SQL:
Triggers, Views, Indexes

Introduction to Database Management

CS348 Spring 2021

Announcements (Tue., May 25)

- Milestone 0 - Project groups are formed by tonight!
  - Questions are welcome on Piazza
  - Watch out for updates

- Assignment #1 due next Mon (May 31, 11pm)
  - Servers:
    - ubuntu2004-002.student.cs.uwaterloo.ca
    - ubuntu2004-004.student.cs.uwaterloo.ca
  - Setup db2 environment:
    - $ source ~cs348/public/db2profile

SQL

- Basic SQL (queries, modifications, and constraints)

- Intermediate SQL
  - Triggers
  - Views
  - Indexes

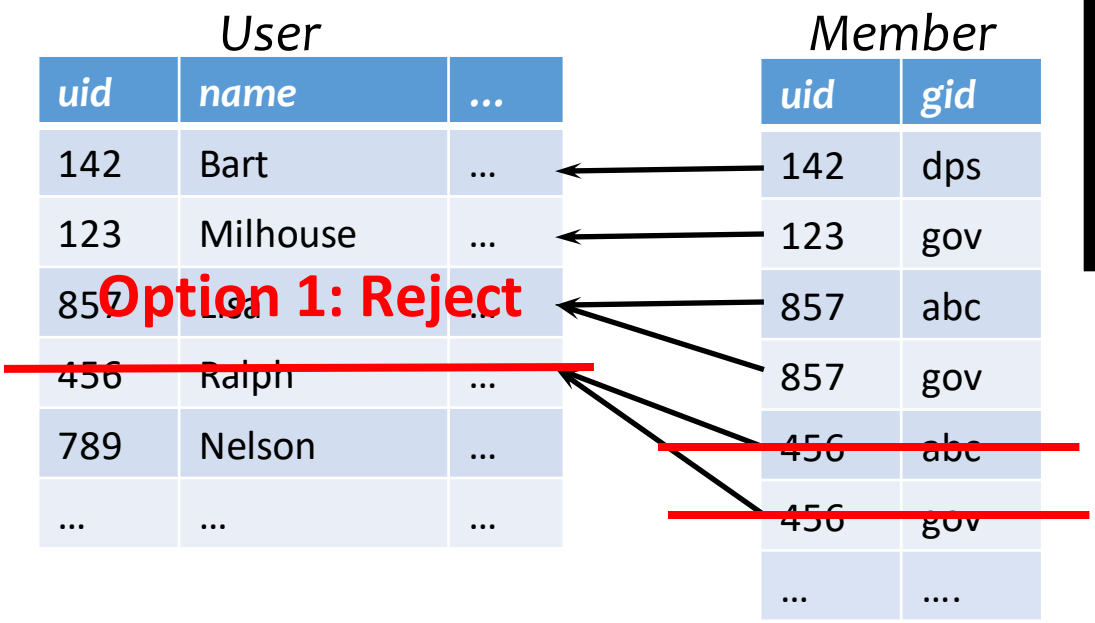
- Advanced SQL
  - Programming
  - Recursive queries

this week

Still remember "referential integrity"?

