SQL Application Development

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CS 348
Introduction to Database Management
Winter 2017
SQL APIs

- Interactive SQL command interpreters (e.g., DB2’s command line processor) are simply domain-independent client programs that interact with an SQL database server.
- In general, it is necessary to write other client programs for specific applications.
- SQL has “bindings” for various programming languages that describe how applications written in those languages can be made to interact with a database server.
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**Note**

*The main problem is the “impedance mismatch” between set-oriented SQL and the application programming language. How should data be passed back and forth between the two?*
Outline

1 Embedded SQL
   Static Embedded SQL
   Dynamic Embedded SQL
   SQLJ

2 Call Level Interfaces

3 Stored Procedures
Development Process for Embedded SQL Applications

SOURCE CODE
EMBEDDED SQL

EMBEDDED SQL
PREPROCESSOR

SOURCE CODE

General structure
Development Process for Embedded SQL Applications

General structure

- SOURCE CODE
- EMBEDDED SQL
- EMBEDDED SQL PREPROCESSOR
- SOURCE CODE

EMBEDDED SQL / C SOURCE

EMBEDDED SQL PREPROCESSOR

C SOURCE

C COMPILER

OBJECT CODE

OBJECT CODE

LINKER

EXECUTABLE

CS 348 (Intro to DB Mgmt)
#include <stdio.h>
EXEC SQL INCLUDE SQLCA;
main() {
    EXEC SQL WHENEVER SQLERROR GOTO error;
    EXEC SQL CONNECT TO sample;
    EXEC SQL UPDATE Employee
        SET salary = 1.1*salary
        WHERE empno = '000370';
    EXEC SQL COMMIT WORK;
    EXEC SQL CONNECT RESET;
    return(0);
error:
    printf("update failed, sqlcode = \%ld\n",SQLCODE);
    EXEC SQL ROLLBACK WORK
    return(-1);
}
Static Embedded SQL

- SQL DML and DDL can be embedded in a C program by prefixing with “EXEC SQL” and suffixing with “;”.

- host variables are used to send and receive values from the database system
  - values can be sent by using host variables in place of constants.
  - values can be received by using host variables in an INTO clause.

Note

The SELECT statement is (potentially) different in embedded SQL.
EXEC SQL BEGIN DECLARE SECTION;
char deptno[4];
char deptname[30];
char mgrno[7];
char admrdept[4];
char location[17];
EXEC SQL END DECLARE SECTION;

/* program assigns values to variables */

EXEC SQL INSERT INTO Department (deptno, deptname, mgrno, admrdept, location) VALUES (:deptno, :deptname, :mgrno, :admrdept, :location);
## Domain and Type Correspondence

<table>
<thead>
<tr>
<th>Domain</th>
<th>C Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTEGER</td>
<td>long int v;</td>
</tr>
<tr>
<td>SMALLINT</td>
<td>short int v;</td>
</tr>
<tr>
<td>REAL</td>
<td>float v;</td>
</tr>
<tr>
<td>DOUBLE</td>
<td>double v;</td>
</tr>
<tr>
<td>CHAR($n$)</td>
<td>char v[$n$+1];</td>
</tr>
<tr>
<td>VARCHAR($n$)</td>
<td>char v[$n$+1]; or</td>
</tr>
<tr>
<td></td>
<td>struct tag { short int len; char v[$n$]; }</td>
</tr>
<tr>
<td>DATE</td>
<td>char v[11];</td>
</tr>
</tbody>
</table>

