SQL: Programming

Introduction to Databases

CompSci 316 Fall 2017

DUKE COMPUTER SCIENCE

Announcements (Wed., Mar. 1)

- Keep working on the project!
- TA/UTA assignment to each project soon

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

☞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*);

Parameters in PSM

- Triples mode-name-type
- name and type
  - similar to standard programming languages
- mode in a procedure
  - new
  - IN : parameter is input-only -- default
  - OUT : output only
  - INOUT : both input and output
- mode in a function
  - only can be IN
  - PSM forbids side effect in functions
  - only output through return values

SQL/PSM example

User(uid, name, age, pop)

```
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
```

Declare a variable with a name and type – local – value not preserved by the DBMS

Cursor ranges over the tuples of the relation produced by the query

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;
```

CURRENT OF refers to the current tuple that has been fetched

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

```
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

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

You can iterate over cur one tuple at a time

Transactions in programming

Using pyscopg2 as an example:

```
conn = psycopg2.connect(dbname='beers')
conn.set_session(isolation_level='SERIALIZABLE',
                 ready_only=False,
                 autocommit=True)
```

- isolation_level defaults to READ COMMITTED
- read_only defaults to False
- autocommit defaults to False

- When autocommit is False, commit/abort current transaction as follows:

```
conn.commit()
conn.rollback()
```

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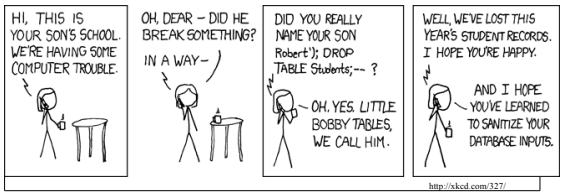
"Exploits of a mom"



- The school probably had something like:

```
cur.execute("SELECT * FROM Students " + \
        "WHERE (name = '" + name + "')")
```

  where name is a string input by user
- Called an SQL injection attack

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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

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Augmenting SQL vs. API

- Pros of augmenting SQL:
  - More processing features for DBMS
  - More application logic can be pushed closer to data
    - Less data "shipping," more optimization opportunities ⇒ more efficient
    - Less code ⇒ easier to maintain multiple applications
- Cons of augmenting SQL:
  - SQL is already too big—at some point one must recognize that SQL/DBMS are not for everything!
  - General-purpose programming constructs complicate optimization and make it impossible to guarantee safety