beer at that bar.
- Assumes database has our usual Sells(bar, beer, price) relation.

Example: C Plus SQL

```
EXEC SQL BEGIN DECLARE SECTION;
   char [redacted];
   float thePrice;
EXEC SQL END DECLARE SECTION;
   /* obtain values for theBar and theBeer */
EX[redacted]
   /* do something with thePrice */
```

Note 21-char arrays needed for 20 chars + endmarker

SELECT-INTO just like PSM

Embedded Queries

- Embedded SQL has the same limitations as PSM regarding queries:
  - You may use SELECT-INTO for a query guaranteed to produce a single tuple.
  - Otherwise, you have to use a cursor.
    - Small syntactic differences between PSM and Embedded SQL cursors, but the key ideas are identical.

Cursor Statements

- Declare a cursor *c* with:

EXEC SQL DECLARE *c* CURSOR FOR <query>;

- Open and close cursor c with:

EXEC SQL OPEN CURSOR c;

EXEC SQL CLOSE CURSOR c;

- Fetch from *c* by:

EXEC SQL FETCH c INTO <variable(s)>;

  - Macro NOT FOUND is true if and only if the FETCH fails to find a tuple.

Example --- (1)

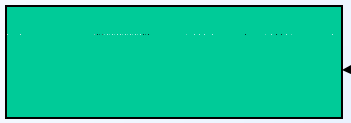
- Let's write C + SQL to print Joe's menu --- the list of beer-price pairs that we find in Sells(bar, beer, price) with bar = Joe's Bar.
- A cursor will visit each Sells tuple that has bar = Joe's Bar.

Example --- (2: Declarations)

```
EXEC SQL BEGIN DECLARE SECTION;
  char theBeer[21]; float thePrice;
EXEC SQL END DECLARE SECTION;
```

The cursor declaration goes outside the declare-section

Example --- (3: Executable)

```
EXEC SQL OPEN CURSOR c;

{
  EXEC SQL FETCH c
           INTO :theBeer, :thePrice;

  /* format and print theBeer and thePrice */
}
EXEC SQL CLOSE CURSOR c;
```

The C style of breaking loops

Need for Dynamic SQL

- Most applications use specific queries and modification statements to interact with the database.
  - The DBMS compiles EXEC SQL ... statements into specific procedure calls and produces an ordinary host-language program that uses a library.
- What about sqlplus, which doesn't know what it needs to do until it runs?

Dynamic SQL

- Preparing a query:

EXEC SQL PREPARE <query-name>
FROM <text of the query>;

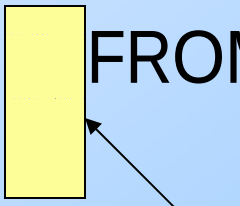
- Executing a query:

EXEC SQL EXECUTE <query-name>;

- “Prepare” = optimize query.
- Prepare once, execute many times.

Example: A Generic Interface

```
EXEC SQL BEGIN DECLARE SECTION;
   char query[MAX_LENGTH];
EXEC SQL END DECLARE SECTION;
while(1) {
   /* issue SQL> prompt */
   /* read user's query into array query */
   EXEC SQL PREPARE  q  FROM :query;
   EXEC SQL EXECUTE  q ;
}
```



q is an SQL variable representing the optimized form of whatever statement is typed into :query

Execute-Immediate

- If we are only going to execute the query once, we can combine the PREPARE and EXECUTE steps into one.
- Use:

EXEC SQL EXECUTE IMMEDIATE <text>;

Example: Generic Interface Again

```
EXEC SQL BEGIN DECLARE SECTION;
  char query[MAX_LENGTH];
EXEC SQL END DECLARE SECTION;
while(1) {
  /* issue SQL> prompt */
  /* read user's query into array
  query */
  EXEC SQL EXECUTE IMMEDIATE :query;
}
```

SQL/CLI

- Instead of using a preprocessor, we can use a library of functions and call them as part of an ordinary C program.
  - The library for C is called SQL/CLI = “Call-Level Interface.”
  - Embedded SQL’s preprocessor will translate the EXEC SQL ... statements into CLI or similar calls, anyway.

Data Structures

- C connects to the database by structs of the following types:
  1. *Environments* : represent the DBMS installation.
  2. *Connections* : logins to the database.
  3. *Statements* : SQL statements to be passed to a connection.
  4. *Descriptions* : records about tuples from a query or parameters of a statement.

Environments, Connections, and Statements

- Function SQLAllocHandle(T,I,O) is used to create these structs, which are called environment, connection, and statement *handles*.
  - *T* = type, e.g., SQL_HANDLE_STMT.
  - *I* = input handle = struct at next higher level (statement < connection < environment).
  - *O* = (address of) output handle.

Example: SQLAllocHandle

```
SQLAllocHandle(SQL_HANDLE_STMT,
  myCon, &myStat);
```

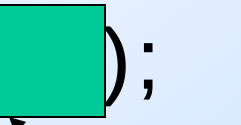
- `myCon` is a previously created connection handle.
- `myStat` is the name of the statement handle that will be created.

