SQL: Programming

Introduction to Databases
CompSci 316 Fall 2014
Announcements (Tue., Oct. 7)

• **Homework #2** due today midnight
  • Sample solution to be posted by tomorrow evening

• **Midterm** in class this Thursday
  • Open-book, open-notes
  • Same format as the sample midterm (posted on Sakai)

• **Project milestone #1** due next Thursday
Motivation

• Pros and cons of SQL
  • Very high-level, possible to optimize
  • Not intended for general-purpose computation

• Solutions
  • Augment SQL with constructs from general-purpose programming languages
    • E.g.: SQL/PSM
  • Use SQL together with general-purpose programming languages
    • E.g.: Python DB API, JDBC, embedded SQL
  • Extend general-purpose programming languages with SQL-like constructs
    • E.g.: LINQ (Language Integrated Query for .NET)
An “impedance mismatch”

• SQL operates on a set of records at a time
• Typical low-level general-purpose programming languages operate on one record at a time

_solution: cursor
  • Open (a result table): position the cursor before the first row
  • Get next: move the cursor to the next row and return that row; raise a flag if there is no such row
  • Close: clean up and release DBMS resources

_found in virtually every database language/API
  • With slightly different syntaxes

_found some support more positioning and movement options, modification at the current position, etc._
Augmenting SQL: SQL/PSM

• **PSM** = Persistent Stored Modules

• **CREATE PROCEDURE** `proc_name(param_decls)`
  `local_decls`
  `proc_body;`

• **CREATE FUNCTION** `func_name(param_decls)`
  `RETURNS return_type`
  `local_decls`
  `func_body;`

• **CALL** `proc_name(params);`

• Inside procedure body:
  `SET variable = CALL func_name(params);`
SQL/PSM example

CREATE FUNCTION SetMaxPop(IN newMaxPop FLOAT)
    RETURNS INT
    -- Enforce newMaxPop; return # rows modified.
BEGIN
    DECLARE rowsUpdated INT DEFAULT 0;
    DECLARE thisPop FLOAT;
    -- A cursor to range over all users:
    DECLARE userCursor CURSOR FOR
        SELECT pop FROM User
        FOR UPDATE;
    -- Set a flag upon “not found” exception:
    DECLARE noMoreRows INT DEFAULT 0;
    DECLARE CONTINUE HANDLER FOR NOT FOUND
        SET noMoreRows = 1;
    ... (see next slide) ...
    RETURN rowsUpdated;
END

SQL/PSM example continued

-- Fetch the first result row:
OPEN userCursor;
FETCH FROM userCursor INTO thisPop;
-- Loop over all result rows:
WHILE noMoreRows <> 1 DO
  IF thisPop > newMaxPop THEN
    -- Enforce newMaxPop:
    UPDATE User SET pop = newMaxPop
    WHERE CURRENT OF userCursor;
    -- Update count:
    SET rowsUpdated = rowsUpdated + 1;
  END IF;
  -- Fetch the next result row:
  FETCH FROM userCursor INTO thisPop;
END WHILE;
CLOSE userCursor;
Other SQL/PSM features

• Assignment using scalar query results
  • SELECT INTO

• Other loop constructs
  • FOR, REPEAT UNTIL, LOOP

• Flow control
  • GOTO

• Exceptions
  • SIGNAL, RESIGNAL

...  

• For more PostgreSQL-specific information, look for “PL/pgSQL” in PostgreSQL documentation
  • Link available from course website (under Help: PostgreSQL Tips)
Interfacing SQL with another language

• **API** approach
  • SQL commands are sent to the DBMS at runtime
  • Examples: Python DB API, JDBC, ODBC (C/C++; VB)
  • These API’s are all based on the SQL/CLI (Call-Level Interface) standard

• **Embedded SQL** approach
  • SQL commands are embedded in application code
  • A **precompiler** checks these commands at compile-time and converts them into DBMS-specific API calls
  • Examples: embedded SQL for C/C++, SQLJ (for Java)
Example API: Python psycopg2

```python
import psycopg2
conn = psycopg2.connect(dbname='beers')
cur = conn.cursor()

# list all drinkers:
cur.execute('SELECT * FROM Drinker')
for drinker, address in cur:
    print drinker + ' lives at ' + address

# print menu for bars whose name contains “a”:
cur.execute('SELECT * FROM Serves WHERE bar LIKE %s', ('%a%',))
for bar, beer, price in cur:
    print bar + ' serves ' + beer + ' at ${:,.2f}'.format(price)

cur.close()
conn.close()
```

