TRƯỜNG ĐẠI HỌC BÁCH KHOA HÀ NỘI
HANOI UNIVERSITY OF SCIENCE AND TECHNOLOGY

Database
Lesson 6. Constraints and Triggers

Viet-Trung Tran
https://is.hust.edu.vn/~trungtv/

Learning Map

Sequence	Title
1	Introduction to Databases
2	Relational Databases
3	Relational Algebra
4	Structured Query Language – Part 1
5	Structured Query Language – Part 2
6	Constraints and Triggers
7	Entity Relationship Model
8	Functional Dependency
9	Normalization
10	Storage - Indexing
11	Query Processing
12	Transaction Management – Part 1
13	Transaction Management – Part 2

Outline

- Overview
- Constraints
- Triggers

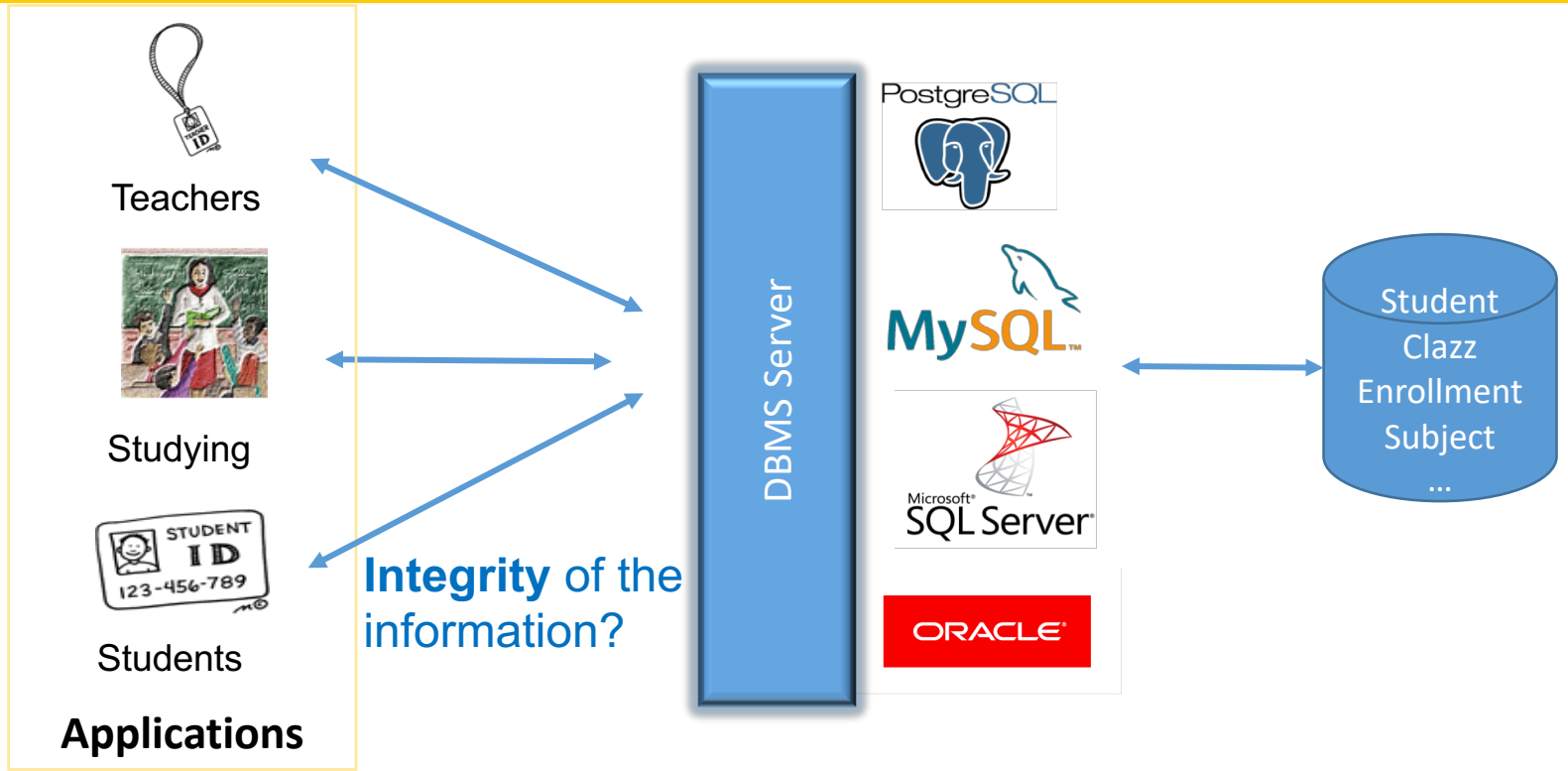
Learning objectives

- Upon completion of this lesson, students will be able to:
  - Well known about different constraints and define them correctly
  - Understand triggers: What is a trigger? how it works ? When using?
  - Define simple triggers

