Chapter 9

Introduction to SQL Programming Techniques
Chapter Outline

- 9.1 General Constraints as Assertions
- 9.2 Views in SQL
- 9.3 Database Programming
- 9.4 Embedded SQL
- 9.5 Functions Calls, SQL/CLI
- 9.6 Stored Procedures, SQL/PSM
- 9.7 Summary
Chapter Objectives

- Specification of more general constraints via assertions
- SQL facilities for defining views (virtual tables)
- Various techniques for accessing and manipulating a database via programs in general-purpose languages
  - E.g., Java, C++, etc.
Constraints as Assertions

- General constraints: constraints that do not fit in the basic SQL categories (presented in chapter 8)

- Mechanism: CREATE ASSERTION

- Components include:
  - a constraint name,
  - followed by CHECK,
  - followed by a condition
Assertions: An Example

- "The salary of an employee must not be greater than the salary of the manager of the department that the employee works for’’

\[
\text{CREATE ASSERTION SALARY CONSTRAINT CHECK (NOT EXISTS (SELECT * FROM EMPLOYEE E, EMPLOYEE M, DEPARTMENT D WHERE E.SALARY > M.SALARY AND E.DNO=D.NUMBER AND D.MGRSSN=M.SSN))}
\]
Using General Assertions

- Specify a query that violates the condition; include inside a `NOT EXISTS` clause.
- Query result must be empty.
  - if the query result is not empty, the assertion has been violated.
SQL Triggers

- Objective: to monitor a database and take initiate action when a condition occurs
- Triggers are expressed in a syntax similar to assertions and include the following:
  - Event
    - Such as an insert, deleted, or update operation
  - Condition
  - Action
    - To be taken when the condition is satisfied
A trigger to compare an employee’s salary to his/her supervisor during insert or update operations:

```
CREATE TRIGGER INFORM_SUPERVISOR
BEFORE INSERT OR UPDATE OF
  SALARY, SUPERVISOR_SSN ON EMPLOYEE
FOR EACH ROW
WHEN
  (NEW.SALARY > (SELECT SALARY FROM EMPLOYEE
                 WHERE SSN=NEW.SUPERVISOR_SSN))
INFORM_SUPERVISOR (NEW.SUPERVISOR_SSN, NEW.SSN);
```
Views in SQL

- A view is a “virtual” table that is derived from other tables
- Allows for limited update operations
  - Since the table may not physically be stored
- Allows full query operations
- A convenience for expressing certain operations
Specification of Views

- SQL command: CREATE VIEW
  - a table (view) name
  - a possible list of attribute names (for example, when arithmetic operations are specified or when we want the names to be different from the attributes in the base relations)
  - a query to specify the table contents
SQL Views: An Example

- Specify a different WORKS_ON table

```sql
CREATE VIEW WORKS_ON_NEW AS
SELECT FNAME, LNAME, PNAME, HOURS
FROM EMPLOYEE, PROJECT, WORKS_ON
WHERE SSN=ESSN AND PNO=PNUMBER
GROUP BY PNAME;
```
Using a Virtual Table

- We can specify SQL queries on a newly create table (view):
  
  ```sql
  SELECT FNAME, LNAME
  FROM WORKS_ON_NEW
  WHERE PNAME='Seena';
  ```

- When no longer needed, a view can be dropped:
  
  ```sql
  DROP WORKS_ON_NEW;
  ```
Efficient View Implementation

- **Query modification:**
  - Present the view query in terms of a query on the underlying base tables

- **Disadvantage:**
  - Inefficient for views defined via complex queries
    - Especially if additional queries are to be applied to the view within a short time period
Efficient View Implementation

- View materialization:
  - Involves physically creating and keeping a temporary table

- Assumption:
  - Other queries on the view will follow

- Concerns:
  - Maintaining correspondence between the base table and the view when the base table is updated

- Strategy:
  - Incremental update
Update Views

- Update on a single view without aggregate operations:
  - Update may map to an update on the underlying base table

- Views involving joins:
  - An update may map to an update on the underlying base relations
    - Not always possible
Un-updatable Views

- Views defined using groups and aggregate functions are not updateable
- Views defined on multiple tables using joins are generally not updateable
- WITH CHECK OPTION: must be added to the definition of a view if the view is to be updated
  - To allow check for updatability and to plan for an execution strategy
Database Programming