### Note

*Each SQL domain (type) corresponds to a type in the host language. See, e.g., the DB2 Application Development Guide for complete list.*
Queries Using INTO

```c
int PrintEmployeeName( char employeenum[] ) {

EXEC SQL BEGIN DECLARE SECTION;
    char empno[7];
    char fname[16];
    char lname[16];
EXEC SQL END DECLARE SECTION;
strcpy(empno,employeenum);
EXEC SQL
    SELECT firstname, lastname INTO :fname, :lname
    FROM employee
    WHERE empno = :empno;
if( SQLCODE < 0 ) { return( -1 ); } /* error */
else if(SQLCODE==100){printf("no such employee\n");}
else { printf("%s\n",lname); }  
return( 0 );
}
```
• What if a returned value is NULL?
• What if a returned value is NULL?
  • NULLs are handled using special flags called *indicator variables*.
  • Any host variable that might receive a NULL should have a corresponding indicator variable.
  • In C/C++, indicator variables are *short ints*
int PrintEmployeePhone( char employeenum[] ) {
    EXEC SQL BEGIN DECLARE SECTION;
    char empno[7];
    char phonenum[5];
    short int phoneind;
    EXEC SQL END DECLARE SECTION;
    strcpy(empno,employeenum);
    EXEC SQL
        SELECT phoneno INTO :phonenum :phoneind
        FROM employee WHERE empno = :empno;
    if( SQLCODE < 0) { return( -1 ); } /* error */
    else if(SQLCODE==100){printf("no such employee\n");}
    else if (phoneind<0){printf("phone unknown\n");}
    else { printf("%s\n",phonenum); }
    return( 0 );
}
Cursors

- If a query may return more than one row, then a cursor must be used to retrieve values from the result.
- A cursor is like a pointer that refers to some row of the result. At any time, a cursor may be in one of three places:
  - before first tuple
  - on a tuple
  - after last tuple

<table>
<thead>
<tr>
<th></th>
<th>BEFORE FIRST TUPLE</th>
<th>−n - 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>−n</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>−n + 1</td>
</tr>
<tr>
<td>n</td>
<td></td>
<td>−2</td>
</tr>
<tr>
<td>n</td>
<td></td>
<td>−1</td>
</tr>
<tr>
<td>n + 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AFTER LAST TUPLE</td>
<td></td>
</tr>
</tbody>
</table>
Using Cursors

1. Declare the cursor
   - Declaring a cursor associates a cursor identifier with a query.

2. Open the cursor
   - Opening a cursor (conceptually) causes the query to be evaluated, generating a result.

3. Fetch one or more tuples using the cursor
   - Each call to the FETCH command returns values from one tuple of the generated result.

4. Close the cursor
The FETCH Command Syntax

`fetch [ <location> ] <cursor-name>
[ INTO <host-var1>, <host-var2> ... ]`

- Possible locations:
  - NEXT (this is the default)
  - PRIOR
  - FIRST
  - LAST
  - ABSOLUTE $n$
  - RELATIVE $n$

Unfortunately, locations cannot be specified in DB2
int PrintEmpNames() {
    int rval; /* -1 for error, 0 for success */
    EXEC SQL BEGIN DECLARE SECTION;
    char fullname[30];
    EXEC SQL END DECLARE SECTION;
    EXEC SQL DECLARE C1 CURSOR FOR
        SELECT firstname || ' ' || lastname FROM Employee;
    EXEC SQL OPEN C1;
    for( ;; ) {
        EXEC SQL FETCH NEXT C1 INTO :fullname;
        if (SQLCODE == 100) { rval = 0; break; } 
        else if (SQLCODE < 0) { rval = -1; break;} 
        printf("%s\n", fullname );
    }
    EXEC SQL CLOSE C1;
    return(rval); }
• Must be used when tables, columns or predicates are not known at the time the application is written.
Dynamic Embedded SQL

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- Basic idea:
  1. prepare the statement for execution: PREPARE
     - in static embedded SQL programs, statement preparation is handled at compile time by the preprocessor
  2. execute the prepared statement: EXECUTE
Dynamic Embedded SQL

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- Basic idea:
  1. prepare the statement for execution: PREPARE
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  2. execute the prepared statement: EXECUTE
- Once prepared, a statement may be executed multiple times, if desired
EXEC SQL BEGIN DECLARE SECTION;
char s[100] =
"INSERT INTO department VALUES ('000456','Legal',..)";
EXEC SQL END DECLARE SECTION;
EXEC SQL EXECUTE IMMEDIATE :s;

or, to factor cost of “preparing”

