SQL: Triggers, Views, Indexes
Introduction to Databases
CompSci 316 Fall 2015

Announcements (Tue., Sep. 22)
- Homework #1 sample solution posted on Sakai
- Homework #2 due in two weeks (Tuesday)
  - Midterm on Thursday of the same week
- Project Milestone #1 due Thursday, Oct. 15
  - See project description on what to accomplish by then

“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

Trigger example

CREATE TRIGGER PickyJessica
AFTER UPDATE OF pop ON User
REFERENCING NEW ROW AS newUser
FOR EACH ROW
WHEN (newUser.pop < 0.5)
   AND (newUser.uid IN (SELECT uid FROM Member
                           WHERE gid = 'jes'))
DELETE FROM Member
WHERE uid = newUser.uid AND gid = 'jes';

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 only use **NEW TABLE**
- **BEFORE DELETE** row-level triggers
  - Can only use **NEW TABLE**
  - 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?
• Certain triggers are only possible at statement level
• 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)

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
  • CREATE VIEW JessicaCircle AS
    SELECT * FROM User
    WHERE uid IN (SELECT uid FROM Member
      WHERE gid = 'jes');
  • 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
    • SELECT AVG(pop)
      FROM (SELECT * FROM User
        WHERE uid IN
        (SELECT uid FROM Member
          WHERE gid = 'jes'))
      AS JessicaCircle;

Why use views?

• To hide data from users
• To hide complexity from users
• Logical data independence
  • If applications deal with views, we can change the underlying schema without affecting applications
  • Recall physical data independence: change the physical organization of data without affecting applications
• To provide a uniform interface for different implementations or sources
  • Real database applications use tons of 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

```sql
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

```sql
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
  * No join
  * No aggregation
  * No subqueries

* Arguably somewhat restrictive
* Still might get it wrong in some cases
  * See the slide titled “An impossible case”
  * Adding WITH CHECKOPTION 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
  - $R.A = \text{value}$
  - $R.A > \text{value}$ (sometimes; depending on the index type)
- An index on $(R.A_1, \ldots, R.A_n)$ can speed up
  - $R.A_1 = \text{value}_1 \land \ldots \land R.A_n = \text{value}_n$
  - $(R.A_1, \ldots, R.A_n) > (\text{value}_1, \ldots, \text{value}_n)$ (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

- SELECT * FROM User WHERE name = 'Bart';
  - Without an index on User.name: must scan the entire table if we store User as a flat file of unordered rows
  - With index: go “directly” to rows with name = 'Bart'
- SELECT * FROM User, Member
  WHERE User.uid = Member.uid
  AND Member.gid = 'jes';
  - With an index on Member.gid or (gid, uid) find relevant Member rows directly
  - With an index on User.uid: for each relevant Member row, directly look up User rows with matching uid
    - Without it: for each Member row, scan the entire User table for matching uid
    - Sorting could help

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?

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