SQL: Triggers, Views, Indexes

Introduction to Databases

CompSci 316 Spring 2017

DUKE
COMPUTER SCIENCE

Announcements (Mon., Feb. 13)

- Homework #2 due Friday 02/17 11:59 pm
  - Q6 and X1 due on Thursday, 02/23 11:59 pm, after the midterm

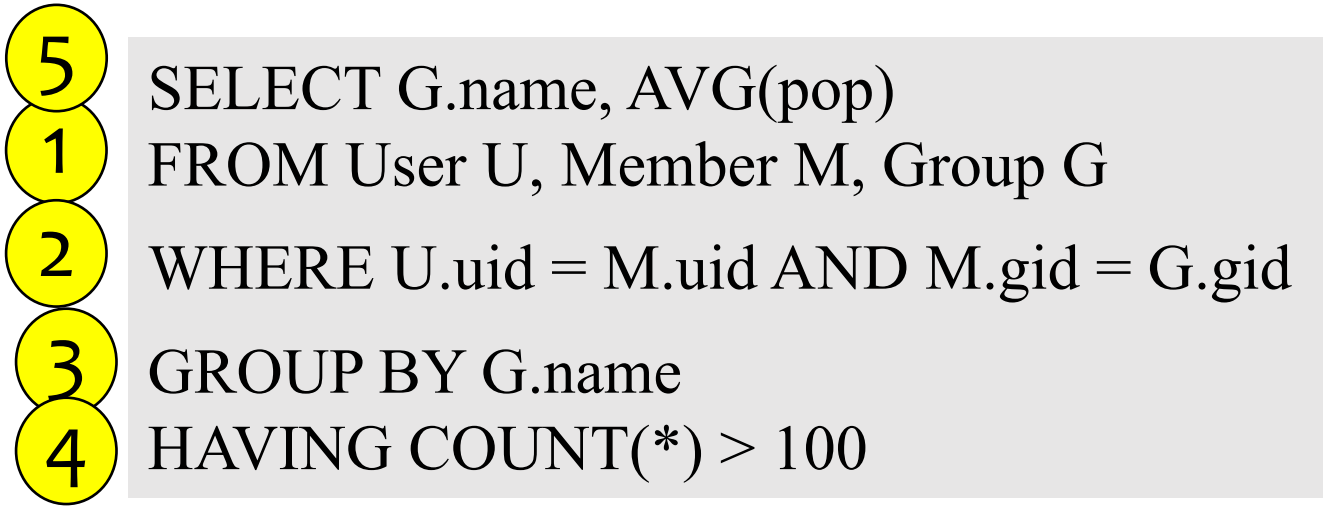
- You can now submit your homework also on sakai

- Permanent office hour locations!
  - Mon, Tues, Wed, Thurs (7-9 pm): LSRC D105
  - Fri (Bill – 4:30-6:30 pm): LSRC A247

SQL: Review of Lecture 7

User (uid, name, age, pop)
Group (gid, name)
Member (uid, gid)

- SQL queries and semantics
- e.g. Find average popularity of members in groups of size > 100



- Set (no duplicates) and bag operations (duplicates allowed)
- Subqueries – FROM, WHERE, WITH
- EXISTS, IN, UNION, ALL, ANY
- Ordering – ORDER BY ASC/DESC

SQL: Review of Lecture 8

User (uid, name, age, pop)
Group (gid, name)
Member (uid, gid)

- NULL and three valued logic
- Outerjoins (full-, left-, right-)
- INSERT / DELETE / UPDATE
- Constraints
  - NOT NULL
  - Key
  - Referential integrity (foreign key)
  - General Assertion
  - Tuple- and attribute-based CHECK's
- Today: a new type of constraint enforcement – "Trigger"

“Active” data

- DBMS may have to take some actions automatically on update/insert/delete

- Examples?

"Active" data

- Constraint enforcement: When an operation violates a constraint, abort the operation or try to "fix" data
  - Example: enforcing referential integrity constraints
  - Generalize to arbitrary constraints?

