SQL: Triggers, Views, Indexes

CPS 116
Introduction to Database Systems

Announcements (Thu. Nov. 10)

- Homework #3 sample solution available next Tuesday
- Project milestone #2 due today!
- Homework #4 (last one) will be assigned in 12 days
  - Good time to work on the extra credit and project

“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: whenever there comes a new student…
  - Condition: with GPA higher than 3.0…
  - Action: then make him/her take CPS116!

Trigger example

```
CREATE TRIGGER CPS116AutoRecruit
AFTER INSERT ON Student
REFERENCING NEW ROW AS newStudent
FOR EACH ROW
WHEN (newStudent.GPA > 3.0)
INSERT INTO Enroll
VALUES(newStudent.SID, 'CPS116');
```

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 modified rows 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 CPS116AutoRecruit
AFTER INSERT ON Student
REFERENCING NEW TABLE AS newStudents
FOR EACH STATEMENT
INSERT INTO Enroll
(SELECT SID, 'CPS116'
FROM newStudents
WHERE GPA > 3.0);
```

BEFORE trigger example

- Never give faculty more than 50% raise in one update

```
CREATE TRIGGER NotTooGreedy
BEFORE UPDATE OF salary ON Faculty
REFERENCING OLD ROW AS o, NEW ROW AS n
FOR EACH ROW
WHEN (n.salary > 1.5 * o.salary)
SET n.salary = 1.5 * o.salary;
```

Statement- vs. row-level triggers

Why are both needed?

- Certain triggers are only possible at statement level
  - If the average GPA of students inserted by this statement exceeds 3.0, do …
- 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 does get fired for each row, so complex row-level triggers may be inefficient for statements that generate lots of modifications

Another statement-level trigger

- Give faculty a raise if GPA’s in one update statement are all increasing

```
CREATE TRIGGER AutoRaise
AFTER UPDATE OF GPA ON Student
REFERENCING OLD TABLE AS o, NEW TABLE AS n
FOR EACH STATEMENT
WHEN (NOT EXISTS(SELECT * FROM o, n
WHERE o.SID = n.SID
AND o.GPA >= n.GPA))
UPDATE Faculty SET salary = salary + 1000;
```

System issues

- Recursive firing of triggers
  - Action of one trigger causes another trigger to fire
  - Can get into an infinite loop
  - Some leave it to programmers/database administrators (e.g., PostgreSQL)
  - Some DBMS restrict trigger actions (e.g., Oracle)
  - Many DBMS set a maximum level of recursion (e.g., 16 in DB2)
- Interaction with constraints (very 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 implement a different policy)
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: CPS116 roster
  - CREATE VIEW CPS116Roster AS
    SELECT SID, name, age, GPA
    FROM Student
    WHERE SID IN (SELECT SID FROM Enroll
    WHERE CID = 'CPS116');
  - To drop a view
    - DROP VIEW view_name;

Using views in queries

- Example: find the average GPA of CPS116 students
  - SELECT AVG(GPA) FROM CPS116Roster;
  - To process the query, replace the reference to the view by its definition
  - SELECT AVG(GPA)
    FROM (SELECT SID, name, age, GPA
    FROM Student
    WHERE SID IN (SELECT SID
    FROM Enroll
    WHERE CID = 'CPS116'));

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 not seem to make sense since views are virtual
- But does make sense if that is how users see the database
- Goal: modify the base tables such that the modification would appear to have been accomplished on the view

A simple case

CREATE VIEW StudentGPA AS
SELECT SID, GPA FROM Student;
DELETE FROM StudentGPA WHERE SID = 123;
translates to:
DELETE FROM Student WHERE SID = 123;
An impossible case

CREATE VIEW HighGPAStudent AS
SELECT SID, GPA FROM Student
WHERE GPA > 3.7;
INSERT INTO HighGPAStudent
VALUES(987, 2.5);

No matter what you do on Student, the inserted row will not be in HighGPAStudent.

A case with too many possibilities

CREATE VIEW AverageGPA(GPA) AS
SELECT AVG(GPA) FROM Student;

Note that you can rename columns in view definition.

UPDATE AverageGPA SET GPA = 2.5;
SET everybody’s GPA to 2.5?
Adjust everybody’s GPA by the same amount?
Just lower Lisa’s GPA?

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 CHECK OPTION to the end of the view definition will make DBMS reject such modifications

INDEX OF triggers for views

CREATE TRIGGER AdjustAverageGPA
INSTEAD OF UPDATE ON AverageGPA
REFERENCING OLD ROW AS o, NEW ROW AS n
FOR EACH ROW
UPDATE Student
SET GPA = GPA + (n.GPA-o.GPA);

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
• $R.A_1 = value_1 \land \ldots \land R.A_n = value_n$
• $(R.A_1, \ldots, R.A_n) > (value_1, \ldots, value_n)$ (again depends)
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 index on $R.B$?

Examples of using indexes

SELECT * FROM Student WHERE name = ’Bart’
• Without an index on Student.name: must scan the entire table if we store Student as a flat file of unordered rows
• With index: go "directly" to rows with name = ’Bart’
SELECT * FROM Student, Enroll
WHERE Student.SID = Enroll.SID;
• Without any index: for each Student row, scan the entire Enroll table for matching SID
• Sorting could help
• With an index on Enroll.SID: for each Student row, directly look up Enroll rows with matching SID
Creating and dropping indexes in SQL

- CREATE (UNIQUE) INDEX index_name ON table_name(column_name_1, ..., column_name_n);
  - With UNIQUE, the DBMS will also enforce that \{column_name_1, ..., column_name_n\} is a key of table_name
- DROP INDEX index_name;

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

Choosing indexes to create

More indexes = better performance?
- Indexes take space
- Indexes need to be maintained when data is updated
- Indexes have one more level of indirection

- Optimal index selection depends on both query and update workload and the size of tables
  - Automatic index selection is still an area of active research

Summary of SQL features covered

- Query
- Modification
- Constraints
- API
- Transactions
- Triggers
- Views
- Indexes