Example: *Member.uid* references *User.uid*

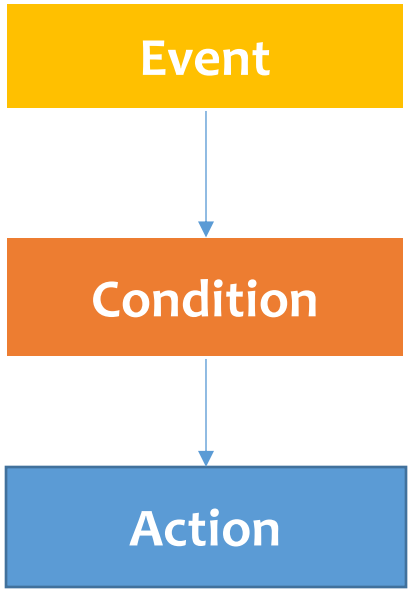
- Delete or update a *User* row whose *uid* is referenced by some *Member* row
  - Multiple Options (in SQL)




```
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?



Delete/update a User row

Some user's popularity is updated

Whether its uid is referenced by some Member row

Whether the user is a member of "S group" and *pop* drops below 0.5

Yes: reject/delete cascade/null

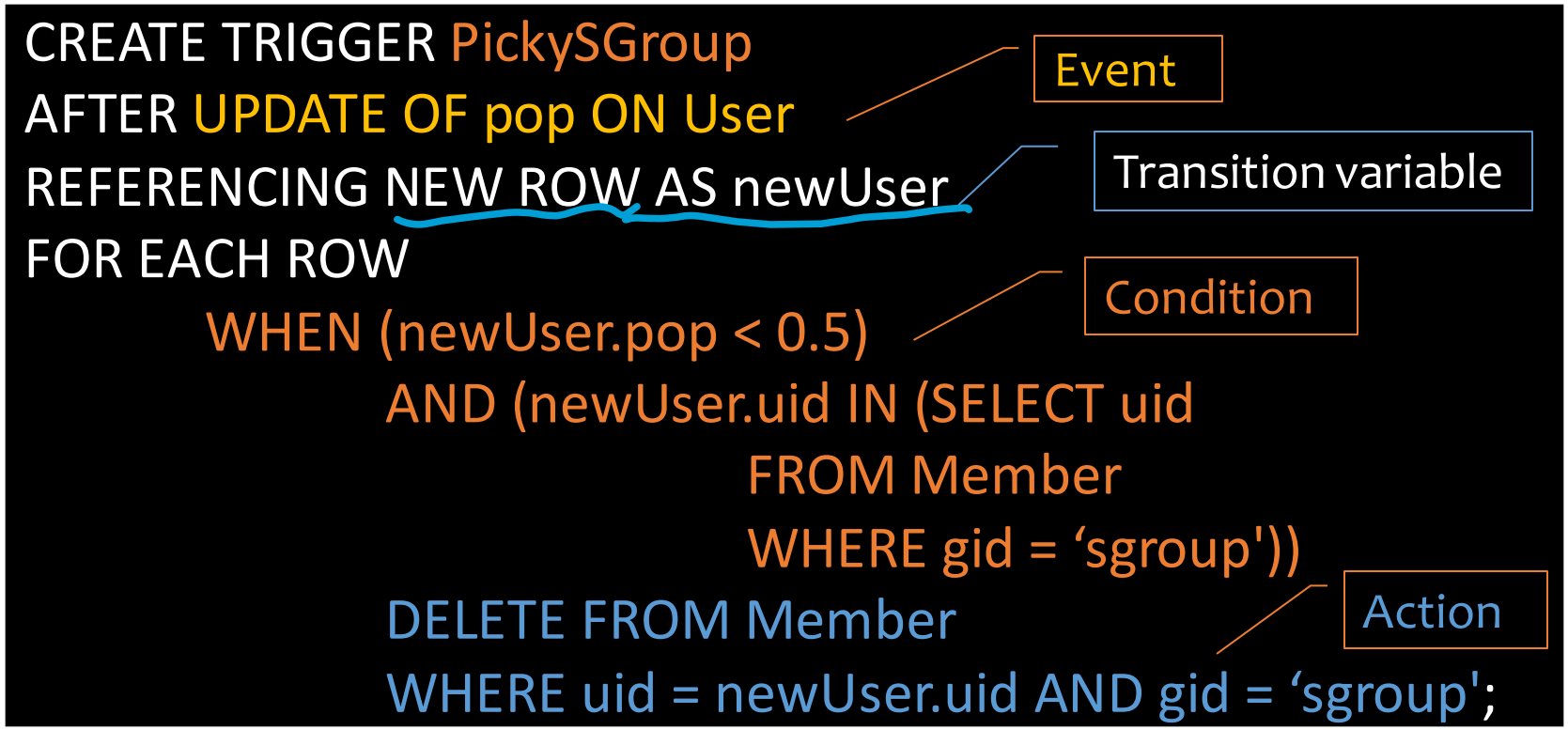
Yes: kick that user out of S group

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



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

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

```
SELECT … FROM 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	
	0.6 +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 $(R.A_1, \ldots, R.A_n)$ 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)

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: Recursion, programming