Application Programming and SQL

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Databases CS338

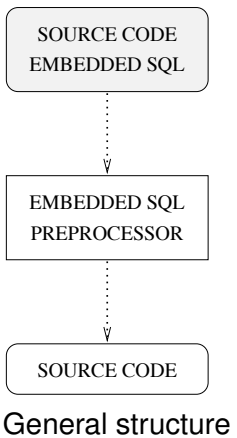
Database Applications

- SQL isn't sufficient to write general applications.
  ⇒ connect it with a general-purpose PL!
- Language considerations:
  ⇒ Library calls (CLI/ODBC)
  ⇒ Embedded SQL
  ⇒ Advanced *persistent* PL (usually OO)
- Client-server:
  ⇒ SQL runs on the server
  ⇒ Application runs on the client

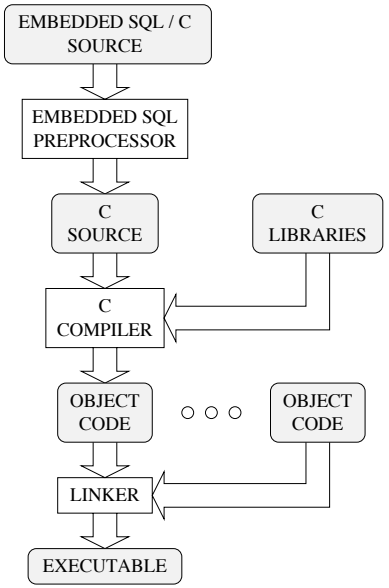
Embedded SQL

- SQL Statements are *embedded* into
  a *host language* (C, C++, FORTRAN, . . .)
- The application is *preprocessed*
  pure host language program + library calls
  - Advantages:
    * Preprocessing of (static) parts of queries
    * MUCH easier to use
  - Disadvantages:
    * Needs precompiler
    * Needs to be *bound* to a database

Development Process for Embedded SQL Applications



General structure



Embedded SQL (cont.)

- Considerations:

  ⇒ How much can SQL be parameterized?
  - How to pass parameters into SQL?
  - How to get results?
  - Errors?

  ⇒ Static vs. dynamic SQL statements.
- How much does the DBMS know about an application?

  ⇒ precompiling: `PREP`
  ⇒ binding: `BIND`

Application Structure

```
Include SQL support (SQLCA, SQLDA)
main(int argc, char **argv)
{
    Declarations

    Connect to Database

    Do your work

    Process errors

    Commit/Abort and Disconnect
};
```


Declarations

- Include SQL communication area:

  ```
  EXEC SQL  INCLUDE SQLCA;
  ```

  it defines:

  ⇒ the return code of SQL statements (sqlcode)
  ⇒ the error messages (if any)
  ⇒ . . . you can't live without it.
- SQL statements inserted using magic words

  ```
  EXEC SQL <sql statement> ;
  ```


Host Variables

are used to pass values between a SQL and the rest of the program:

- parameters in SQL statements:

  communicate **single values** between
  SQL a statement and host language variables
- must be declared within SQL declare section:

  ```
  EXEC SQL  BEGIN DECLARE SECTION;
    declarations of variables to be used
    in SQL statements go here
  EXEC SQL  END DECLARE SECTION;
  ```
- can be used in the `EXEC SQL` statements:

  ⇒ to distinguish them from SQL identifiers
  they are preceded by `':'` (colon)

Errors

What if a SQL statement fails?

- check `sqlcode != 0`
- use "exception" handling:

```
EXEC SQL WHENEVER SQLERROR   GO TO lbl;
EXEC SQL WHENEVER SQLWARNING GO TO lbl;
EXEC SQL WHENEVER NOT FOUND  GO TO lbl;
```

⇒ designed for COBOL (lbl has to be in scope).

