CS143 Notes: Database Integrity

Book Chapters

(5th) Chapter 4.2, 8.6
(6th) Chapter 4.4, 5.3
(7th) Chapter 4.4, 5.3

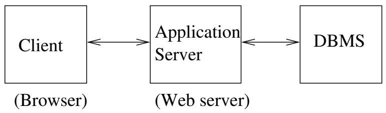
Things to Learn

- Key constraints
- Referential integrity (Foreign key constraints)
- CHECK constraints
- SQL trigger (part of SQL99)

What are integrity constraints?

- An example database with invalid entries (Show the example)
- A statement about what a valid database should look like
  - As a human being, we understand what is a "valid" database
  - The system needs an explicit specification of the semantics/rules
- Arbitrary predicate pertaining to the database (in principle)
  - In practice, only the ones that are easy to enforce
- If a SQL statement violates IC, the statement is aborted and generates an error
- **Q:** What rules/constaints can you find from the example?

- Database constraints checks the rules in the DB (Three tier diagram)



- **Q:** Why do we check these rules in DB, not in application?
  Checking them at application/Web browser can be cheaper

Data validity enforcement in RDBMS

- 3 ways to enforce data validity in RDBMS
  - Domain: GPA is real
  - Constraints: Gives error. Abort statement
    - Key
    - Referential Integrity
    - CHECK constraint
  - Trigger: Event-Condition-Action rule. If a certain event happens, invoke an action to handle it

Key Constraints

- A set of attributes should be unique in a table

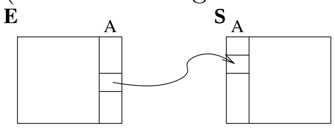
- Course(dept, cnum, sec, unit, instructor, title)
  Course(dept, cnum, sec, unit, instructor, title)
  Course(dept, cnum, sec, unit, instructor, title)

  -
    ```
    CREATE TABLE Course (
        dept CHAR(2) NOT NULL,
        cnum INTEGER NOT NULL,
        sec INTEGER NOT NULL,
        unit INTEGER,
        instructor VARCHAR(30),
        title VARCHAR(30),
        PRIMARY KEY(dept, cnum, sec),
        UNIQUE(dept, cnum, instructor),
        UNIQUE(dept, sec, title) )
    ```
  - One primary key per table

  - Unique for other keys
  - Primary key, unique are enforced through index (more discussion later)

Referential Integrity Constraints

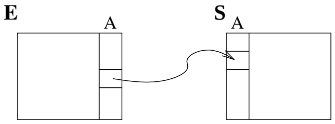
- **Example:**
  - If an sid appears in Enroll, it should also appear in Student
  - If an (dept, cnum, sec) appears in Enroll, it should also appear in Class
    - **Q:** Is the reverse true?
- **Terminology**
  - (Two table diagram: E.A references S.A)



  - E.A **references** S.A
  - E.A: referencing attribute or **foreign key**
  - S.A: referenced attribute
  - **Referential integrity** means that referenced value always exists
    - **foreign key can be NULL. When a foreign key is NULL, no constraint checking**
- **Referential Integrity in SQL**
  - **Example:**

```
CREATE TABLE Enroll (
    sid INTEGER REFERENCES Student(sid),
    dept CHAR(2),
    cnum INTEGER,
    sec INTEGER,
    FOREIGN KEY (dept, cnum, sec) REFERENCES Class(dept, cnum, sec) )
```

  - **Notes:**
    - Referenced attributes must be PRIMARY KEY or UNIQUE
    - Referenced attributes may be omitted if they are the same name with referencing attributes
      - e.g., `sid INT REFERENCES Student`
    - One attribute foreign key may be defined directly
- **Referential Integrity Violation**
  - **Q:** When is the RI violated (two table diagram)?



e.g., do we have to worry if a tuple is deleted from E?

- RI violation from E (insert to E or update to E.A) is not allowed
  - System rejects the statement
  - Always insert/update S first.
- RI violation from S is not allowed by default
  - But we can instruct DBMS to allow it and "fix the violation" automatically.

- **Q:** If a tuple in S is updated/deleted, what can we do to fix RI violation?

  `ON DELETE/UPDATE SET NULL/SET DEFAULT/CASCADE` in SQL

  1. Default: disallow the statement and generate error
  2. `SET NULL/SET DEFAULT`: Change E.A value to NULL or default value
  3. `CASCADE`:
     - On deletion of S: delete the referencing tuples in E
     - On update of S.A: change E.A to the new S.A
- **Example:**