Objective:
- To access a database from an application program (as opposed to interactive interfaces)

Why?
- An interactive interface is convenient but not sufficient
  - A majority of database operations are made thru application programs (increasingly thru web applications)
Database Programming Approaches

- **Embedded commands:**
  - Database commands are embedded in a general-purpose programming language

- **Library of database functions:**
  - Available to the host language for database calls; known as an API
    - API standards for Application Program Interface
  - A brand new, full-fledged language
    - Minimizes impedance mismatch
Impedance Mismatch

- Incompatibilities between a host programming language and the database model, e.g.,
  - type mismatch and incompatibilities; requires a new binding for each language
  - set vs. record-at-a-time processing
    - need special iterators to loop over query results and manipulate individual values
Steps in Database Programming

1. Client program opens a connection to the database server
2. Client program submits queries to and/or updates the database
3. When database access is no longer needed, client program closes (terminates) the connection
Embedded SQL

- Most SQL statements can be embedded in a general-purpose host programming language such as COBOL, C, Java
- An embedded SQL statement is distinguished from the host language statements by enclosing it between EXEC SQL or EXEC SQL BEGIN and a matching END-EXEC or EXEC SQL END (or semicolon)
  - Syntax may vary with language
  - *Shared variables* (used in both languages) usually prefixed with a colon (:) in SQL
Example: Variable Declaration in Language C

- Variables inside DECLARE are shared and can appear (while prefixed by a colon) in SQL statements.
- SQLCODE is used to communicate errors/exceptions between the database and the program.

```c
int loop;
EXEC SQL BEGIN DECLARE SECTION;
varchar dname[16], fname[16], ...
char ssn[10], bdate[11], ...
int dno, dnumber, SQLCODE, ...
EXEC SQL END DECLARE SECTION;
```
SQL Commands for Connecting to a Database

- **Connection** (multiple connections are possible but only one is active)
  
  CONNECT TO server-name AS connection-name
  AUTHORIZATION user-account-info;

- **Change from an active connection to another one**
  
  SET CONNECTION connection-name;

- **Disconnection**
  
  DISCONNECT connection-name;
loop = 1;
while (loop) {
    prompt("Enter SSN: ", ssn);
    EXEC SQL
        select FNAME, LNAME, ADDRESS, SALARY
        into :fname, :lname, :address, :salary
        from EMPLOYEE where SSN == :ssn;
    if (SQLCODE == 0) printf(fname, ...);
    else printf("SSN does not exist: ", ssn);
    prompt("More SSN? (1=yes, 0=no): ", loop);
    END-EXEC
}

A cursor (iterator) is needed to process multiple tuples

FETCH commands move the cursor to the next tuple

CLOSE CURSOR indicates that the processing of query results has been completed
Dynamic SQL

Objective:
- Composing and executing new (not previously compiled) SQL statements at run-time
  - a program accepts SQL statements from the keyboard at run-time
  - a point-and-click operation translates to certain SQL query

Dynamic update is relatively simple; dynamic query can be complex
- because the type and number of retrieved attributes are unknown at compile time
Dynamic SQL: An Example

EXEC SQL BEGIN DECLARE SECTION;
  varchar sqlupdatestring[256];
EXEC SQL END DECLARE SECTION;

... 
prompt ("Enter update command:“, sqlupdatestring);
EXEC SQL PREPARE sqlcommand FROM :sqlupdatestring;
EXEC SQL EXECUTE sqlcommand;
Embedded SQL in Java

- SQLJ: a standard for embedding SQL in Java
- An SQLJ translator converts SQL statements into Java
  - These are executed thru the JDBC interface
- Certain classes have to be imported
  - E.g., `java.sql`
Java Database Connectivity

- **JDBC:**
  - SQL connection function calls for Java programming
  - A Java program with JDBC functions can access any relational DBMS that has a JDBC driver
  - JDBC allows a program to connect to several databases (known as data sources)
Steps in JDBC Database Access

