SQL: Programming

Introduction to Databases
CompSci 316 Fall 2016

Announcements (Thu., Oct. 13)

- Project milestone #1 due tonight
  - Only one member per team needs to submit
  - Remember `members.txt`
- Midterm is being graded
  - Sample solution to be posted by tonight

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)

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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.

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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*`);`

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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

```
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

```
# "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
```

# of tuples modified

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?

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Prepared statements: example

See `/opt/dbcourse/examples/psycopg2/` on your VM for a complete code example

```
cur.execute('''
PREPARE update_price AS
UPDATE Serves
SET price = $1
WHERE bar = $2 AND beer = $3''')  # Prepare once (in SQL).
                                  # Name the prepared plan,
                                  # and note the $1, $2, ... notation for
                                  # parameter placeholders.
while True:
    # Input bar, beer, price...
    cur.execute('EXECUTE update_price(%s, %s, %s)',\  # Execute many times.
                (price, bar, beer))
                                  # Note the switch back to %s for parameter placeholders.
    # 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

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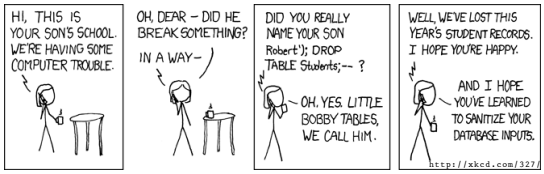
"Exploits of a mom"



- 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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If one fails to learn the lesson…

… P.S. To Ashley Madison's Development Team: You should be embarrased [sic] for your train wreck of a database (and obviously security), not sanitizing your phone numbers to your database is completely amateur, it's as if the entire site was made by Comp Sci 1XX students.

— Creators of `CheckAshleyMadison.com`

http://www.washingtonpost.com/news/the-intersect/wp/2015/08/19/how-to-see-if-you-or-your-spouse-appear-in-the-ashley-madison-leak/

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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

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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)

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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 convert 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

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Embedded SQL example (in C)

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

Declare variables to be "shared" between the application and DBMS

```
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;
```

Specify a handler for NOT FOUND exception

```
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;
```

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Adding SQL to a language

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

```
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