CS 235: Introduction to Databases
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Lecture Notes #10

Outline
- Database application programming.
  - SQL limitations.
- SQL Persistent, Stored Modules (PSM).
  - Extension of SQL.
  - PL/SQL: Oracle’s version of PSM.

DB Application Programming
- Application is written in general-purpose programming language: C, C++, Java...
  - Not in SQL!
- Application-driven database queries.
  - E.g., user makes a bid, starts an auction.
- Impedance mismatch:
  - Sets (relations) are first class objects in DBMS, but not in C, Java...
  - Vice versa for pointers, conditional statements.

Interface Solutions
1. Extend SQL with general-purpose programming: PSM.
2. Execute DB queries within application code: embedded SQL.
3. Call function from DB library: call-level interface (CLI), ODBC, JDBC.

Persistent Stored Modules
- Stored procedures as DB elements.
- Combine general-purpose programming with SQL.
- Extends functionality of DBMS.

Basic PSM Form
CREATE PROCEDURE <name> ( <parameters>)
<br> <declarations> <body>;
- For functions:
CREATE FUNCTION <name> ( <parameters>) RETURNS <type>;

...
Parameters in PSM

- For each parameter:
  - Mode: IN, OUT, INOUT
  - Name: as usual
  - Type: as usual
- Examples:
  IN newprice NUMBER
  OUT oldprice NUMBER
  INOUT drinker VARCHAR[30]

Example

- A procedure to add a beer and price to Spoon’s menu:
  ```sql
  CREATE PROCEDURE spoonMenu(
    IN beer VARCHAR[30],
    IN price NUMBER
  )
  INSERT INTO Sells
  VALUES('Spoon', beer, price);
  ```

Invoking Procedures

- Using SQL/PSM command CALL
  ```sql
  CALL spoonMenu('BudHeavy', '7.50')
  ```
- Functions can be used in SQL expressions, provided that the return type is appropriate.

PSM Statements

- DECLARE <name> <type>;
- SET <variable> = <expression>
- BEGIN <statements> END
- RETURN <expression>
  - Does not terminate execution!

IF Statements

- Simplest form:
  ```sql
  IF <condition> THEN <statements> END IF;
  ```
- With ELSE:
  ```sql
  IF...THEN...ELSE...END IF;
  ```
- Nested:
  ```sql
  IF...THEN...ELSEIF...ELSEIF...ELSE...END IF;
  ```

Loops

- Basic form:
  ```sql
  LOOP <statements> END LOOP;
  ```
- Exiting loops:
  ```sql
  <loop name>: LOOP ...
  ...LEAVE <loop name>...
  END LOOP;
  ```
- Other forms:
  ```sql
  WHILE <cond> DO <stmts> END WHILE;
  REPEAT <stmts> UNTIL <cond> END REPEAT;
  ```
Queries in PSM

- The following rules apply to the use of queries:
  1. Queries returning a single value can be used in assignments
  2. Queries returning a single tuple can be used with INTO.
  3. Queries returning several tuples can be used via a cursor.

Cursors

- A cursor serves as a tuple-variable that ranges over the tuples of the result of a query.
  - Opening a cursor evaluates \(<query>\).
  - Closed with `CLOSE c`;

Fetching Tuples From a Cursor

- Get next tuple:
  - `FETCH c INTO a1, a2, ..., ak`;
  - `a1, a2, ..., ak` are the attributes of the result of the query of `c`.
  - `c` is moved to the next tuple.
- A cursor is used by creating a loop around `FETCH`.

End of Cursor

- SQL operations return status in `SQLSTATE` (in PSM).
  - `FETCH` returns '02000' in `SQLSTATE` when no more tuples are found.
  - Useful declaration:
    - `DECLARE NotFound CONDITION FOR SQLSTATE '02000'`

Cursor Structure

```
DECLARE c CURSOR FOR...
...cursorLoop: LOOP
  ...
  FETCH c INTO...;
  IF NotFound THEN LEAVE cursorLoop;
  END IF;
...END LOOP;
```

