SQL:
Triggers, Views, Indexes

Introduction to Database Management

CS348 Fall 2022

Announcements (Tue., Sep 27)

- Milestone 0 - Project groups are formed by tonight!
  - Form a team on Learn
  - Report.pdf and link to GitHub repo
  - Not graded, but very important!

- Assignment #1 due by Sep 29 (Thur), 11:59pm
  - Part 1: general questions and r.a.
    - Submit via Crowdmark
  - Part 2: writing SQL on DB2 on school servers (try soon)
    - Submit via Marmoset

SQL

- Basic SQL (queries, modifications, and constraints)

- Intermediate SQL
    - Triggers
    - Views
    - Indexes

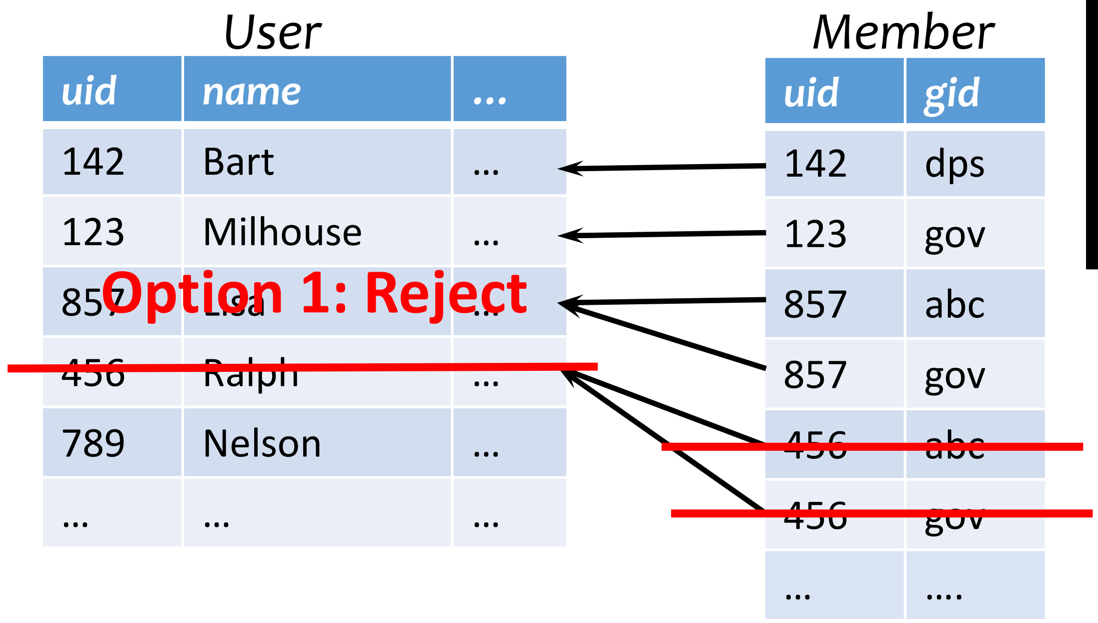
- Advanced SQL
    - Programming
    - Recursive queries (Optional)

Lectures 5-6

Still remember "referential integrity"?

Example: *Member.uid references User.uid*

- Delete or update a *User* row whose *uid* is referenced by some *Member* row
  - Multiple Options (in SQL)



User

uid	name	…
142	Bart	…
123	Milhouse	…
857	Lisa	…
~~456~~	~~Ralph~~	~~…~~
789	Nelson	…
…	…	…

Option 1: Reject

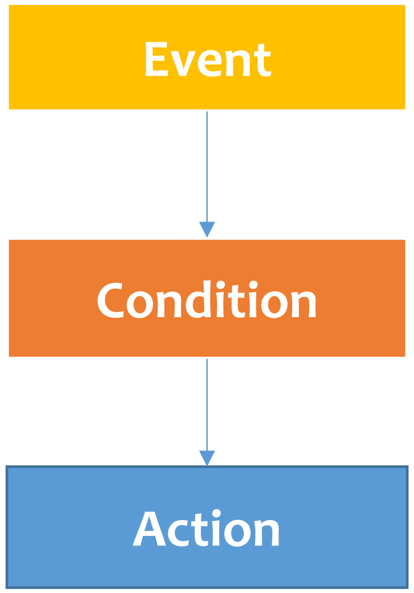
Member

uid	gid
142	dps
123	gov
857	abc
857	gov
~~456~~	~~abc~~
~~456~~	~~gov~~
…	….

```
CREATE TABLE Member
(uid DECIMAL(3,0) NOT NULL
REFERENCES User(uid)
ON DELETE CASCADE,
…..);
```

Option 2: Cascade
(ripple changes to all referring rows)

Can we generalize it?