Keywords

Keyword	Description
Constraints	Constraints are the rules enforced on the data columns of a table. C onstraints could be either on a column level or a table level
Triggers	A trigger is a SQL procedure that initiates an action (i.e., fires an acti on) when an event (INSERT, DELETE or UPDATE) occurs. They ar e stored in and managed by the DBMS
PL/SQL	Procedural Language/Structured Query Language is Oracle Corpora tion's procedural extension for SQL and the Oracle relational databa se

1. Overview


Teachers
Studying
STUDENT ID 123-456-789
Students
Applications
Integrity of the information?
DBMS Server
PostgreSQL
MySQL
Microsoft SQL Server
ORACLE
Student
Clazz
Enrollment
Subject
...

1. Overview: Database Schema

student(**student_id**, first_name,last_name, dob, gender,

address, note, email, *clazz_id*)

clazz(**clazz_id**, name, *lecturer_id*, *monitor_id*, number_students)

subject(**subject_id**, name, credit, percentage_final_exam)

enrollment(***student_id*, *subject_id*, semester**, midterm_score, final_score)

lecturer(**lecturer_id**, first_name, last_name, dob, gender, address, email)

teaching(***subject_id, lecturer_id***)

grade(**code**, from_score, to_score)

1. Overview : Constraints and Triggers

- A **constraint** is a relationship among data elements that the DBMS is required to enforce
  - Example: key constraints
- **Triggers** are only executed when a specified condition occurs, e.g., insertion of a tuple
  - Easier to implement than complex constraints

2. Constraints: Kinds of Constraints

- Keys: PRIMARY KEY vs. UNIQUE
- Foreign-key, or referential-integrity
- Attribute-based constraints
  - Constrain values of a particular attribute.
- Tuple-based constraints
  - Relationship among components
- Assertions: any SQL Boolean expression

2.1. Keys: PRIMARY KEY vs. UNIQUE

- Declaring: similar syntax as primary key
- Example:

```
CREATE TABLE student (
        student_id CHAR(8) NOT NULL,
        first_name VARCHAR(20) NOT NULL,
        last_name VARCHAR(20) NOT NULL,
        ...
        email varchar(50) UNIQUE,
        clazz_id CHAR(8),
        CONSTRAINT student_pk PRIMARY KEY (student_id));
```

2.1. Keys: PRIMARY KEY vs. UNIQUE (2)

	PRIMARY KEY	UNIQUE KEY
Number defined on table	One	Multiple
Null columns allowed	No	Yes
Default index	CLUSTERED	NON-CLUSTERED
Purpose	Enforce Entity Integrity	Enforce Unique Data
Number of columns	One or more columns	One or more columns
Referenced by a Foreign Key Constraint	Yes	Yes

2.2. Foreign keys: Expressing Foreign Keys

- Use keyword REFERENCES, either:
  - After an attribute (for one-attribute keys)
  - As an element of the schema:

    [CONSTRAINT <name>] FOREIGN KEY (<list of attributes>)
    REFERENCES <relation> (<attributes>)
- Referenced attributes must be declared PRIMARY KEY or UNIQUE

2.2. Foreign keys: Example

```
CREATE TABLE clazz (
        clazz_id CHAR(8) NOT NULL PRIMARY KEY,
        name VARCHAR(20), … );

CREATE TABLE student (
        student_id CHAR(8) NOT NULL,
        ... ,
        clazz_id CHAR(8),
        CONSTRAINT student_pk PRIMARY KEY (student_id));

ALTER TABLE student ADD CONSTRAINT student_fk_class
FOREIGN KEY (clazz_id) REFERENCES clazz(clazz_id);
```