Dummy Application (DB2)

```
#include <stdio.h>
#include "util.h"

EXEC SQL INCLUDE SQLCA;

int main(int argc, char *argv[]) {
   EXEC SQL BEGIN DECLARE SECTION;
      char db[6] = "DBCLASS";
   EXEC SQL END DECLARE SECTION;
   printf("Sample C program: CONNECT\n" );
   EXEC SQL WHENEVER SQLERROR  GO TO error;
   EXEC SQL CONNECT TO :db;
   printf("Connected to DB2\n");
// do your stuff here
   EXEC SQL COMMIT;
   EXEC SQL CONNECT reset;
   exit(0);
error:
   check_error("My error",&sqlca);
   EXEC SQL WHENEVER SQLERROR CONTINUE;
   EXEC SQL ROLLBACK;
   EXEC SQL CONNECT reset;
   exit(1);
}
```


Dummy Application (Oracle)

```
#include <stdio.h>

EXEC SQL INCLUDE SQLCA;

int main(int argc, char *argv[]) {
   EXEC SQL BEGIN DECLARE SECTION;
      char user[6] = "DBCLASS";
      char pwd[10];
   EXEC SQL END DECLARE SECTION;
   printf("Sample C program: CONNECT\n" );
   strncpy(pwd,getpass("Password: "),10);
   EXEC SQL WHENEVER SQLERROR  GO TO error;
   EXEC SQL CONNECT :user IDENTIFIED BY :pwd;
   printf("Connected to Oracle\n");
// do your stuff here
   EXEC SQL COMMIT RELEASE;
   exit(0);
error:
   sqlca.sqlerrm.sqlerrmc[sqlca.sqlerrm.sqlerrml] ='\0';
   printf("MyError %s\n", sqlca.sqlerrm.sqlerrmc);
   EXEC SQL WHENEVER SQLERROR CONTINUE;
   EXEC SQL ROLLBACK RELEASE;
   exit(1);
}
```


Preparing your Application (DB2)

1. write the application in a file called `<name>.sqc`
2. preprocess the application:

   ```
   db2 prep <name>.sqc
   ```

3. compile the application:

   ```
   cc -c -O <name>.c
   ```

4. link with DB2 libraries:

   ```
   cc -o <name> <name.o> -L... -l...
   ```

5. run it:

   ```
   ./<name> [arguments]
   ```

Typically comes with a Makefile

⇒ sets options

⇒ knows the path(s) and libraries

Example of a build (DB2)

```
bash$ make NAME=sample1
db2 connect to DBCLASS

 Database server        = DB2/SUN 6.1.0
 SQL authorization ID   = DAVID
 Local database alias   = DBCLASS

db2 prep sample1.sqc bindfile
LINE    MESSAGES FOR sample1.sqc
------  --------------------------------------------------
        SQL0060W  The "C" precompiler is in progress.
        SQL0091W  Precompilation or binding was ended with
                  "0" errors and "0" warnings.
db2 bind sample1.bnd
LINE    MESSAGES FOR sample1.bnd
------  --------------------------------------------------
        SQL0061W  The binder is in progress.
        SQL0091N  Binding was ended with "0" errors and
                  "0" warnings.
db2 connect reset
DB20000I  The SQL command completed successfully.
cc -I/usr/db2/include -c sample1.c
cc -I/usr/db2/include -o sample1 sample1.o util.o
                -L/usr/db2/lib -R/usr/db2/lib -ldb2
```


Example

```
bash$ ./sample1
Sample C program: CONNECT
Connected to DB2
bash$
```

```
bash$ ./sample1
Sample C program: CONNECT
DB2 database error 0x80004005:  SQL30081N
A communication error has been detected.
Communication protocol being used: "TCP/IP".
...
SQLSTATE=08001
bash$
```


“Real” SQL Statements

So far we introduced only the surounding infrastructure.
Now for the real SQL statements:

- simple statements:
  - ⇒ “constant” statements
  - ⇒ statements with parameters
  - ⇒ statements returning a single tuple
- general queries with many answers
- dynamic queries (not covered here)