EXEC SQL BEGIN DECLARE SECTION;
char s[100] =
"INSERT INTO department VALUES ('000456','Legal',..)";
EXEC SQL END DECLARE SECTION;
EXEC SQL PREPARE S1 FROM :s;
EXEC SQL EXECUTE S1;
EXEC SQL EXECUTE S1;
Dynamic Embedded SQL: Using Host Variables for Input

EXEC SQL BEGIN DECLARE SECTION;
char s[100] = "INSERT INTO employee VALUES (?, ?, ... )";
char empno[7];
char firstname[13];
...
EXEC SQL END DECLARE SECTION;

EXEC SQL PREPARE S1 FROM :s;
strcpy(empno,"000111");
strcpy(firstname,"Ken");
...
EXEC SQL EXECUTE S1 USING :empno, :firstname, ... ;
Placeholders

- In the query string
  "INSERT INTO employee VALUES (?, ?, ... )";
  the ? are called placeholders
- placeholders can appear where literals can appear - not in place of relation names, column names, etc.
- host variable values replace the placeholders when the prepared statement is executed
- the USING clause is used to specify which host variables should replace the placeholders:
  EXEC SQL EXECUTE S1 USING :empno, :firstname, ... ;
- USING can only use used with previously-prepared statements, not with EXECUTE IMMEDIATE
Dynamic Single-Row Queries

EXEC SQL BEGIN DECLARE SECTION;
char s[100] = 
  "select lastname,salary from employee where empno = ?"
char empno[7];
char lastname[16];
double salary;
short int salaryind;
EXEC SQL END DECLARE SECTION;
EXEC SQL PREPARE S1 FROM :s;
EXEC SQL EXECUTE S1
  INTO :lastname, :salary :salaryind USING :empno

• INTO (with EXECUTE) in dynamic SQL is like INTO (with SELECT) in static
• Note: our DB2 version does not allow the use of INTO with EXECUTE. A dynamic cursor must be used to retrieve values.
Dynamic Cursors

```sql
EXEC SQL BEGIN DECLARE SECTION;
char s[100] = 
"select lastname,salary from employee where edlevel = ?" 
short int edlevel;
char lastname[16];
double salary;
short int salaryind;
EXEC SQL END DECLARE SECTION;
EXEC SQL PREPARE S1 FROM :s;
EXEC SQL DECLARE C1 CURSOR FOR S1;
edlevel = 18;
EXEC SQL OPEN C1 USING :edlevel;
while( ... ) {
    EXEC SQL FETCH FROM C1
    INTO :lastname, :salary:salaryind;
}
```
Descriptors and the SQLDA

- if the numbers and types of input and output values are not known in advance, SQL descriptors can be used determine them at run-time
- an SQLDA (descriptor area) is used to hold a description of the structure (number of attributes and their types) of a query result.
- the DESCRIBE command can be used to populate a descriptor area, that is, to find out the structure of a query result
- SQLJ allows embedding of SQL into Java
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- Like Embedded SQL, utilizes preprocessing step
  - static type checking against database schema
  - DBMS can optimize static queries at compile time

Unlike Embedded SQL, runtime connection established via JDBC connection
forces compliance to SQL standard syntax
• SQLJ allows embedding of SQL into Java
• Not part of SQL standard, but supported by most DBMSs
• Like Embedded SQL, utilizes preprocessing step
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  • DBMS can optimize static queries at compile time
• Unlike Embedded SQL, runtime connection established via JDBC connection
  • forces compliance to SQL standard syntax
JDBC, ODBC and CLI

- CLI (Call-Level Interface) is a vendor-neutral ISO standard programming interface for SQL database systems. It is similar to ODBC.
- ODBC (Open Database Connectivity), popularized by Microsoft, is a programming interface for SQL database systems.
- JDBC (Java Database Connectivity) is a collection of Java classes that provide an ODBC/CLI-like programming interface.
- Why?
  - An embedded SQL program used to access one DBMS must be recompiled before it can be used to access a different DBMS.
  - A CLI/ODBC/JDBC program need not be recompiled - a single application may even access multiple DBMS at the same time.
Main ideas for both dynamic SQL and CLI/ODBC/JDBC