2.2. Foreign keys: Enforcing constraint

- An insert or update to student that introduces a non-existent clazz_id (clazz_id value is not found in clazz)
  ➔ Reject
- A deletion or update to clazz that removes a clazz_id value found in some tuples of student?
  - Default: reject the modification
  - Cascade: make the same changes in student
  - Set NULL: change clazz_id in student to NULL

2.2. Foreign keys: Choosing policy

```
ALTER TABLE student
        ADD CONSTRAINT student_fk_class FOREIGN KEY
(clazz_id) REFERENCES clazz(clazz_id)
        ON DELETE SET NULL
        ON UPDATE CASCADE;
```

2.3. Attribute-based checks: Declaring

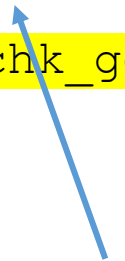
- Constraints on the value of a particular attribute
  - Add CHECK(<condition>) to the declaration for the attribute or add as relation-schema element
  - The condition may use the name of the attribute, but any other relation or attribute name must be in a subquery
- Example:

```
CREATE TABLE student (
    student_id CHAR(8) NOT NULL PRIMARY KEY, ...,
    gender CHAR(1),
    clazz_id CHAR(8) CHECK (clazz_id IN (SELECT clazz_id FROM clazz)),
    CONSTRAINT student_chk_gender CHECK (gender = 'F' OR gender = 'M') );
```

2.3. Attribute-based checks: Timing of checks

- Only when a value for that attribute is inserted or updated

```
CREATE TABLE student (
    student_id CHAR(8) NOT NULL PRIMARY KEY, ...,
    gender CHAR(1),
    clazz_id CHAR(8) CHECK (clazz_id IN (SELECT
clazz_id FROM clazz)),
    CONSTRAINT student_chk_gender CHECK (gender = 'F'
OR gender = 'M') );
```



Not checked if a class is deleted from **clazz**

2.4. Tuple-based checks

- CHECK (<condition>) may be added as a relation-schema element.
- The condition may refer to any attribute of the relation
  - But other attributes or relations require a subquery
- Timing of checks: on insert or update only.

```
CREATE TABLE grade(
        code CHAR(1) NOT NULL,
        from_score DECIMAL(3,1) NOT NULL,
        to_score DECIMAL(3,1) NOT NULL, ...,
        CONSTRAINT grade_chk_toScore CHECK (to_score >
from_score) );
```

2.5. Assertions: Declaring

- Database-schema elements, like relations or views
- Defined by:

  CREATE ASSERTION <name>
  CHECK (<condition>);
- Condition may refer to any relation or attribute in the database schema
- Drop an assertion:

  DROP ASSERTION <assertion name>;

2.5. Assertions: Example

```
CREATE ASSERTION teachingSubject CHECK (
       (SELECT COUNT(*) FROM teaching) >=
       (SELECT COUNT(*) FROM subject) );

CREATE ASSERTION numberStdInClass CHECK (
       NOT EXISTS (
              SELECT * FROM clazz c
              WHERE number_students <>
                     (SELECT count(*) FROM student
                      WHERE clazz_id = c.clazz_id)
       )
);
```

2.5. Assertions: Timing of Assertion Checks

- In principle, we must check every assertion after every modification to any relation of the database
- A clever system can observe that only certain changes could cause a given assertion to be violated
  - No change to student can affect teaching Subject
  - Neither can an insertion to teaching
- Very hard to implement assertions efficiently

