

SQL: Triggers, Views, Indexes

CPS 116
Introduction to Database Systems

Announcements (Thu. Nov. 10) ²

- ❖ 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 ³

- ❖ 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

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- ❖ 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

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

Trigger options

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- ❖ 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 for triggers on views (more later)

Transition variables

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- ❖ 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
 - etc.

Statement-level trigger example

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```
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

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- ❖ 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;
```
- ☞ 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

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## Statement- vs. row-level triggers

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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 does get fired for each row, so complex row-level triggers may be inefficient for statements that generate lots of modifications

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## Another statement-level trigger

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- ❖ 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 (
)
)
```

```
UPDATE Faculty SET salary = salary + 1000;
```

☞ A row-level trigger would be difficult to write in this case

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## System issues

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- ❖ 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)

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## Views

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- ❖ 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

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## Creating and dropping views

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- ❖ Example: CPS116 roster
  - ```
CREATE VIEW CPS116Roster AS
  SELECT SID, name, age, GPA
  FROM Student
  WHERE SID IN (SELECT SID FROM Enroll
                WHERE CID = 'CPS116');
```

Called “base tables”
- ❖ To drop a view
 - ```
DROP VIEW view_name;
```

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## Using views in queries

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- ❖ 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'));
```

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## Why use views?

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- ❖ 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

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## Modifying views

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- ❖ 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

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## A simple case

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```
CREATE VIEW StudentGPA AS
 SELECT SID, GPA FROM Student;

DELETE FROM StudentGPA WHERE SID = 123;
```

translates to:

```
DELETE FROM Student WHERE SID = 123;
```

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## An impossible case

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

- ❖ No matter what you do on *Student*, the inserted row will not be in *HighGPASStudent*

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## A case with too many possibilities

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```
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?

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## SQL92 updateable views

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- ❖ 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

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## INSTEAD OF triggers for views

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```
❖ 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?

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## Indexes

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- ❖ An index is an auxiliary persistent data structure
  - Search tree (e.g., B<sup>+</sup>-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  $(R.A_1, \dots, R.A_n)$  can speed up
  - $R.A_1 = value_1 \wedge \dots \wedge R.A_n = value_n$
  - $(R.A_1, \dots, R.A_n) > (value_1, \dots, value_n)$  (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  $R.B$ ?

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## Examples of using indexes

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- ❖ `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`

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## Creating and dropping indexes in SQL <sup>25</sup>

- ❖ CREATE {UNIQUE} INDEX *index\_name* ON *table\_name*(*column\_name*<sub>1</sub>, ..., *column\_name*<sub>*n*</sub>);
  - With UNIQUE, the DBMS will also enforce that {*column\_name*<sub>1</sub>, ..., *column\_name*<sub>*n*</sub>} is a key of *table\_name*
- ❖ DROP INDEX *index\_name*;
  
- ❖ Typically, the DBMS will automatically create indexes for PRIMARY KEY and UNIQUE constraint declarations

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## Choosing indexes to create <sup>26</sup>

More indexes = better performance?

- ☞ 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

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## Summary of SQL features covered <sup>27</sup>

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

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