You can iterate over `cur` one tuple at a time

Placeholder for query parameter

Tuple of parameter values, one for each `%s`
(note that the trailing “,” is needed when the tuple contains only one value)
More `psycopg2` examples

```python
# “commit” each change immediately—need to set this option just once at the start of the session
conn.set_session(autocommit=True)
#
bar = raw_input('Enter the bar to update: ').strip()
beer = raw_input('Enter the beer to update: ').strip()
price = float(raw_input('Enter the new price: '))
try:
    cur.execute('''
UPDATE Serves
SET price = %s
WHERE bar = %s AND beer = %s''', (price, bar, beer))
    if cur.rowcount != 1:
        print '{} row(s) updated: correct bar/beer?'
    .format(cur.rowcount)
except Exception as e:
    print e
```

Exceptions can be thrown (e.g., if positive-price constraint is violated)
Prepared statements: motivation

while True:
    # Input bar, beer, price...
    cur.execute('''
UPDATE Serves
SET price = %s
WHERE bar = %s AND beer = %s''', (price, bar, beer))
    # Check result...

• Every time we send an SQL string to the DBMS, it must perform parsing, semantic analysis, optimization, compilation, and finally execution

• A typical application issues many queries with a small number of patterns (with different parameter values)

• Can we reduce this overhead?
Prepared statements: example

```python
cur.execute('''
PREPARE update_price AS
UPDATE Serves
SET price = $1
WHERE bar = $2 AND beer = $3''')

while True:
    # Input bar, beer, price...
    cur.execute('EXECUTE update_price(%s, %s, %s)',
                (price, bar, beer))

    # Check result...

• The DBMS performs parsing, semantic analysis, optimization, and compilation only once, when it “prepares” the statement

• At execution time, the DBMS only needs to check parameter types and validate the compiled plan

• Most other API’s have better support for prepared statements than psycopg2
  • E.g., they would provide a `cur.prepare()` method
```

See `/opt/dbcourse/examples/psycopg2/` on your VM for a complete code example
“Exploits of a mom”

- The school probably had something like:
  ```python
cur.execute("SELECT * FROM Students " + \
  "WHERE (name = " + name + ")")
```
  where `name` is a string input by user

- Called an **SQL injection attack**
Guarding against SQL injection

• Escape certain characters in a user input string, to ensure that it remains a single string
  • E.g., ' which would terminate a string in SQL, must be replaced by '' (two single quotes in a row) within the input string

• Luckily, most API’s provide ways to “sanitize” input automatically (if you use them properly)
  • E.g., pass parameter values in psycopg2 through %s’s
Augmenting SQL vs. API

- Pros of augmenting SQL:

- Cons of augmenting SQL:
A brief look at other approaches

• “Embed” SQL in general-purpose programming languages
  • E.g.: embedded SQL

• Extend general-purpose programming languages with SQL-like constructs
  • E.g.: LINQ (Language Integrated Query for .NET)
Embedded SQL

- Embed SQL inside code written in a general-purpose language
  - Special keywords mark code sections containing SQL or variables holding data to be passed to/from SQL
- A “pre-compiler” parses the program and automatically converts the special sections to code with appropriate API calls
  - Pros: more compile-time checking, and potentially more optimization opportunities
  - Cons: DBMS-specific:
    - Different pre-compilers for different DBMS vendors
    - Program executable not portable across DBMS’s
    - Difficult for a program to talk to DBMS’s from different vendors
Embedded SQL example (in C)

```c
EXEC SQL BEGIN DECLARE SECTION;
int thisUid; float thisPop;
EXEC SQL END DECLARE SECTION;

EXEC SQL DECLARE ABCMember CURSOR FOR
SELECT uid, pop FROM User
WHERE uid IN (SELECT uid FROM Member WHERE gid = 'abc')
FOR UPDATE;

EXEC SQL OPEN ABCMember;
EXEC SQL WHENEVER NOT FOUND DO break;
while (1) {
    EXEC SQL FETCH ABCMember INTO :thisUid, :thisPop;
    printf("uid %d: current pop is %f\n", thisUid, thisPop);
    printf("Enter new popularity: ");
    scanf("%f", &thisPop);
    EXEC SQL UPDATE User SET pop = :thisPop
    WHERE CURRENT OF ABCMember;
}
EXEC SQL CLOSE ABCMember;
```
Adding SQL to a language

• Example: LINQ (Language Integrated Query) for Microsoft .NET languages (e.g., C#)

```csharp
int someValue = 5;
var results = from c in someCollection
             let x = someValue * 2
             where c.SomeProperty < x
             select new {c.SomeProperty, c.OtherProperty};
foreach (var result in results) {
    Console.WriteLine(result);
}
```

• Automatic data mapping and query translation

• But syntax may vary for different host languages