- Data monitoring: When something happens to the data, automatically execute some action
  - Example: When price rises above $20 per share, sell
  - Example: When enrollment is at the limit and more students try to register, email the instructor

Triggers

- A trigger is an event-condition-action (ECA) rule
  - When event occurs, test condition;
  - if condition is satisfied, execute action

- Example:
  - Event: some user's popularity is updated
  - Condition: the user is a member of "Jessica's Circle," and *pop* drops below 0.5
  - Action: kick that user out of Jessica's Circle

http://pt.simpsons.wikia.com/wiki/Arquivo:Jessica_lovejoy.jpg

Trigger example

```
CREATE TRIGGER PickyJessica

AFTER UPDATE OF pop ON User                    Event

REFERENCING NEW ROW AS newUser

FOR EACH ROW

WHEN (newUser.pop < 0.5)                       Condition
 AND (newUser.uid IN (SELECT uid
                      FROM Member
                      WHERE gid = 'jes'))

DELETE FROM Member
WHERE uid = newUser.uid AND gid = 'jes';       Action
```

Trigger options

- Possible events include:
  - INSERT ON *table*
  - DELETE ON *table*
  - UPDATE [OF *column*] ON *table*
- Granularity—trigger can be activated:
  - FOR EACH ROW modified
  - FOR EACH STATEMENT that performs modification
- Timing—action can be executed:
  - AFTER or BEFORE the triggering event
  - INSTEAD OF the triggering event on views (more later)

Transition variables

- OLD ROW: the modified row before the triggering event
- NEW ROW: the modified row after the triggering event
- OLD TABLE: a hypothetical read-only table containing all rows to be modified before the triggering event
- NEW TABLE: a hypothetical table containing all modified rows after the triggering event

☞ Not all of them make sense all the time, e.g.

- AFTER INSERT statement-level triggers
  - Can use only NEW TABLE
- BEFORE DELETE row-level triggers
  - Can use only OLD ROW
- etc.

Statement-level trigger example

```
CREATE TRIGGER PickyJessica

AFTER UPDATE OF pop ON User

REFERENCING NEW TABLE AS newUsers

FOR EACH STATEMENT

DELETE FROM Member
WHERE gid = 'jes'
AND uid IN (SELECT uid
            FROM newUsers
            WHERE pop < 0.5);
```

BEFORE trigger example

- Never allow age to decrease

```
CREATE TRIGGER NoFountainOfYouth

BEFORE UPDATE OF age ON User

REFERENCING OLD ROW AS o,
            NEW ROW AS n

FOR EACH ROW

WHEN (n.age < o.age)

SET n.age = o.age;
```

☞ BEFORE triggers are often used to "condition" data

☞ Another option is to raise an error in the trigger body to abort the transaction that caused the trigger to fire

Statement- vs. row-level triggers

Why are both needed?

pros/cons?

- Certain triggers are only possible at statement level
  - If the number of users inserted by this statement exceeds 100 and their average age is below 13, then …
- Simple row-level triggers are easier to implement
  - Statement-level triggers require significant amount of state to be maintained in OLD TABLE and NEW TABLE
  - However, a row-level trigger gets fired for each row, so complex row-level triggers may be less efficient for statements that modify many rows

System issues

- Recursive firing of triggers
  - Action of one trigger causes another trigger to fire
  - Can get into an infinite loop
    - Some DBMS leave it to programmers/database administrators (e.g., PostgreSQL)
    - Some restrict trigger actions (e.g., Oracle)
    - Many set a maximum level of recursion (e.g., 16 in DB2)

- Interaction with constraints (tricky to get right!)
  - When do we check if a triggering event violates constraints?
    - After a BEFORE trigger (so the trigger can fix a potential violation)
    - Before an AFTER trigger
  - AFTER triggers also see the effects of, say, cascaded deletes caused by referential integrity constraint violations

  (Based on DB2; other DBMS may differ)

Example in class

User (uid, name, age, pop)

- If after update of “pop” values, the average pop drops below 0.7, restore old table
- NOTE: difficult to do row by row

Views

- A view is like a "virtual" table
  - Defined by a query, which describes how to compute the view contents on the fly
  - DBMS stores the view definition query instead of view contents
  - Can be used in queries just like a regular table

Creating and dropping views

- Example: members of Jessica's Circle

User (uid, name, age, pop)
Group (gid, name)
Member (uid, gid)

  - Tables used in defining a view are called "base tables"
    - *User* and *Member* above

- To drop a view
  - DROP VIEW JessicaCircle;

Using views in queries

- Example: find the average popularity of members in Jessica's Circle
  - SELECT AVG(pop) FROM JessicaCircle;
  - To process the query, replace the reference to the view by its definition

Why use views?

