SQL Application Development

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CS 348
Introduction to Database Management
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SQL APIs

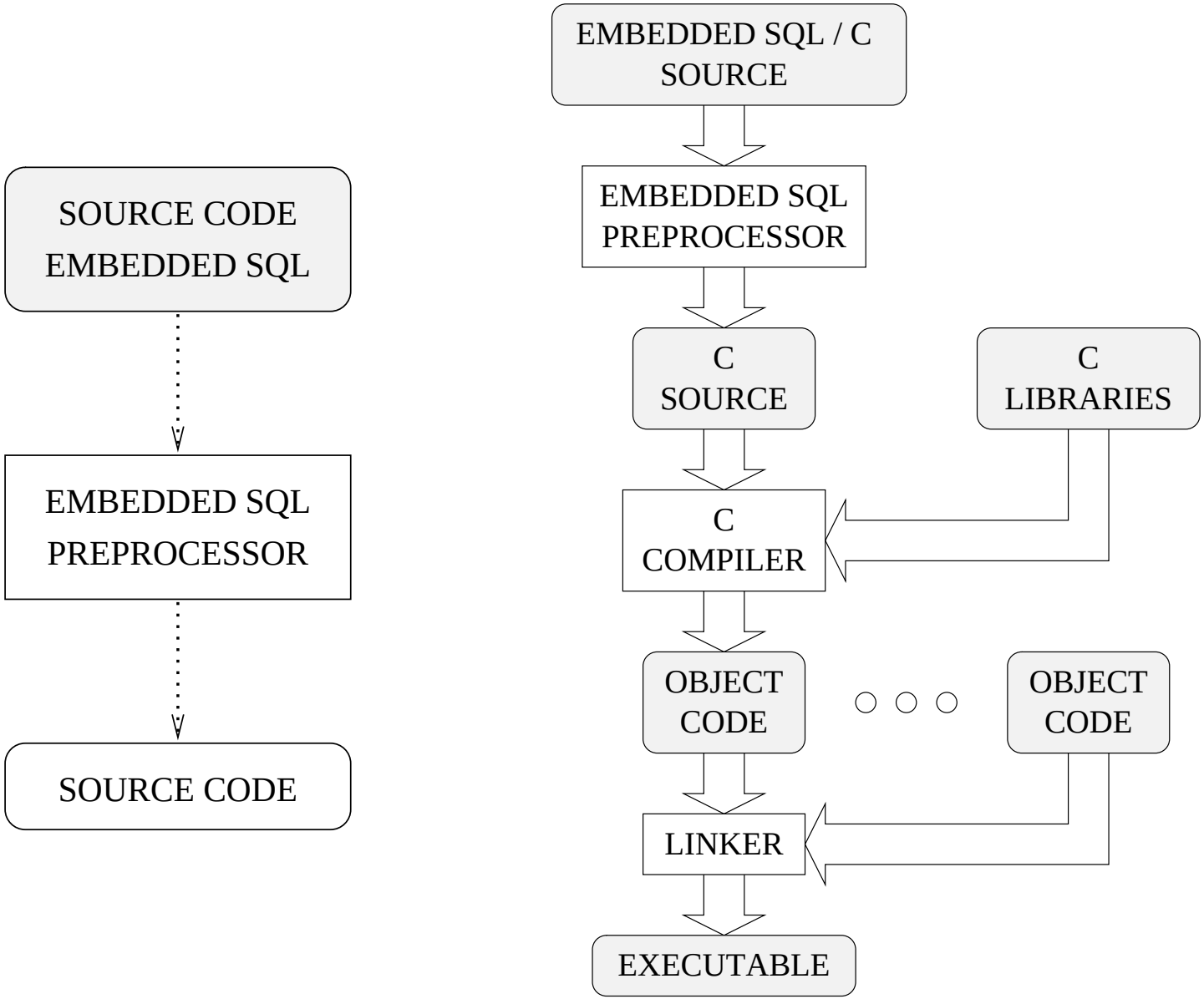
- Interactive SQL command interpreters (e.g., DB2's command line processor) are simply domain-independent client programs that interact with an SQL database server
- In general, it is necessary to write other client programs for specific applications
- SQL has "bindings" for various programming languages 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?

Outline

Development Process for Embedded SQL Applications



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 );
   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.

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);
```

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.

Queries Using INTO

- Print the last name of a specified employee.

```
int PrintEmployeeName( char employeenum[] ) {
EXEC SQL BEGIN DECLARE SECTION;
  char empno[7];
  char lastname[16];
EXEC SQL END DECLARE SECTION;
  strcpy(empno,employeenum);
  EXEC SQL
      SELECT lastname INTO :lastname
      FROM employee
      WHERE empno = :empno;
  if( SQLCODE < 0 ) { return( -1 ); } /* error */
  else if(SQLCODE==100){printf("no such employee\n");}
  else { printf("%s\n",lastname); }
  return( 0 );
}
```

Indicator Variables

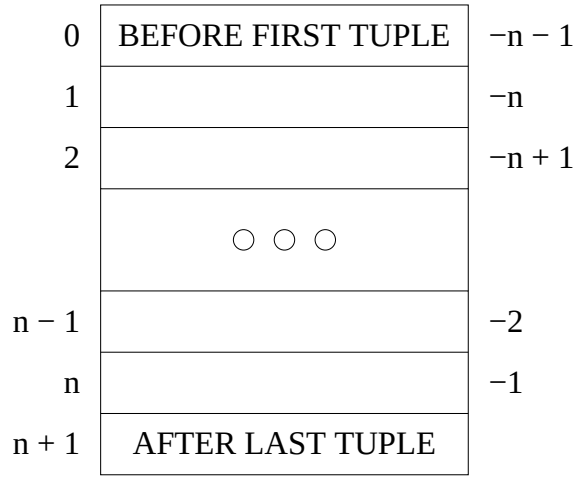
- What if a returned value is NULL?
  - NULLs are handled using special flags called *indicator variables*.
  - Any host variable that might receive a NULL should have a corresponding indicator variable.
  - In C/C++, indicator variables are `short ints`

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 );
}
```

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



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

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 firstnme || ' ' || 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); }
```

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

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;
```

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, :firsname, ... ;
  ```
- 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

```
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

- SQLJ allows embedding of SQL into Java
- Not part of SQL standard, but supported by most DBMSs
- 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

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.
- 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.

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 ); /* execut
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.

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 deptTotalSalaries(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: 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')

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"
```

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
```