



Chapter 10 Outline

- Database Programming: Techniques and Issues
- Embedded SQL, Dynamic SQL, and SQLJ
- Database Programming with Function Calls: SQL/CLI and JDBC
- Database Stored Procedures and SQL/PSM
- Comparing the Three Approaches

Introduction to SQL Programming Techniques

- **Database applications**
 - Host language
 - Java, C/C++/C#, COBOL, or some other programming language
 - Data sublanguage
 - SQL
- **SQL standards**
 - Continually evolving
 - Each DBMS vendor may have some variations from standard

Database Programming: Techniques and Issues

- **Interactive interface**
 - SQL commands typed directly into a monitor
- **Execute file of commands**
 - *@<filename>*
- **Application programs or database applications**
 - Used as canned transactions by the end users access a database
 - May have **Web interface**

Approaches to Database Programming

- **Embedding** database commands in a general-purpose programming language
 - Database statements identified by a special prefix
 - **Precompiler** or **preprocessor** scans the source program code
 - Identify database statements and extract them for processing by the DBMS
 - Called **embedded SQL**

EMPLOYEE

Fname	Minit	Lname	<u>Ssn</u>	Bdate	Address	Sex	Salary	Super_ssn	Dno
-------	-------	-------	------------	-------	---------	-----	--------	-----------	-----

Approaches to Database Programming (cont'd.)

- Using a library of database functions
 - **Library of functions** available to the host programming language
 - **Application programming interface (API)**

Approaches to Database Programming (cont'd.)

- Designing a brand-new language
 - **Database programming language** designed from scratch (Oracle PL SQL)
 - Use of Loops, If statement etc.

Impedance Mismatch

- Differences between database model and programming language model
- **Binding** for each host programming language
 - Specifies for each attribute type the compatible programming language types
- Cursor or iterator variable
 - Loop over the tuples in a query result

Typical Sequence of Interaction in Database Programming

- Open a connection to database server
 - (use database name, password, etc.
- Interact with database by submitting queries, updates, and other database commands
- Terminate or close connection to database

Embedded SQL, Dynamic SQL, and SQLJ

- **Embedded SQL**
 - C language
- **SQLJ**
 - Java language
- Programming language called **host language**

Retrieving Single Tuples with Embedded SQL

- EXEC SQL
 - Prefix
 - **Preprocessor** separates embedded SQL statements from host language code
 - Terminated by a matching END-EXEC
 - Or by a semicolon (;)
- **Shared variables**
 - Used in both the C program and the embedded SQL statements
 - Prefixed by a colon (:) in SQL statement

Figure 10.1 C program variables used in the embedded SQL examples E1 and E2.

```
0) int loop ;
1) EXEC SQL BEGIN DECLARE SECTION ;
2) varchar dname [16], fname [16], lname [16], address [31] ;
3) char ssn [10], bdate [11], sex [2], minit [2] ;
4) float salary, raise ;
5) int dno, dnumber ;
6) int SQLCODE ; char SQLSTATE [6] ;
7) EXEC SQL END DECLARE SECTION ;
```

EMPLOYEE

Fname	Minit	Lname	<u>Ssn</u>	Bdate	Address	Sex	Salary	Super_ssn	Dno
-------	-------	-------	------------	-------	---------	-----	--------	-----------	-----

Retrieving Single Tuples with Embedded SQL (cont'd.)

- Connecting to the database

```
CONNECT TO <server name>AS <connection name>  
AUTHORIZATION <user account name and password> ;
```

- Change connection

```
SET CONNECTION <connection name> ;
```

- Terminate connection

```
DISCONNECT <connection name> ;
```

Retrieving Single Tuples with Embedded SQL (cont'd.)

- **SQLCODE** and **SQLSTATE** communication variables
 - Used by DBMS to communicate exception or error conditions
- **SQLCODE** variable
 - 0 = statement executed successfully
 - 100 = no more data available in query result
 - < 0 = indicates some error has occurred

Retrieving Single Tuples with Embedded SQL (cont'd.)