Preparing and Executing

- SQLPrepare(H, S, L) causes the string *S*, of length *L*, to be interpreted as an SQL statement and optimized; the executable statement is placed in statement handle *H*.
- SQLExecute(H) causes the SQL statement represented by statement handle *H* to be executed.

Example: Prepare and Execute

```
SQLPrepare(myStat, ”SELECT beer, price
   FROM Sells WHERE bar = ’Joe’’s Bar’ ”,
   [redacted]);
SQLExecute(myStat);
```



This constant says the second argument is a “null-terminated string”; i.e., figure out the length by counting characters.

Dynamic Execution

- If we will execute a statement *S* only once, we can combine PREPARE and EXECUTE with:

SQLExecuteDirect(H,S,L);

  - As before, *H* is a statement handle and *L* is the length of string *S*.

Fetching Tuples

- When the SQL statement executed is a query, we need to fetch the tuples of the result.
  - That is, a cursor is implied by the fact we executed a query, and need not be declared.
- SQLFetch(H) gets the next tuple from the result of the statement with handle *H*.

Accessing Query Results

- When we fetch a tuple, we need to put the components somewhere.
- Thus, each component is bound to a variable by the function SQLBindCol.
  - This function has 6 arguments, of which we shall show only 1, 2, and 4:

    1 = handle of the query statement.

    2 = column number.

    4 = address of the variable.

Example: Binding

- Suppose we have just done SQLExecute(myStat), where myStat is the handle for query

SELECT beer, price FROM Sells

WHERE bar = 'Joe''s Bar'

- Bind the result to theBeer and thePrice:

SQLBindCol(myStat, 1, , &theBeer, ,);

SQLBindCol(myStat, 2, , &thePrice, ,);

Example: Fetching

- Now, we can fetch all the tuples of the answer by:

```
while ( SQLFetch(myStat) != [          ])
  {
      /* do something with theBeer and
         thePrice */
  }
```

CLI macro representing SQLSTATE = 02000 = “failed to find a tuple.”

JDBC

- Java Database Connectivity (JDBC) is a library similar to SQL/CLI, but with Java as the host language.
- JDBC/CLI differences are often related to the object-oriented style of Java, but there are other differences.

Environments, Connections, and Statements

- The same progression from environments to connections to statements that we saw in CLI appears in JDBC.
- A *connection object* is obtained from the environment in a somewhat implementation-dependent way.
- We'll start by assuming we have `myCon`, a connection object.

Statements

- JDBC provides two classes:
  1. *Statement* = an object that can accept a string that is an SQL statement and can execute such a string.
  2. *PreparedStatement* = an object that has an associated SQL statement ready to execute.

Creating Statements

- The Connection class has methods to create Statements and PreparedStatements.

```
Statement stat1 = myCon.                    ();
PreparedStatement stat2 =
   myCon.                                   (
        "SELECT beer, price FROM Sells "
        "WHERE bar = 'Joe''s Bar' "
   );
```

Java trick: + concatenates strings.

createStatement with no argument returns a Statement; with one argument it returns a PreparedStatement.

Executing SQL Statements

- JDBC distinguishes queries from modifications, which it calls “updates.”
- Statement and PreparedStatement each have methods executeQuery and executeUpdate.
  - For Statements, these methods have one argument: the query or modification to be executed.
  - For PreparedStatements: no argument.

Example: Update

- stat1 is a Statement.
- We can use it to insert a tuple as:

```
stat1.executeUpdate(
  ”INSERT INTO Sells ” +
  ”VALUES(’Brass Rail’, ’Bud’, 3.00)”
);
```

Example: Query

- stat2 is a PreparedStatement holding the query ”SELECT beer, price FROM Sells WHERE bar = ’Joe’’s Bar’ ”.
- executeQuery returns an object of class ResultSet --- we’ll examine it later.
- The query:

```
ResultSet Menu = stat2.executeQuery();
```

Accessing the ResultSet

- An object of type ResultSet is something like a cursor.
- Method Next() advances the "cursor" to the next tuple.
  - The first time Next() is applied, it gets the first tuple.
  - If there are no more tuples, Next() returns the value FALSE.

Accessing Components of Tuples

- When a ResultSet is referring to a tuple, we can get the components of that tuple by applying certain methods to the ResultSet.
- Method get*X*(*i*), where *X* is some type, and *i* is the component number, returns the value of that component.
  - The value must have type *X*.

Example: Accessing Components

- Menu is the ResultSet for the query “SELECT beer, price FROM Sells WHERE bar = ‘Joe’’s Bar’”.
- Access the beer and price from each tuple by:

```
while ( Menu.Next() ) {
  theBeer = Menu.getString(1);
  thePrice = Menu.getFloat(2);
     /* do something with theBeer and
        thePrice */
}
```