Simple Application

Write a program that for each publication id supplied as an argument prints out the title of the publication:

```
main(int argc, char *argv[]) {
   ...
   printf("Connected to DB2\n");
   for (i=1; i<argc; i++) {
     strncpy(pubid,argv[i],8);

     EXEC SQL WHENEVER NOT FOUND GO TO nope;

     EXEC SQL SELECT title INTO :title
              FROM   publication
              WHERE  pubid = :pubid;

     printf("%10s: %s\n",pubid,title);
     continue;
   nope:
     printf("%10s: *** not found *** \n",pubid);
   };
   ...
}
```

Simple Application (cont.)

```
bash$ ./sample2 ChTo98 nopubid
Sample C program: SAMPLE2
Connected to DB2
  ChTo98: Temporal Logic in Information Systems
 nopubid: *** not found ***
```

⇒ it is important that at most **one** title is returned for each *pubid*.

NULLs and Indicator Variables

- what if a host variable is assigned a NULL?

  ⇒ not a valid value in the datatype

  ⇒ ESQL uses an extra *Indicator* variable, e.g.:

```
smallint ind;
SELECT firstname INTO :firstname
                 INDICATOR :ind
FROM   ...
```

  then if `ind` < 0 then `firstname` is NULL
- if the indicator variable is not provided and the result is a null we get an run-time error
- the same rules apply for host variables in updates.

Impedance Mismatch

What if we `EXEC SQL` a query and it **returns more than one tuple**?

1. Declare the *cursor*:

```
EXEC SQL DECLARE <name> CURSOR
         FOR <query>;
```

2. Iterate over it:

```
EXEC SQL OPEN <name>;
EXEC SQL WHENEVER NOT FOUND GO TO end;
for (;;) {
   <set up host parameters>
   EXEC SQL FETCH <name>
            INTO <host variables>;
   <process the fetched tuple>
 };
end:
 EXEC SQL CLOSE <name>;
```


Application with a Cursor

Write a program that lists all author names and publication titles with author name matching a pattern given as an argument:

```
main(int argc, char *argv[]) {
   ...
   strncpy(apat,argv[1],8);

   EXEC SQL DECLARE author CURSOR
        FOR SELECT name, title
            FROM author , wrote, publication
            WHERE name LIKE :apat
              AND aid=author AND pubid=publication;

   EXEC SQL OPEN author;
   EXEC SQL WHENEVER NOT FOUND GO TO end;
   for (;;) {
     EXEC SQL FETCH author INTO :name, title;
     printf("%10s -> %20s: %s\n",apat,name,title);
   };
end:
   ...
}
```

Application with a Cursor (cont.)

```
bash$ ./sample3 "%"
Sample C program: SAMPLE3
Connected to DB2
 % -> Toman, David  : Temporal Logic in Information
 % -> Toman, David  : Datalog with Integer Periodic
 % -> Toman, David  : Point-Based Temporal Extensio
 % -> Chomicki, Jan : Logics for Databases and Info
 % -> Chomicki, Jan : Datalog with Integer Periodic
 % -> Chomicki, Jan : Temporal Logic in Information
 % -> Saake, Gunter : Logics for Databases and Info
bash$ ./sample3 "T%"
Sample C program: SAMPLE3
Connected to DB2
T% -> Toman, David  : Temporal Logic in Information
T% -> Toman, David  : Datalog with Integer Periodic
T% -> Toman, David  : Point-Based Temporal Extensio
```


Summary

- Declarations:

```
EXEC SQL INCLUDE SQLCA;
EXEC SQL BEGIN DECLARE SECTION;
   <host variables here>
EXEC SQL END DECLARE SECTION;
```

- Simple statements:

```
EXEC SQL <SQL statement>;
```

- Queries (with multiple answers)

```
EXEC SQL DECLARE <id> CURSOR FOR <qry>;
EXEC SQL OPEN <id>;
do {
  EXEC SQL FETCH <id> INTO <vars>;
} while (SQLCODE == 0);
EXEC SQL CLOSE <id>;
```

- Don't forget to check errors!!