3. Triggers

- Motivation
- Trigger Syntax
- Using triggers
- Examples

3.1 Trigger motivation

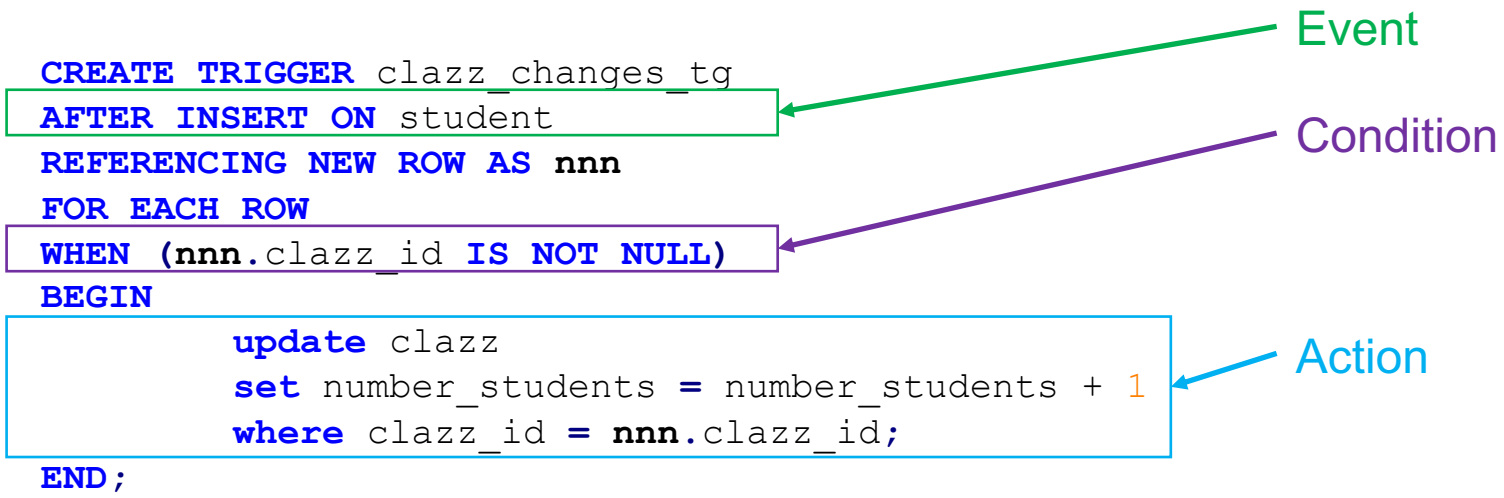
- Assertions
  - powerful,
  - but the DBMS often can’t tell when they need to be checked
- Attribute and tuple-based checks
  - checked at known times,
  - but are not powerful in some circumstances
- Triggers let the user decide when to check for any condition

3.1. Motivation: ECA Rules

- A trigger defines an operation that is performed when a specific event occurs on a relation:
  - inserts a new record / updates an existing record / deletes a record
- Trigger functions have access to special variables from the database engine
- Called also ECA rules (Event-Condition-Action)
  - Event: type of database modification
  - Condition: Any SQL Boolean-valued expression
  - Action: Any SQL statements

3.1. Motivation: Example

- Constraint: when a new student is inserted into student relation, the number of students in his class must be increased
  - student(student_id, first_name,last_name, dob, gender, address, note, email, clazz_id)
  - clazz(clazz_id, name, lecturer_id, monitor_id, number_students)



3.2. Trigger syntax

- Creating a trigger:

```
CREATE [OR REPLACE] TRIGGER <trigger_name>
       {BEFORE | AFTER | INSTEAD OF }
       {INSERT | DELETE | UPDATE [OF <attribute_name>]}
       ON <table_name>
       REFERENCING {NEW | OLD} {ROW | TABLE} AS <name>
       [FOR EACH ROW ]
       [WHEN (<condition>) ]
       BEGIN
              <trigger body goes here >
       END;
```

- Dropping a trigger:

```
DROP TRIGGER <trigger_name>;
```

3.2. Trigger syntax: Event

- AFTER, BEFORE, INSTEAD OF:
  - AFTER, BEFORE: used for tables / views
  - INSTEAD OF: used only for views
    - A way to execute view modifications: triggers translate them to appropriate modifications on the base tables
- INSERT, DELETE, UPDATE , UPDATE OF
  - UPDATE OF <columns>: update on a particular column

3.2. Trigger syntax: Level

- Row-level trigger:
  - Indicated by option FOR EACH ROW
  - Trigger executes once for each modified tuple
- Statement-level trigger:
  - Without option FOR EACH ROW or with FOR EACH STATEMENT
  - Trigger execute once for a SQL statement, regardless how many tuples are modified

3.2. Trigger syntax: REFERENCING

- INSERT statements imply a new tuple (for row-level) or new table (for statement-level)
  - The table is the set of inserted tuples
- DELETE implies an old tuple or table
- UPDATE implies both
- Refer to these by
  - REFERENCING [NEW | OLD] [TUPLE | TABLE] AS <name>
- Each DBMS has its own implementation, REFERENCING may not be used in:
  - Access directly to special variables from the database engine: NEW, OLD,…