Modifying views

- Does it even make sense, since views are virtual?
- It does make sense if we want users to really see views as tables
- Goal: modify the base tables such that the modification would appear to have been accomplished on the view

A simple case

```
CREATE VIEW UserPop AS
SELECT uid, pop FROM User;
```

```
DELETE FROM UserPop WHERE uid = 123;
```

translates to:

```
DELETE FROM User WHERE uid = 123;
```

An impossible case

```
CREATE VIEW PopularUser AS
  SELECT uid, pop FROM User
  WHERE pop >= 0.8;
```

```
INSERT INTO PopularUser
  VALUES(987, 0.3);
```

- No matter what we do on *User*, the inserted row will not be in *PopularUser*

A case with too many possibilities

```
CREATE VIEW AveragePop(pop) AS
  SELECT AVG(pop) FROM User;
```

- Note that you can rename columns in view definition

```
UPDATE AveragePop SET pop = 0.5;
```

- Set everybody's *pop* to 0.5?
- Adjust everybody's *pop* by the same amount?
- Just lower Jessica's *pop*?

SQL92 updateable views

- More or less just single-table selection queries (why?)
  - No join
  - No aggregation
  - No subqueries
  - Other restrictions like "default/ no NOT NULL" values for attributes that are projected out in the view
    - so that they can be extended with valid/NULL values in the base table
- Arguably somewhat restrictive
- Still might get it wrong in some cases
  - See the slide titled "An impossible case"
  - Adding WITH CHECK OPTION to the end of the view definition will make DBMS reject such modifications

INSTEAD OF triggers for views

```
CREATE TRIGGER AdjustAveragePop

INSTEAD OF UPDATE ON AveragePop

REFERENCING OLD ROW AS o,
            NEW ROW AS n

FOR EACH ROW

UPDATE User

SET pop = pop + (n.pop-o.pop);
```

- What does this trigger do?

Indexes

- An index is an auxiliary persistent data structure
  - Search tree (e.g., B⁺-tree), lookup table (e.g., hash table), etc.
  - ☞More on indexes later in this course!
- An index on $R.A$ can speed up accesses of the form
  - $R.A = value$
  - $R.A > value$ (sometimes; depending on the index type)
- An index on $(R.A_1, \ldots, R.A_n)$ can speed up
  - $R.A_1 = value_1 \wedge \cdots \wedge R.A_n = value_n$
  - $(R.A_1, \ldots, R.A_n) > (value_1, \ldots, value_n)$ (again depends)

☞Ordering or index columns is important—is an index on $(R.A, R.B)$ equivalent to one on $(R.B, R.A)$?

☞How about an index on $R.A$ plus another on $R.B$?

Examples of using indexes: 1/2

- SELECT * FROM User WHERE name = 'Bart';
- Without an index on *User.name*:
- With an index on *User.name*:

Examples of using indexes: 2/2

- SELECT * FROM User, Member
  WHERE User.uid = Member.uid
  AND Member.gid = 'jes';

Recall the semantic for SQL evaluation!

- With an index on *Member.gid* or (*gid*, *uid*):
- With an index on *User.uid*:
- Without an index:

Creating and dropping indexes in SQL

CREATE [UNIQUE] INDEX *indexname* ON *tablename*(*columnname*$_1$,…,*columnname*$_n$);

- With UNIQUE, the DBMS will also enforce that {*columnname*$_1$, … , *columnname*$_n$} is a key of *tablename*

DROP INDEX *indexname*;

- Typically, the DBMS will automatically create indexes for PRIMARY KEY and UNIQUE constraint declarations

Choosing indexes to create

More indexes = better performance? problems?

☞Optimal index selection depends on both query and update workload and the size of tables

- Automatic index selection is now featured in some commercial DBMS

SQL features covered so far

- Query
- Modification
- Constraints
- Triggers
- Views
- Indexes