- **SQLSTATE**
 - String of five characters
 - '00000' = no error or exception
 - Other values indicate various errors or exceptions
 - For example, '02000' indicates 'no more data' when using SQLSTATE

Figure 10.2 Program segment E1, a C program segment with embedded SQL.

```
0) int loop ;
1) EXEC SQL BEGIN DECLARE SECTION ;
2) varchar dname [16], fname [16], lname [16], address [31] ;
3) char ssn [10], bdate [11], sex [2], minit [2] ;
4) float salary, raise ;
5) int dno, dnumber ;
6) int SQLCODE ; char SQLSTATE [6] ;
7) EXEC SQL END DECLARE SECTION ;

//Program Segment E1:
0) loop = 1 ;
1) while (loop) {
2)     prompt("Enter a Social Security Number: ", ssn) ;
3)     EXEC SQL
4)         SELECT Fname, Minit, Lname, Address, Salary
5)         INTO :fname :minit, :lname, :address, :salary
6)         FROM EMPLOYEE WHERE Ssn = :ssn ;
7)     if (SQLCODE == 0) printf(fname, minit, lname, address, salary)
8)     else printf("Social Security Number does not exist: ", ssn) ;
9)     prompt("More Social Security Numbers (enter 1 for Yes, 0 for No): ", loop) ;
10) }
```

Result:
One row only

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
-------	-------	-------	-----	-------	---------	-----	--------	-----------	-----

Retrieving Multiple Tuples with Embedded SQL Using Cursors

- **Cursor**
 - Points to a single tuple (row) from result of query
- **OPEN CURSOR** command
 - Fetches query result and sets cursor to a position before first row in result
 - Becomes current row for cursor
- **FETCH** commands
 - Moves cursor to next row in result of query

Figure 10.3 Program segment E2, a C program segment that uses cursors with

```
em //Program Segment E2:
0) prompt("Enter the Department Name: ", dname) ;
1) EXEC SQL
2)   SELECT Dnumber INTO :dnumber
3)   FROM DEPARTMENT WHERE Dname = :dname ;
4) EXEC SQL DECLARE EMP CURSOR FOR
5)   SELECT Ssn, Fname, Minit, Lname, Salary
6)   FROM EMPLOYEE WHERE Dno = :dnumber
7)   FOR UPDATE OF Salary ;
8) EXEC SQL OPEN EMP ;
9) EXEC SQL FETCH FROM EMP INTO :ssn, :fname, :minit, :lname, :salary ;
10) while (SQLCODE == 0) {
11)   printf("Employee name is:", Fname, Minit, Lname) ;
12)   prompt("Enter the raise amount: ", raise) ;
13)   EXEC SQL
14)     UPDATE EMPLOYEE
15)     SET Salary = Salary + :raise
16)     WHERE CURRENT OF EMP ;
17)   EXEC SQL FETCH FROM EMP INTO :ssn, :fname, :minit, :lname, :salary ;
18) }
19) EXEC SQL CLOSE EMP ;
```

Result:
many rows→
Use CURSOR

Retrieving Multiple Tuples with Embedded SQL Using Cursors (cont'd.)

■ Fetch orientation

- Added using value: NEXT, PRIOR, FIRST, LAST, ABSOLUTE *i*, and RELATIVE *i*

```
DECLARE <cursor name> [ INSENSITIVE ] [ SCROLL ] CURSOR  
[ WITH HOLD ] FOR <query specification>  
[ ORDER BY <ordering specification> ]  
[ FOR READ ONLY | FOR UPDATE [ OF <attribute list> ] ] ;
```

Specifying Queries at Runtime Using Dynamic SQL

- **Dynamic SQL**
 - Execute different SQL queries or updates dynamically at runtime
- Dynamic update
- Dynamic query

Figure 10.4 Program segment E3, a C program segment that uses dynamic SQL for updating a table.

```
//Program Segment E3:  
0) EXEC SQL BEGIN DECLARE SECTION ;  
1) varchar sqlupdatestring [256] ;  
2) EXEC SQL END DECLARE SECTION ;  
   ...  
3) prompt("Enter the Update Command: ", sqlupdatestring) ;  
4) EXEC SQL PREPARE sqlcommand FROM :sqlupdatestring ;  
5) EXEC SQL EXECUTE sqlcommand ;  
   ...
```