3.2. Trigger syntax: Condition

- Any boolean-valued condition
- Evaluated on the database as it would exist before or after the triggering event, depending on whether BEFORE or AFTER is used.
  - But always before the changes take effect.
- Access the new/old tuple/table through the names in the REFERENCING clause

Trigger syntax: Action

- Can be more than one SQL statement:
  - Surrounded by BEGIN .. END
- Language:
  - Simple SQL statements
  - Extention of SQL: procedural languages, depends on each DBMD
    - PL/SQL (Oracle), PL/pgSQL (PostgreSQL), T-SQL(SQL Server) ,..

3.3. Using triggers: When

- Auditing data modification (keeping history of data), providing transparent event logging
- Validation and business security checking if so is desired
  - Eg. column formatting before and after inserts into database
- Enforcing complex integrity constraints
- Enforcing complex business rules
- Maintaining replicate tables
- Building complex views that are updatable

3.3. Using triggers: Guidelines for designing triggers

- Do not define triggers that duplicate database features
  - do not define triggers to reject bad data if you can do the same checking through constraints
- Use triggers only for centralized, global operations that must fire for the triggering statement, regardless of which user or database application issues the statement
- Do not create recursive triggers
- Use triggers on DATABASE judiciously (e.g. server error, logon, logoff,…):
  - they are executed for every user every time the event occurs on which the trigger is created

3.4. Trigger example: In Oracle

- Add a new column in clazz relation

```
alter table clazz
add column number_students integer not null default 0;
```

- Create a trigger on student relation

```
CREATE TRIGGER clazz_changes_tg
AFTER UPDATE ON student
FOR EACH ROW
WHEN (:NEW.clazz_id <> :OLD.clazz_id)
BEGIN
        update clazz set number_students= number_students+1
        where clazz_id = :NEW.clazz_id;
        update clazz set number_students = number_students-1
        where clazz_id = :OLD.clazz_id;
END;
```

3.4. Trigger example: In PostgreSQL

```
CREATE FUNCTION public.tg_fnc_change_clazz()
    RETURNS trigger LANGUAGE 'plpgsql' AS $$
BEGIN
   update clazz set number_students = number_students+1
         where clazz_id = NEW.clazz_id;
   update clazz set number_students = number_students-1
         where clazz_id = OLD.clazz_id;
   return NEW;
END; $$

CREATE TRIGGER tg_af_update_clazz
    AFTER UPDATE OF clazz_id
    ON student
    FOR EACH ROW
    EXECUTE PROCEDURE public.tg_fnc_change_clazz();
```

Remark

- Constraints, Assertions, Triggers:
  - How to declare
  - Timing of checks
  - Differences
- Only use them if you really need to, especially triggers
- Each DBMS has its own variation in implementation:
  - Options
  - Syntax: triggers as an example

➔ Reading documentation for each DBMS installed

Quiz 1.

Quiz Number	1	Quiz Type	OX	Example Select
Question	How many attributes are there in one unique key?			
Example	A. Only one B. One, two or more			
Answer	B			
Feedback	As other constraints, each constraint can have many attributes			

Quiz 2.

Quiz Number	2	Quiz Type	OX	Example Select
Question	A trigger can be explicitly called by user?			
Example	A. Yes B. No			
Answer	B			
Feedback	No, trigger is invoked by an event occurring inside database engine. You can not explicitly invoke it			

Quiz 2.

Quiz Number	3	Quiz Type	OX	Example Select
Question	Application users know while a trigger is executed?			
Example	A. Yes B. No			
Answer	B			
Feedback	Trigger is invoked by database engine, it is transparent to users			

Summary

- Introduction
  - Why we need constraints and triggers?
- Constraints
  - Keys
  - Foreigner key
  - Check constraints
  - Assertion
- Triggers
  - Motivation
  - Triggers definition
  - Using triggers

Next lesson: Entity Relationship Model

- Hector Garcia-Molina, Jeffrey D. Ullman, Jennifer Widom. Database Systems: The Complete Book. Pearson Prentice Hall. the 2nd edition. 2008: Chapter 7
- Nguyen Kim Anh, Nguyên lý các hệ cơ sở dữ liệu, NXB Giáo dục. 2004: Chương 7