Cursor Example

- Write a procedure that makes free all beers sold for more than $5 at Spoon.
  - `CREATE PROCEDURE FreeBeer()`
  - `DECLARE aBeer VARCHAR[30];`
  - `DECLARE aPrice REAL;`
  - `DECLARE NotFound CONDITION FOR SQLSTATE '02000';`
  - `DECLARE CURSOR c FOR SELECT beer, price FROM Sells WHERE bar = 'Spoon';`
Example

```sql
BEGIN
  OPEN c;
  menuLoop: LOOP
    FETCH c INTO aBeer, aPrice;
    IF NotFound THEN LEAVE menuLoop END IF;
    IF aPrice > 5.00 THEN
      UPDATE Sells
      SET price = 0
      WHERE bar = 'Spoon' and beer = aBeer;
    END IF;
  END LOOP;
  CLOSE c;
END;
```

PL/SQL

- Oracle’s version of PSM (Persistent, Stored Modules).
- Use via sqlplus.
- Can be used as stored procedures or directly in sqlplus
  - This extra functionality is the “plus”.

PL/SQL Basic Structure

```sql
DECLARE
  declarations (optional)
BEGIN
  actions (required)
END;
```

Simplest Form: Sequence of Modifications

```sql
BEGIN
  INSERT INTO Likes VALUES('Leo', 'Bud');
  DELETE FROM Likes
  WHERE drinker = 'Nick'
  AND beer = 'Miller';
END;
```

Procedures

- Stored database objects that use a PL/SQL statement in their bodies.
- `CREATE OR REPLACE PROCEDURE <name>(<arglist>) AS
  <declarations>
  BEGIN
    <PL/SQL statements>
  END;
  END;
  run;
```

Arguments

- Argument list has name-mode-type triples.
- Mode: IN, OUT, or IN OUT for read-only, write-only, read/write, respectively.
- Types: standard SQL + generic types like `NUMBER` = any integer or real type.
- Since types in procedures must match their types in the DB schema, you should generally use an expression of the form `relation.attribute %TYPE` to capture the type correctly.
Example

- A procedure to add a beer and price to Spoon’s menu:
  
  ```sql
  CREATE PROCEDURE spoonMenu(
      b IN Sells.beer %TYPE,
      p IN Sells.price %TYPE
  ) AS
  BEGIN
      INSERT INTO Sells
      VALUES('Spoon', b, p);
  END;
  END; 
  ```

  Note run only stores the procedure; it doesn’t execute the procedure.

Invoking Procedures

- Call the procedure directly
  ```sql
  CALL spoonMenu('Guinness', 7.50);
  ```

- A procedure call may appear in the body of a PL/SQL statement.
  ```sql
  BEGIN
    spoonMenu('Bud', 5.50);
    spoonMenu('LionBlood', 12.00);
  END;
  END; 
  ```

PL/SQL Constructs

- Assignments:
  ```sql
  <variable> := <expression>
  ```

- Variables must be declared.

- Branches
  ```sql
  IF <condition> THEN
      <statement(s)>
  ELSE
      <statement(s)>
  END IF;
  ```

  But in nests, use ELSIF in place of ELSEIF.

More Constructs

- Loops:
  ```sql
  LOOP
      . . .
  EXIT WHEN <condition>
      . . .
  END LOOP;
  ```

- For-Loops:
  ```sql
  FOR <var> IN <start>..<finish>
  LOOP
      . . .
  END LOOP;
  ```

Queries in PL/SQL

1. *Single-row selects* allow retrieval into a variable of the result of a query that is guaranteed to produce one tuple.

2. *Cursors* allow the retrieval of many tuples, with the cursor and a loop used to process each in turn.

Cursors in PL/SQL

- The cursor declaration is:
  ```sql
  CURSOR <name> IS <query>;
  ```

- Fetching is done with:
  ```sql
  FETCH c INTO <variables>;
  ```

- Also, with tuple variables:
  ```sql
  FETCH c INTO <variable>;
  ```
Example

- The FreeBeer in PL/SQL:
  CREATE OR REPLACE PROCEDURE FreeBeer() AS
  aBeer Sells.beer%TYPE;
aPrice Sells.price%TYPE;
CURSOR c IS
  SELECT beer, price
  FROM Sells
  WHERE bar = 'Spoon';
BEGIN
  OPEN c;
  LOOP
    FETCH c INTO aBeer, aPrice;
    EXIT WHEN c%NOTFOUND;
    IF aPrice > 5.00 THEN
      UPDATE Sells SET price = 0
      WHERE bar = 'Spoon' AND beer = aBeer;
    END IF;
  END LOOP;
  CLOSE c;
END;