SQLJ: Embedding SQL Commands in Java

- Standard adopted by several vendors for embedding SQL in Java
- Import several class libraries
- **Default context**
- Uses **exceptions** for error handling
 - `SQLException` is used to return errors or exception conditions

Figure 10.5 Importing classes needed for including SQLJ in Java programs in Oracle, and establishing a connection and default context.

```
1) import java.sql.* ;
2) import java.io.* ;
3) import sqlj.runtime.* ;
4) import sqlj.runtime.ref.* ;
5) import oracle.sqlj.runtime.* ;
...
6) DefaultContext cntxt =
7) oracle.getConnection("<url name>", "<user name>", "<password>", true) ;
8) DefaultContext.setDefaultContext(cntxt) ;
...
```

Figure 10.6 Java program variables used in SQLJ examples J1 and J2.

Figure 10.7 Program segment J1, a Java program segment with SQLJ.

```
1) string dname, ssn , fname, fn, lname, ln,  
    bdate, address ;  
2) char sex, minit, mi ;  
3) double salary, sal ;  
4) integer dno, dnumber ;
```

**Result:
One row only**

//Program Segment J1:

```
1) ssn = readEntry("Enter a Social Security Number: ") ;  
2) try {  
3)     #sql { SELECT Fname, Minit, Lname, Address, Salary  
4)         INTO :fname, :minit, :lname, :address, :salary  
5)         FROM EMPLOYEE WHERE Ssn = :ssn} ;  
6) } catch (SQLException se) {  
7)     System.out.println("Social Security Number does not exist: " + ssn) ;  
8)     Return ;  
9) }  
10) System.out.println(fname + " " + minit + " " + lname + " " + address  
    + " " + salary)
```

EMPLOYEE

Fname	Minit	Lname	<u>Ssn</u>	Bdate	Address	Sex	Salary	Super_ssn	Dno
-------	-------	-------	------------	-------	---------	-----	--------	-----------	-----

Retrieving Multiple Tuples in SQLJ Using Iterators

- **Iterator**

- Object associated with a collection (set or multiset) of records in a query result

- **Named iterator**

- Associated with a query result by listing attribute names and types in query result

- **Positional iterator**

- Lists only attribute types in query result

Figure 10.8 Program segment J2A, a Java program segment that uses a **named iterator** to print employee information in a particular department.

```
//Program Segment J2A:
0) dname = readEntry("Enter the Department Name: ") ;
1) try {
2)     #sql { SELECT Dnumber INTO :dnumber
3)         FROM DEPARTMENT WHERE Dname = :dname} ;
4) } catch (SQLException se) {
5)     System.out.println("Department does not exist: " + dname) ;
6)     Return ;
7) }
8) System.out.println("Employee information for Department: " + dname) ;
9) #sql iterator Emp(String ssn, String fname, String minit, String lname,
    double salary) ;
10) Emp e = null ;
11) #sql e = { SELECT ssn, fname, minit, lname, salary
12)     FROM EMPLOYEE WHERE Dno = :dnumber} ;
13) while (e.next()) {
14)     System.out.println(e.ssn + " " + e.fname + " " + e.minit + " " +
        e.lname + " " + e.salary) ;
15) } ;
16) e.close() ;
```

Result:
many rows →
Use iterator

Figure 10.9 Program segment J2B, a Java program segment that uses a **positional iterator** to print employee information in a particular department.

```
//Program Segment J2B:
0) dname = readEntry("Enter the Department Name: ") ;
1) try {
2)     #sql { SELECT Dnumber INTO :dnumber
3)         FROM DEPARTMENT WHERE Dname = :dname} ;
4) } catch (SQLException se) {
5)     System.out.println("Department does not exist: " + dname) ;
6)     Return ;
7) }
8) System.out.println("Employee information for Department: " + dname) ;
9) #sql iterator Emppos(String, String, String, String, double) ;
10) Emppos e = null ;
11) #sql e = { SELECT ssn, fname, minit, lname, salary
12)     FROM EMPLOYEE WHERE Dno = :dnumber} ;
13) #sql { FETCH :e INTO :ssn, :fn, :mi, :ln, :sal} ;
14) while (!e.endFetch()) {
15)     System.out.println(ssn + " " + fn + " " + mi + " " + ln + " " + sal) ;
16)     #sql { FETCH :e INTO :ssn, :fn, :mi, :ln, :sal} ;
17) } ;
18) e.close() ;
```