1. Queries are represented as strings in the application.
2. Queries are prepared and then executed.
3. In general, app will not know number and type of input parameters and number and type of output parameters - descriptor areas are used to hold type info (meta data) and actual data.
   - “describing” a query causes DBMS to analyze query and place type info into descriptor area.
   - app can read type info.
   - app can place data into descriptor (or into vars to which descriptor points) before executing the query, and can place result data into the descriptor through a cursor afterwards.
A CLI Example

SQLHANDLE henv;    /* an environment handle */
SQLHANDLE hdbc;    /* a connection handle */
SQLHANDLE hstmt;   /* a statement handle */
SQLCHAR numteamsquery[] = "select count(*) from teams";
SQLAllocHandle(SQL_HANDLE_ENV, SQL_NULL_HANDLE, &henv);
DBconnect(henv,&hdbc,server,uid,pwd);
SQLAllocHandle(SQL_HANDLE_STMT, hdbc, &hstmt);
SQLExecDirect(hstmt,numteamsquery,SQL_NTS); /* execute */
SQLFetch(hstmt);    /* get one row of the result */
SQLGetData(hstmt,1,SQL_C_LONG,&numteams,sizeof(numteams),&bytesremaining);
SQLFreeStmt(hstmt,SQL_CLOSE); /* close the statement */

Note

CLI/ODBC interface is similar to dynamic embedded SQL, but syntax is entirely valid host language.
Idea

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

<table>
<thead>
<tr>
<th>DEPTNO</th>
<th>SAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>A00</td>
<td>128500.00</td>
</tr>
<tr>
<td>B01</td>
<td>41250.00</td>
</tr>
<tr>
<td>C01</td>
<td>90470.00</td>
</tr>
<tr>
<td>D01</td>
<td>-</td>
</tr>
<tr>
<td>D11</td>
<td>222100.00</td>
</tr>
<tr>
<td>D21</td>
<td>150920.00</td>
</tr>
<tr>
<td>E01</td>
<td>40175.00</td>
</tr>
<tr>
<td>E11</td>
<td>104990.00</td>
</tr>
<tr>
<td>E21</td>
<td>95310.00</td>
</tr>
</tbody>
</table>

9 record(s) selected.
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: Multiple Results

CREATE PROCEDURE deptSalariesP(IN dept CHAR(3))
RESULT SETS 2
LANGUAGE SQL
BEGIN

DECLARE emp_curs CURSOR WITH RETURN FOR
SELECT salary
FROM employee
WHERE workdept = dept;

DECLARE dept_curs CURSOR WITH RETURN FOR
SELECT deptno, sumSalaries(deptno) as sumsal
FROM department;

OPEN emp_curs;
OPEN dept_curs;
END
A Stored Procedure Example: Multiple Results

db2 => call deptSalariesP('A00')

<table>
<thead>
<tr>
<th>SALARY</th>
<th>SUMSAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>52750.00</td>
<td></td>
</tr>
<tr>
<td>46500.00</td>
<td></td>
</tr>
<tr>
<td>29250.00</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DEPTNO</th>
<th>SUMSAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>A00</td>
<td>128500.00</td>
</tr>
<tr>
<td>B01</td>
<td>41250.00</td>
</tr>
<tr>
<td>C01</td>
<td>90470.00</td>
</tr>
<tr>
<td>D01</td>
<td>NULL</td>
</tr>
<tr>
<td>D11</td>
<td>222100.00</td>
</tr>
<tr>
<td>D21</td>
<td>150920.00</td>
</tr>
<tr>
<td>E01</td>
<td>40175.00</td>
</tr>
<tr>
<td>E11</td>
<td>104990.00</td>
</tr>
<tr>
<td>E21</td>
<td>95310.00</td>
</tr>
</tbody>
</table>

"DEPTSALARIESP" RETURN_STATUS: "0"
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