SQL:
Triggers, Views, Indexes

CS348 Spring 2023

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Sections: **002 and 004 only**

Announcements (Thu, May 25th)

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

- Assignment #1 due by next Tue May 30th, 11:59pm
  - Submit via Crowdmark

(Basic SQL) WITH clause

- The WITH clause provides a way of defining a temporary relation whose definition is available only to the query in which the with clause occurs

```
WITH max_pop(popVal) AS (SELECT
max(pop) FROM user)
SELECT uid, name FROM user, max_pop
WHERE user.pop = max_pop.popVal
```

```
WITH max_pop AS (SELECT max(pop) AS
popVal FROM user)
SELECT uid, name FROM user, max_pop
WHERE user.pop = max_pop.popVal
```

- Supported by many but not all DBMSs
- Can be written using subqueries

SQL

- Basic SQL (queries, modifications, and constraints)

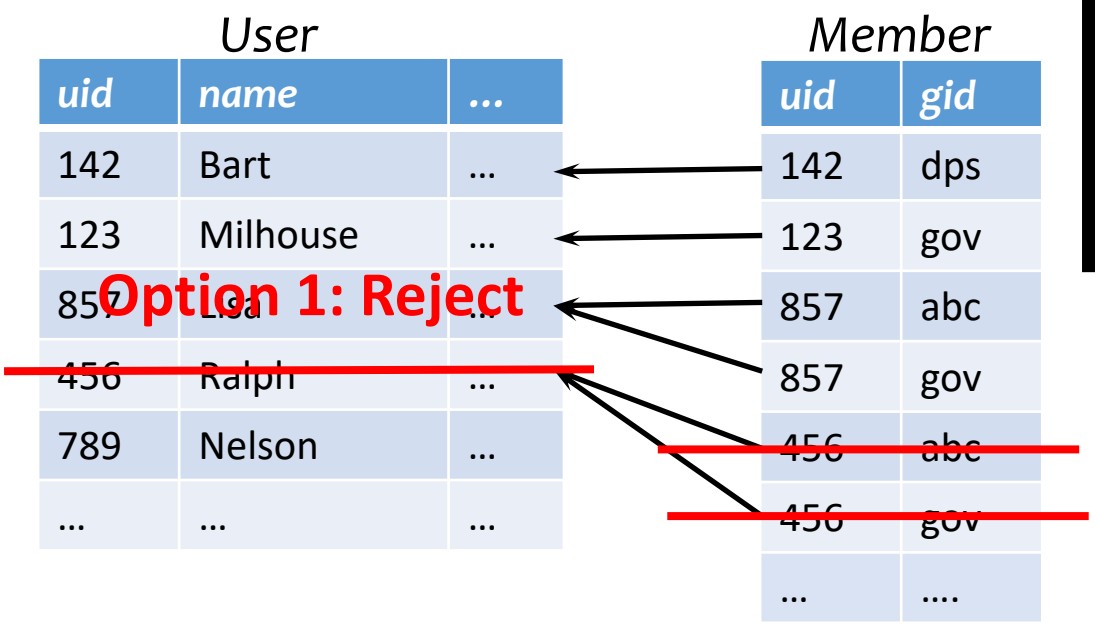
- Intermediate SQL
  - Triggers
  - Views
  - Indexes

- Advanced SQL
  - Programming
  - Recursive queries

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)



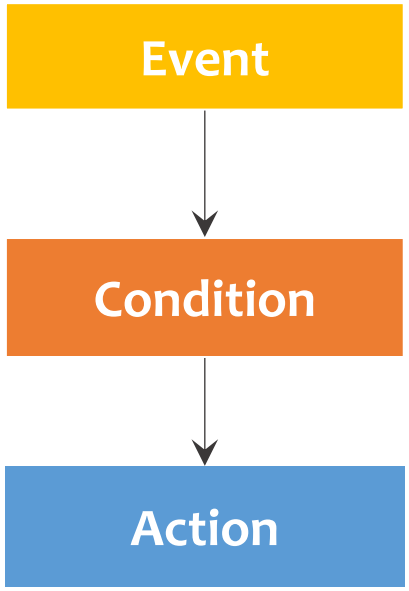

```
CREATE TABLE Member
(uid INT NOT NULL
REFERENCES User(uid)
ON DELETE CASCADE,
……);
```

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

Can we generalize it?

Referential constraints

Data Monitoring



Triggers

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

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

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 PickyPopGroup
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 = 'popgroup'))
                DELETE FROM Member
                WHERE uid = newUser.uid AND gid = 'popgroup';
```

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 PickyPopGroup
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 = 'popgroup'))
                DELETE FROM Member
                WHERE uid = newUser.uid AND gid = 'popgroup';
```

Event

Condition

Action

Trigger option 3 – granularity

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

```
CREATE TRIGGER PickyPopGroup2
AFTER UPDATE OF pop ON User
REFERENCING NEW TABLE AS newUsers
FOR EACH STATEMENT
        DELETE FROM Member
                WHERE gid = 'popgroup'
                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 PickyPopGroup2
AFTER UPDATE OF pop ON User
REFERENCING NEW TABLE AS newUsers
FOR EACH STATEMENT
        DELETE FROM Member
                WHERE gid = 'popgroup'
                AND uid IN (SELECT uid
                                FROM newUsers
                                WHERE pop < 0.5);
```

Transition table: contains all the affected rows

Can only 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 read-only table containing all old rows modified by the triggering event
- NEW TABLE: a 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
- However, in some cases a row-level trigger may be less efficient
  - E.g., 4B rows and a trigger may affect 15% of the rows. Recording an action for 4 Billion rows, one at a time, is not feasible due to resource constraints.
- Certain triggers are only possible at statement level
  - E.g., ??

Certain triggers are only possible at statement level

```
CREATE TRIGGER MaintainAvgPop
AFTER UPDATE OF pop ON User
REFERENCING NEW TABLE AS newUsers
                OLD TBALE AS oldUsers
FOR EACH STATEMENT
        WHEN (0.5 > (SELECT AVG(pop) from User)
        BEGIN
                DELETE FROM User WHERE uid IN (SELECT uid
                FROM newUsers)
                INSERT INTO User (SELECT * FROM oldUsers)
        END
```

Event

Transition tables

Condition

Action

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)
- Best to avoid 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 as a query by DBMS instead of query contents
  - Can be used in queries just like a regular table

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

Base tables

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

```
SELECT AVG(pop) FROM PopGroup;
SELECT MIN(pop) FROM PopGroup;
SELECT … FROM PopGroup;
```

```
DROP VIEW popGroup;
```

Why use views?

- To hide complexity from users
- To hide data from users
- Logical data independence
- To provide a uniform interface

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 or group by
  - No subqueries
  - Attributes not listed in SELECT must be nullable
- 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 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;
```

Materialized views

- Some systems allow view relations to be stored in db
  - If the actual relations used in the view definition change, the view is kept up-to-date
- Such views are called materialized views

- Used to enhance performance: avoid recomputing view each time

- View maintenance: updating the materialized view upon base table changes
  - Immediately or lazily, up to the DBMS

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 = 'popgroup';
```

- Can we find relevant *Member* rows "directly"?

  → index on *Member.gid*

- 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 that helps with efficient searches
  - 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: Programming & recursion