Database Programming with Function Calls: SQL/CLI & JDBC

- Use of function calls
 - **Dynamic** approach for database programming
- Library of functions
 - Also known as **application programming interface (API)**
 - Used to access database
- **SQL Call Level Interface (SQL/CLI)**
 - Part of SQL standard

SQL/CLI: Using C as the Host Language

- **Environment record**

- Track one or more database connections
- Set environment information

- **Connection record**

- Keeps track of information needed for a particular database connection

- **Statement record**

- Keeps track of the information needed for one SQL statement

SQL/CLI: Using C as the Host Language (cont'd.)

- **Description record**
 - Keeps track of information about tuples or parameters
- **Handle to the record**
 - C pointer variable makes record accessible to program

Figure 10.10 Program segment CLI1, a C program segment with SQL/CLI.

```
//Program CLI1:
0) #include sqlcli.h ;
1) void printSal() {
2) SQLHSTMT stmt1 ;
3) SQLHDBC con1 ;
4) SQLHENV env1 ;
5) SQLRETURN ret1, ret2, ret3, ret4 ;
6) ret1 = SQLAllocHandle(SQL_HANDLE_ENV, SQL_NULL_HANDLE, &env1) ;
7) if (!ret1) ret2 = SQLAllocHandle(SQL_HANDLE_DBC, env1, &con1) else exit ;
8) if (!ret2) ret3 = SQLConnect(con1, "dbs", SQL_NTS, "js", SQL_NTS, "xyz",
    SQL_NTS) else exit ;
9) if (!ret3) ret4 = SQLAllocHandle(SQL_HANDLE_STMT, con1, &stmt1) else exit ;
10) SQLPrepare(stmt1, "select Lname, Salary from EMPLOYEE where Ssn = ?",
    SQL_NTS) ;
11) prompt("Enter a Social Security Number: ", ssn) ;
12) SQLBindParameter(stmt1, 1, SQL_CHAR, &ssn, 9, &fetchlen1) ;
13) ret1 = SQLExecute(stmt1) ;
14) if (!ret1) {
15)     SQLBindCol(stmt1, 1, SQL_CHAR, &lname, 15, &fetchlen1) ;
16)     SQLBindCol(stmt1, 2, SQL_FLOAT, &salary, 4, &fetchlen2) ;
17)     ret2 = SQLFetch(stmt1) ;
18)     if (!ret2) printf(ssn, lname, salary)
19)     else printf("Social Security Number does not exist: ", ssn) ;
20) }
21) }
```

Figure 10.11 Program segment CLI2, a C program segment that uses SQL/CLI for a query with a **collection of tuples** in its result.

```
//Program Segment CLI2:
0) #include sqlcli.h ;
1) void printDepartmentEmps() {
2) SQLHSTMT stmt1 ;
3) SQLHDBC con1 ;
4) SQLHENV env1 ;
5) SQLRETURN ret1, ret2, ret3, ret4 ;
6) ret1 = SQLAllocHandle(SQL_HANDLE_ENV, SQL_NULL_HANDLE, &env1) ;
7) if (!ret1) ret2 = SQLAllocHandle(SQL_HANDLE_DBC, env1, &con1) else exit ;
8) if (!ret2) ret3 = SQLConnect(con1, "dbs", SQL_NTS, "js", SQL_NTS, "xyz",
    SQL_NTS) else exit ;
9) if (!ret3) ret4 = SQLAllocHandle(SQL_HANDLE_STMT, con1, &stmt1) else exit ;
10) SQLPrepare(stmt1, "select Lname, Salary from EMPLOYEE where Dno = ?",
    SQL_NTS) ;
11) prompt("Enter the Department Number: ", dno) ;
12) SQLBindParameter(stmt1, 1, SQL_INTEGER, &dno, 4, &fetchlen1) ;
13) ret1 = SQLExecute(stmt1) ;
14) if (!ret1) {
15)     SQLBindCol(stmt1, 1, SQL_CHAR, &lname, 15, &fetchlen1) ;
16)     SQLBindCol(stmt1, 2, SQL_FLOAT, &salary, 4, &fetchlen2) ;
17)     ret2 = SQLFetch(stmt1) ;
18)     while (!ret2) {
19)         printf(lname, salary) ;
20)         ret2 = SQLFetch(stmt1) ;
21)     }
22) }
23) }
```