Call Level Interface/ODBC

An interface built on a library calls:

- Applications are developed without access to the DB (and without additional tools: no precompilation)
- incorporates ODBC (MS) and X/Open standards
- but it is harder to use and doesn't allow preprocessing (e.g., no checking of your SQL code and data types)

Three fundamental objects in an ODBC program:

- Environments
- Connections
- Statements

Connect and Disconnect

```
int main()
{
   SQLHENV   henv;
   SQLHDBC   hdbc;
   SQLRETURN rc;
   SQLCHAR   server[SQL_MAX_DSN_LENGTH + 1] = "DBCLASS";
   SQLCHAR   uid[19] = "<your uid>";
   SQLCHAR   pwd[31] = "<your password>";

   SQLAllocEnv(&henv);
   SQLAllocConnect(henv, &hdbc);

   rc = SQLConnect(hdbc, server, SQL_NTS, uid, SQL_NTS, pwd, SQL_NTS);
   if (rc != SQL_SUCCESS) {
          printf("Error connecting to %s\n", server); exit(1);
   } else printf("Connected to %s\n", server);

/* DO SOMETHING HERE */

   SQLDisconnect(hdbc);
   SQLFreeConnect(hdbc);
   SQLFreeEnv(henv);
}
```

Errors

- `SQLxxx` functions return error codes
  ⇒ similar to `libc` functions
  ⇒ we should check them after every `SQLxxx` call
- the actual return codes:
  - `SQL_SUCCESS`
  - `SQL_ERROR`
- use the `SQLError` function to get sensible messages

SQL Statements

. . . and what we can do with them:

- `SQLAllocStmt` (allocates object)
- `SQLExecDirect` (execute)
- `SQLPrepare` (compile statement)
- `SQLExecute` (execute compiled statement)
- `SQLSetParam` (initialize a procedure parameter)
- `SQLNumResultCols` (number of result columns)
- `SQLBindCol` (“host variables” in ODBC)
- `SQLGetData` (obtaining values of result columns)
- `SQLFetch` (cursor access in ODBC)
- `SQLError` (obtains diagnostics)
- `SQLRowCount` (number of affected rows)
- ...
- `SQLFreeStmt` (frees object)

Parameters

1. parameter markers
   `'?'` in the text of the query
   `SQLNumParams`
   `SQLBindParameter`
2. results of queries
   ⇒ specified by the number of resulting columns
   `SQLNumResultsCol`
   `SQLDescribeCol`
   `SQLBindCol` or `SQLGetData`
3. number of affected tuples (updates):
   `SQLRowCount`

Example

```
SQLCHAR  stmt[] = "UPDATE author SET url = ? WHERE aid = ?";

SQLINTEGER aid;
SQLCHAR    s[70];
SQLINTEGER ind;

rc = SQLAllocStmt(hdbc, &hstmt);

rc = SQLPrepare(hstmt, stmt, SQL_NTS);

printf"(Enter Author ID:  "); scanf("%ld",&aid);
printf"(Enter Author URL: "); scanf("%s", s);

rc = SQLBindParameter(hstmt, 1,
              SQL_PARAM_INPUT, SQL_C_CHAR,
              SQL_CHAR, 0, 0, s, 70, &ind);

rc = SQLBindParameter(hstmt, 2,
              SQL_PARAM_INPUT, SQL_C_SLONG,
              SQL_INTEGER, 0, 0, &aid, 0, NULL);

rc = SQLExecute(hstmt);
```

Answers

How to get output values from a statement

- number of affected: `SQLRowCount`
- answers to queries:
  1. bind variables before execution: `SQLBindCol`
  2. get values after execution: `SQLGetData`
- get next tuple: `SQLFetch`
  the result of `SQLFetch` is just a result code!