1. Import JDBC library (java.sql.*)
2. Load JDBC driver:
   Class.forName("oracle.jdbc.driver.OracleDriver")
3. Define appropriate variables
4. Create a connect object (via getConnection)
5. Create a statement object from the Statement class:
   - 1. PreparedStatement   2. CallableStatement
6. Identify statement parameters (designated by question marks)
7. Bound parameters to program variables
8. Execute SQL statement (referenced by an object) via JDBC’s executeQuery
9. Process query results (returned in an object of type ResultSet)
   - ResultSet is a 2-dimentional table
Embedded SQL in Java: An Example

```java
ssn = readEntry("Enter a SSN: ");
try {
    #sql{select FNAME< LNAME, ADDRESS, SALARY
    into :fname, :lname, :address, :salary
    from EMPLOYEE where SSN = :ssn};
}
catch (SQLException se) {
    System.out.println("SSN does not exist: ",+ssn);
    return;
}
System.out.println(fname + " " + lname + ... );
```
Multiple Tuples in SQLJ

- SQLJ supports two types of iterators:
  - *named iterator*: associated with a query result
  - *positional iterator*: lists only attribute types in a query result

- A `FETCH` operation retrieves the next tuple in a query result:
  
  ```java
  fetch iterator-variable into program-variable
  ```
Database Programming with Functional Calls

- Embedded SQL provides static database programming
- API: Dynamic database programming with a library of functions

  **Advantage:**
  - No preprocessor needed (thus more flexible)

  **Disadvantage:**
  - SQL syntax checks to be done at run-time
SQL Call Level Interface

- A part of the SQL standard
- Provides easy access to several databases within the same program
- Certain libraries (e.g., sqlcli.h for C) have to be installed and available
- SQL statements are dynamically created and passed as string parameters in the calls
Components of SQL/CLI

- **Environment record:**
  - Keeps track of database connections

- **Connection record:**
  - Keep tracks of info needed for a particular connection

- **Statement record:**
  - Keeps track of info needed for one SQL statement

- **Description record:**
  - Keeps track of tuples
Steps in C and SQL/CLI Programming

1. Load SQL/CLI libraries
2. Declare record handle variables for the above components (called: SQLHSTMT, SQLHDBC, SQLHENV, SQLHDEC)
3. Set up an environment record using SQLAllocHandle
4. Set up a connection record using SQLAllocHandle
5. Set up a statement record using SQLAllocHandle
6. Prepare a statement using SQL/CLI function SQLPrepare
7. Bound parameters to program variables
8. Execute SQL statement via SQLExecute
9. Bound query columns to a C variable via SQLBindCol
10. Use SQLFetch to retrieve column values into C variables
Database Stored Procedures

- Persistent procedures/functions (modules) are stored locally and executed by the database server
  - As opposed to execution by clients

Advantages:
- If the procedure is needed by many applications, it can be invoked by any of them (thus reduce duplications)
- Execution by the server reduces communication costs
- Enhance the modeling power of views

Disadvantages:
- Every DBMS has its own syntax and this can make the system less portable
Stored Procedure Constructs

- A stored procedure
  
  CREATE PROCEDURE procedure-name (params)
  local-declarations
  procedure-body;

- A stored function
  
  CREATE FUNCTION fun-name (params) RETURNS return-type
  local-declarations
  function-body;

- Calling a procedure or function
  
  CALL procedure-name/fun-name (arguments);
SQL Persistent Stored Modules

- **SQL/PSM:**
  - Part of the SQL standard for writing persistent stored modules
  - SQL + stored procedures/functions + additional programming constructs
    - E.g., branching and looping statements
    - Enhance the power of SQL
SQL/PSM: An Example

CREATE FUNCTION DEPT_SIZE (IN deptno INTEGER)
RETURNS VARCHAR[7]
DECLARE TOT_EMPS INTEGER;

SELECT COUNT (*) INTO TOT_EMPS
FROM SELECT EMPLOYEE WHERE DNO = deptno;
IF TOT_EMPS > 100 THEN RETURN "HUGE"
ELSEIF TOT_EMPS > 50 THEN RETURN "LARGE"
ELSEIF TOT_EMPS > 30 THEN RETURN "MEDIUM"
ELSE RETURN "SMALL"
ENDIF;
Summary

- Assertions provide a means to specify additional constraints
- Triggers are assertions that define actions to be automatically taken when certain conditions occur
- Views create temporary (virtual) tables
- A database may be accessed in an interactive mode
- Most often, however, data in a database is manipulate via application programs
- Several methods of database programming:
  - Embedded SQL
  - Dynamic SQL
  - Stored procedure and function