JDBC: SQL Function Calls for Java Programming

- JDBC
 - Java function libraries
- Single Java program can connect to several different databases
 - Called data sources accessed by the Java program
- `Class.forName("oracle.jdbc.driver.OracleDriver")`
 - Load a **JDBC driver** explicitly

JDBC: SQL Function Calls for Java Programming

- **Connection object**
- **Statement object** has two subclasses:
 - PreparedStatement and CallableStatement
- **Question mark (?) symbol**
 - Represents a statement parameter
 - Determined at runtime
- **ResultSet object**
 - Holds results of query

Figure 10.12 Program segment JDBC1, a Java program segment with JDBC.

```
//Program JDBC1:
0) import java.io.* ;
1) import java.sql.*
   ...
2) class getEmpInfo {
3)     public static void main (String args []) throws SQLException, IOException {
4)         try { Class.forName("oracle.jdbc.driver.OracleDriver")
5)             } catch (ClassNotFoundException x) {
6)                 System.out.println ("Driver could not be loaded") ;
7)             }
8)         String dbacct, passwrld, ssn, lname ;
9)         Double salary ;
10)        dbacct = readentry("Enter database account:") ;
11)        passwrld = readentry("Enter password:") ;
12)        Connection conn = DriverManager.getConnection
13)            ("jdbc:oracle:oci8:" + dbacct + "/" + passwrld) ;
14)        String stmt1 = "select Lname, Salary from EMPLOYEE where Ssn = ?" ;
15)        PreparedStatement p = conn.prepareStatement(stmt1) ;
16)        ssn = readentry("Enter a Social Security Number: ") ;
17)        p.clearParameters() ;
18)        p.setString(1, ssn) ;
19)        ResultSet r = p.executeQuery() ;
20)        while (r.next()) {
21)            lname = r.getString(1) ;
22)            salary = r.getDouble(2) ;
23)            system.out.println(lname + salary) ;
24)        } }
25) }
```

Figure 10.13 Program segment JDBC2, a Java program segment that uses JDBC for a query with a **collection of tuples** in its result.

```
//Program Segment JDBC2:
0) import java.io.* ;
1) import java.sql.*
   ...
2) class printDepartmentEmps {
3)     public static void main (String args [])
           throws SQLException, IOException {
4)         try { Class.forName("oracle.jdbc.driver.OracleDriver")
5)         } catch (ClassNotFoundException x) {
6)             System.out.println ("Driver could not be loaded") ;
7)         }
8)         String dbacct, passwr, lname ;
9)         Double salary ;
10)        Integer dno ;
11)        dbacct = readentry("Enter database account:") ;
12)        passwr = readentry("Enter password:") ;
13)        Connection conn = DriverManager.getConnection
14)            ("jdbc:oracle:oci8:" + dbacct + "/" + passwr) ;
15)        dno = readentry("Enter a Department Number: ") ;
16)        String q = "select Lname, Salary from EMPLOYEE where Dno = " +
           dno.toString() ;
17)        Statement s = conn.createStatement() ;
18)        ResultSet r = s.executeQuery(q) ;
19)        while (r.next()) {
20)            lname = r.getString(1) ;
21)            salary = r.getDouble(2) ;
22)            system.out.println(lname + salary) ;
23)        } }
24) }
```