A Query with `SQLBindCol`

```
SQLCHAR  sqlstmt[] = "SELECT pubid, title FROM publication";

SQLINTEGER   rows;
struct { SQLINTEGER ind;
         SQLCHAR    s[70];
       } pubid, title;

rc = SQLAllocStmt(hdbc, &hstmt);

rc = SQLExecDirect(hstmt, sqlstmt, SQL_NTS);

rc = SQLBindCol(hstmt, 1, SQL_C_CHAR,
                (SQLPOINTER)pubid.s, 8, &pubid.ind);
rc = SQLBindCol(hstmt, 2, SQL_C_CHAR,
                (SQLPOINTER)title.s, 70, &title.ind);

while ((rc = SQLFetch(hstmt)) == SQL_SUCCESS)
   printf("%-8.8s %-70.70s\n", pubid.s, title.s);

rc = SQLRowCount(hstmt, &rows);
printf(" %d rows selected\n", rows);

rc = SQLFreeStmt(hstmt, SQL_DROP);
```


Transactions

- transaction start:

  ⇒ implicitly using one of

  `SQLPrepare`,
  `SQLExecute`,
  `SQLExecDirect`, etc.

  functions.
- transaction end:

  ```
  SQLTransact(henv, hdbc, what)
  ```

  where

  `what = SQL_COMMIT`, or
  `what = SQL_ROLLBACK`

Summary

- CLI/ODBC can do everything Embedded SQL can.
- However, all statements are *dynamic*

  ⇒ no precompilation
  ⇒ explicit binding of parameters (user has to make types match!)
- An almost standard (ODBC, X/Open)

  ⇒ independence on DBMS
  ⇒ but: the standard has 100's of functions

Stored Procedures

Idea

A stored procedure executes application logic directly inside the DBMS process.

- Possible implementations
  - invoke externally-compiled application
  - SQL/PSM (or vendor-specific language)
- Possible advantages of stored procedures:
  1. minimize data transfer costs
  2. centralize application code
  3. logical independence

A Stored Procedure Example: Atomic-Valued Function

```
CREATE FUNCTION sumSalaries(dept CHAR(3))
    RETURNS DECIMAL(9,2)
LANGUAGE SQL
RETURN
    SELECT sum(salary)
    FROM employee
    WHERE workdept = dept
```


A Stored Procedure Example: Atomic-Valued Function

```
db2 => SELECT deptno, sumSalaries(deptno) AS sal \
    => FROM department

DEPTNO SAL
------ -----------
A00      128500.00
B01       41250.00
C01       90470.00
D01              -
D11      222100.00
D21      150920.00
E01       40175.00
E11      104990.00
E21       95310.00

  9 record(s) selected.
```


A Stored Procedure Example: Table-Valued Function

```
CREATE FUNCTION deptSalariesF(dept CHAR(3))
    RETURNS TABLE(salary DECIMAL(9,2))
    LANGUAGE SQL
RETURN
    SELECT salary
    FROM employee
    WHERE workdept = dept
```

A Stored Procedure Example: Table-Valued Function

```
db2 => SELECT * FROM TABLE \
    => (deptSalariesF(CAST('A00' AS CHAR(3)))) AS s

SALARY
------------
   52750.00
   46500.00
   29250.00

  3 record(s) selected.
```


A Stored Procedure Example: Branching

```
CREATE PROCEDURE UPDATE_SALARY_IF
      (IN employee_number CHAR(6), INOUT rating SMALLINT)
   LANGUAGE SQL
BEGIN
   DECLARE not_found CONDITION FOR SQLSTATE '02000';
   DECLARE EXIT HANDLER FOR not_found
      SET rating = -1;
   IF rating = 1 THEN
      UPDATE employee
      SET salary = salary * 1.10, bonus = 1000
      WHERE empno = employee_number;
   ELSEIF rating = 2 THEN
      UPDATE employee
      SET salary = salary * 1.05, bonus = 500
      WHERE empno = employee_number;
   ELSE
      UPDATE employee
      SET salary = salary * 1.03, bonus = 0
      WHERE empno = employee_number;
   END IF;
END
```