SQL Application Development

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Notes

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

Note

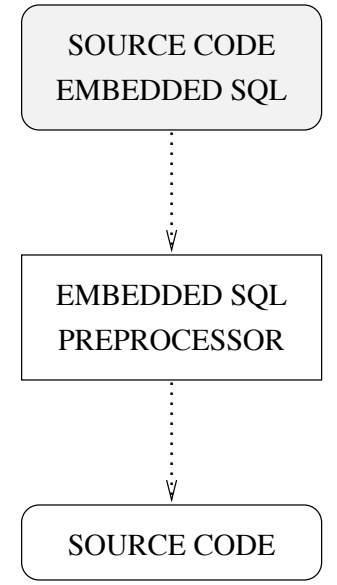
The main problem is the "impedance mismatch" between set-oriented SQL and the application programming language. How should data be passed back and forth between the two?

Notes

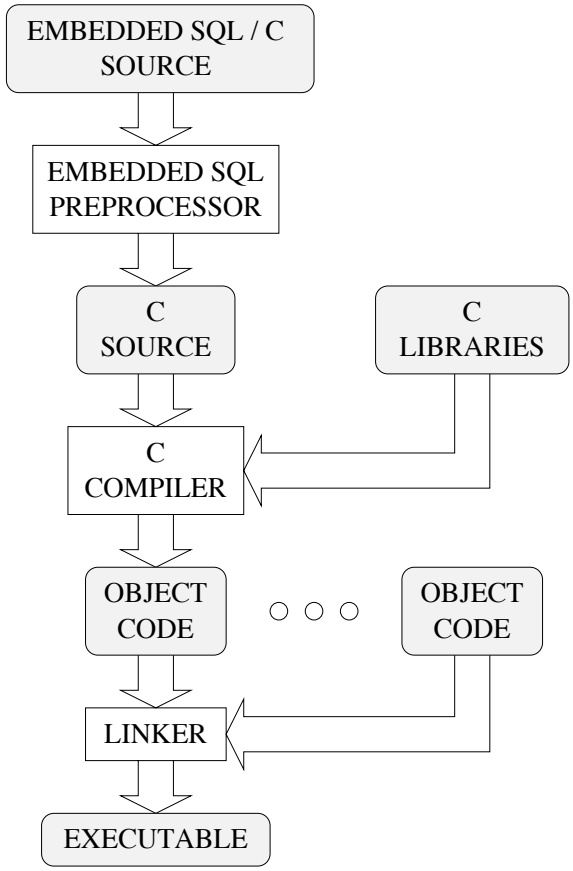
Outline

Notes

Development Process for Embedded SQL Applications



General structure



Notes

A Simple Example

```
#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);
}
```


Notes

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.

Notes

Declaring Host Variables

```
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);
```


Notes

Domain and Type Correspondence

Domain	C Type
INTEGER	long int v;
SMALLINT	short int v;
REAL	float v;
DOUBLE	double v;
CHAR(n)	char v[n+1];
VARCHAR(n)	char v[n+1]; or struct tag { short int len; char v[n]; }
DATE	char v[11];

Note

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

Notes

Queries Using INTO

```
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 );
}
```


Notes

Indicator Variables

- 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 int`s

Notes

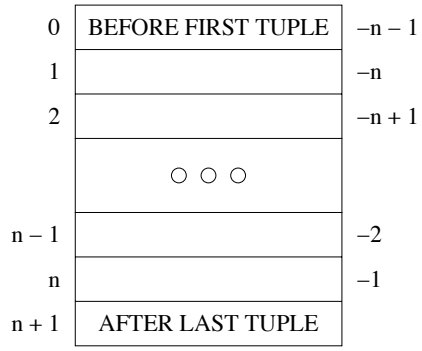
Indicator Variables: An Example

```
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 );
}
```


Notes

Cursors

- If a query may return more than one row, then a *cursor* must be use 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



Notes

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

Notes

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

Notes

Using Cursors: An Example

```
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); }
```


Notes

Dynamic Embedded SQL

- Must be used when tables, columns or predicates are not known at the time the application is written.
- 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
- Once prepared, a statement may be executed multiple times, if desired

Notes

Dynamic Embedded SQL: A Simple Example

```
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;
```


Notes

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, ... ;
```


Notes

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, :firsname, ... ;
  ```
- `USING` can only use used with previously-prepared statements, not with `EXECUTE IMMEDIATE`

Notes

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.

Notes

Dynamic Cursors

```
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;
}
```


Notes

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

Notes

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.

Notes

CLI Overview

- 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.

Notes

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.

Notes

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

Notes

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
```


Notes

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.
```


Notes

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
```


Notes

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.
```


Notes

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
```


Notes

A Stored Procedure Example: Multiple Results

```
db2 => call deptSalariesP('A00')

SALARY
52750.00
46500.00
29250.00

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

"DEPTSALARIESP" RETURN_STATUS: "0"
```


Notes

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
```


Notes