Database Stored Procedures and SQL/PSM

- **Stored procedures**
 - Program modules stored by the DBMS at the database server
 - Can be functions or procedures
- **SQL/PSM (SQL/Persistent Stored Modules)**
 - Extensions to SQL
 - Include general-purpose programming constructs in SQL

```
//Function PSM1:  
0) CREATE FUNCTION Dept_size(IN deptno INTEGER)  
1) RETURNS VARCHAR [7]  
2) DECLARE No_of_ems INTEGER ;  
3) SELECT COUNT(*) INTO No_of_ems  
4) FROM EMPLOYEE WHERE Dno = deptno ;  
5) IF No_of_ems > 100 THEN RETURN "HUGE"  
6) ELSEIF No_of_ems > 25 THEN RETURN "LARGE"  
7) ELSEIF No_of_ems > 10 THEN RETURN "MEDIUM"  
8) ELSE RETURN "SMALL"  
9) END IF ;
```

Database Stored Procedures and Functions

- **Persistent stored modules**
 - Stored persistently by the DBMS
- **Useful:**
 - When database program is needed by several applications
 - To reduce data transfer and communication cost between client and server in certain situations
 - To enhance modeling power provided by views

Database Stored Procedures and Functions (cont'd.)

■ Declaring stored procedures:

```
CREATE PROCEDURE <procedure name> (<parameters>)  
<local declarations>  
<procedure body> ;
```

declaring a function, a return type is necessary,
so the declaration form is

```
CREATE FUNCTION <function name> (<parameters>)  
RETURNS <return type>  
<local declarations>  
<function body> ;
```

Database Stored Procedures and Functions (cont'd.)

- Each parameter has parameter type
 - **Parameter type:** one of the SQL data types
 - **Parameter mode:** IN, OUT, or INOUT
- Calling a stored procedure:
`CALL <procedure or function name>
(<argument list>) ;`

SQL/PSM: Extending SQL for Specifying Persistent Stored Modules

■ Conditional branching statement:

```
IF <condition> THEN <statement list>  
ELSEIF <condition> THEN <statement list>  
...  
ELSEIF <condition> THEN <statement list>  
ELSE <statement list>  
END IF ;
```

SQL/PSM (cont'd.)

■ Constructs for looping

```
WHILE <condition> DO  
    <statement list>
```

```
END WHILE ;
```

```
REPEAT
```

```
    <statement list>
```

```
UNTIL <condition>
```

```
END REPEAT ;
```

```
FOR <loop name> AS <cursor name> CURSOR FOR <query> DO  
    <statement list>
```

```
END FOR ;
```

Figure 10.14 Declaring a function in SQL/PSM.

```
//Function PSM1:  
0) CREATE FUNCTION Dept_size(IN deptno INTEGER)  
1) RETURNS VARCHAR [7]  
2) DECLARE No_of_ems INTEGER ;  
3) SELECT COUNT(*) INTO No_of_ems  
4) FROM EMPLOYEE WHERE Dno = deptno ;  
5) IF No_of_ems > 100 THEN RETURN "HUGE"  
6) ELSEIF No_of_ems > 25 THEN RETURN "LARGE"  
7) ELSEIF No_of_ems > 10 THEN RETURN "MEDIUM"  
8) ELSE RETURN "SMALL"  
9) END IF ;
```

Comparing the Three Approaches

- Embedded SQL Approach
 - Query text checked for syntax errors and validated against database schema at compile time
 - For complex applications where queries have to be generated at runtime
 - Function call approach more suitable

Comparing the Three Approaches (cont'd.)

- Library of Function Calls Approach
 - More flexibility
 - More complex programming
 - No checking of syntax done at compile time
- Database Programming Language Approach
 - Does not suffer from the impedance mismatch problem
 - Programmers must learn a new language

Summary

- Techniques for database programming
 - Embedded SQL
 - SQLJ
 - Function call libraries
 - SQL/CLI standard
 - JDBC class library
 - Stored procedures
 - SQL/PSM