Referential constraints		Data Monitoring
Delete/update a User row	Event	Some user's popularity is updated
Whether its uid is referenced by some Member row	Condition	Whether the user is a member of "S group" and *pop* drops below 0.5
Yes: reject/delete cascade/null	Action	Yes: kick that user out of S group

Referential constraints

Data Monitoring

Triggers

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

```
CREATE TRIGGER PickySGroup
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 = ‘sgroup'))
                DELETE FROM Member
                WHERE uid = newUser.uid AND gid = ‘sgroup';
```

Event

Transition variable

Condition

Action

Trigger option 1 – possible events

- Possible events include:
  - INSERT ON *table*; DELETE ON *table*; UPDATE [OF *column*] ON *table*

```
CREATE TRIGGER PickySGroup
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 = 'sgroup'))
                DELETE FROM Member
                WHERE uid = newUser.uid AND gid = 'sgroup';
```

Event

Condition

Action

Trigger option 2 – timing

- Timing—action can be executed:
  - AFTER or BEFORE the triggering event
  - INSTEAD OF the triggering event on views (more later)

```
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;
```

Event

Condition

Action

Trigger option 3 – granularity

- Granularity—trigger can be activated:
  - FOR EACH ROW modified

```
CREATE TRIGGER PickySGroup
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 = 'sgroup'))
           DELETE FROM Member
           WHERE uid = newUser.uid AND gid = 'sgroup';
```

Event

Condition

Action

Trigger option 3 – granularity

- Granularity—trigger can be activated:
  - FOR EACH ROW modified
  - FOR EACH STATEMENT that performs modification

```
CREATE TRIGGER PickySGroup2
AFTER UPDATE OF pop ON User
REFERENCING NEW TABLE AS newUsers
FOR EACH STATEMENT
         DELETE FROM Member
                   WHERE gid = 'sgroup'
                   AND uid IN (SELECT uid
                                     FROM newUsers
                                     WHERE pop < 0.5);
```

Event

Transition table: contains all the affected rows

Condition & Action

Trigger option 3 – granularity

- Granularity—trigger can be activated:
  - FOR EACH ROW modified
  - FOR EACH STATEMENT that performs modification

```
CREATE TRIGGER PickySGroup2
AFTER UPDATE OF pop ON User
REFERENCING NEW TABLE AS newUsers
FOR EACH STATEMENT
          DELETE FROM Member
                    WHERE gid = ‘sgroup’
                    AND uid IN (SELECT uid
                                        FROM newUsers
                                        WHERE pop < 0.5);
```

Transition table: contains all the affected rows

Only can be used with **AFTER** triggers

Transition variables/tables

- 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

Event	Row	Statement
Delete	old r; old t	old t
Insert	new r; new t	new t
Update	old/new r; old/new t	old/new t

AFTER Trigger

Event	Row	Statement
Update	old/new r	-
Insert	new r	-
Delete	old r	-

BEFORE Trigger

Statement- vs. row-level triggers

- 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

- Exercise 1: However, can you think of a case when a row-level trigger may be less efficient?

- Exercise 2: Certain triggers are only possible at statement level. Can you think of an example?

System issues

- Recursive firing of triggers
  - Action of one trigger causes another trigger to fire
  - Can get into an infinite loop
- Interaction with constraints (tricky to get right!)
  - When to check if a triggering event violates constraints?
    - After a BEFORE trigger
    - Before an AFTER trigger
    - (based on db2, other DBMS may differ)
- Be best avoided when alternatives exist

SQL features covered so far

- Basic SQL
- Intermediate SQL
  - Triggers
  - Views

Views

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

```
CREATE VIEW SGroup AS
    SELECT * FROM User
    WHERE uid IN (SELECT uid
                  FROM Member
                  WHERE gid = 'sgroup');
```

Base tables

```
SELECT AVG(pop) FROM SGroup;
```

```
SELECT MIN(pop) FROM SGroup;
```

```
SELECT … FROM SGroup;
```

```
SELECT AVG(pop)
FROM (SELECT * FROM User
      WHERE uid IN
      (SELECT uid FROM Member
       WHERE gid = 'jes'))
       AS SGroup;
```

```
DROP VIEW SGroup;
```

Why use views?

- To hide complexity from users
- To hide data from users
- Logical data independence
- To provide a uniform interface for different implementations or sources

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;
```

Renamed column

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

- Set everybody's *pop* to 0.5?
- Adjust everybody's *pop* by the same amount?
- Just lower one user'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" (slide 20)
  - Adding WITH CHECK OPTION to the end of the view definition will make DBMS reject such modifications

INSTEAD OF triggers for views

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

```
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?

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

INSTEAD OF triggers for views

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

```
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);
```

0.5

0.4

User

…	pop	…
	0.4 +0.1	
	0.4 +0.1	
	0.5 +0.1	
	0.3 +0.1	

- What does this trigger do?

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

SQL features covered so far

- Basic SQL
- Intermediate SQL
  - Triggers
  - Views
  - Indexes

Motivating examples of using indexes

```
SELECT * FROM User WHERE name = 'Bart';
```

- Can we go “directly” to rows with *name*='Bart’ instead of scanning the entire table?
  - → index on *User.name*

```
SELECT * FROM User, Member
WHERE User.uid = Member.uid AND Member.gid = ‘sgroup';
```

- Can we find relevant *Member* rows “directly”?
  - → index on *Member.gid* or (*gid*, *uid*)
- For each relevant *Member* row, can we “directly” look up *User* rows with matching *uid*
  - → index on *User.uid*

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!

- CREATE [UNIQUE] INDEX $indexname$ ON $tablename(columnname_1,\ldots,columnname_n)$;
  - With UNIQUE, the DBMS will also enforce that $\{columnname_1, \ldots, columnname_n\}$ is a key of $tablename$
- DROP INDEX $indexname$;

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

Indexes

- 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 $(R.A_1, \dots, R.A_n)$ can speed up
  - $R.A_1 = value_1 \wedge \cdots \wedge R.A_n = value_n$
  - $(R.A_1, \dots, R.A_n) > (value_1, \dots, value_n)$ (again depends)

Questions (lecture 12):

☞Ordering of 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 $R.B$?

☞More indexes = better performance?

SQL features covered so far

Basic & Intermediate SQL

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

☞Next: Programming