```
CREATE TABLE Enroll (
    sid INTEGER REFERENCES Student(sid)
        ON DELETE CASCADE
    dept CHAR(2),
    cnum INTEGER,
    sec INTEGER,
    FOREIGN KEY (dept, cnum, sec) REFERENCES
        Class(dept, cnum, sec)
            ON DELETE CASCADE
            ON UPDATE SET NULL )
```

  Comments:

  - By default, Student.sid update is not allowed if RI is violated
  - Many RDBMS does not support all actions
- ***Comments:*** Referential integrity is the only SQL constraint that can "fix itself"
  - Other constraints simply abort and report error

  - **Q:** Why should the referenced attributes be unique?

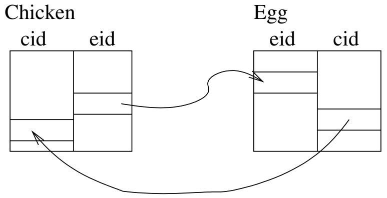
- **Self referencing table**
  - **Example:**

A	B
1	NULL
2	1
3	2
4	3
5	4

```
CREATE TABLE R (
    A INTEGER PRIMARY KEY,
    B INTEGER REFERENCES R(A)
        ON DELETE CASCADE )
```

  - ***Comments:***
    - A table references itself: self-referecing table
    - **Q:** What will happen if we delete (1,NULL)?

- **Circular constraints**
  - **Example:** `ChickenFrom(cid, eid)`: eid became cid, `EggFrom(eid, cid)`: eid is born of cid
    (`Chicken.eid` $\subset$ `Egg.eid`, `Egg.cid` $\subset$ `Chicken.cid`) (diagram)



  - **Q:** Can we insert any tuple to Chicken? or to Egg? How can we fix it?

CHECK constraint

- Add `CHECK(condition)` as part of table definition
  - Rejects any modification statement that will make the condition FALSE.
  - In SQL92, conditions can be complex, e.g., with subqueries
- **Example:** $0 \leq GPA \leq 4.0$

```
CRATE TABLE Student(
        ...
        GPA real,
        ...
        CHECK(0 <= GPA and GPA <= 4.0),
        ...)
```

- **Example:** cnum < 600 AND unit < 10

```
CRATE TABLE Enroll(
        dept CHAR(2),
        cnum INT,
        unit INT,
        title VARCHAR(50),
        CHECK (cnum < 600 AND unit < 10) )
```

- **Q:** The units of all CS classes are above 3 for Class(dept, cnum, unit, title)?
- **Q:** Students whose GPA is below 2.0 cannot take CS classes?
- For performance reasons, most systems do not allow subqueries in condition.
  - This restriction makes CHECK constraint very easy to enforce.
  - Examine the condition only on the tuple that is currently being updated/inserted.

Triggers

Trigger

- Event-Condition-Action rule (or ECA rule)
  - We explicitly specify what events to monitor, what condition to check and what action to take if the condition is met.
- **Query 1:** If a student's GPA goes below 2.0, drop the student from all clases

  Comments: Row-level trigger

- **Query 2:** All new students have to take CS143 (For every insertion to Student, add the corresponding tuple to Enroll.)

  Comments: Statement-level trigger

- Trigger general syntax: Event-Condition-Action rule (or ECA rule)

  -
    ```
    CREATE TRIGGER <name>
    <event>
    <referencing clause>// optional
    WHEN (<condition>)  // optional
    <action>
    ```
  - `<event>`
    - `BEFORE | AFTER INSERT ON R`
    - `BEFORE | AFTER DELETE ON R`
    - `BEFORE | AFTER UPDATE [OF A1, A2, ..., An] ON R`
  - `<action>`
    - Any SQL statement. Multiple statements should be enclosed with `BEGIN ATOMIC ... END` and be separated by ;
  - `<referencing clause>`
    - `REFERENCING OLD|NEW TABLE|ROW AS <var>, ...`

        - `FOR EACH ROW`: row-level trigger
        - `FOR EACH STATEMENT` (default): statement-level trigger

- **Query 3:** For, $R(A)$, after inserting (1), what will happen?

```
CREATE TRIGGER Recursion
AFTER INSERT ON R
BEGIN INSERT INTO R VALUES (1); END
```

- Action sequence

    1. BEFORE trigger
    2. Statement
    3. AFTER trigger
    4. Constraint checking

What is supported in MySQL

- Key constraint
- Under InnoDB, most referential integrity except "ON DELETE/UPDATE SET DEFAULT"
- No `CHECK` constraints
  - MariaDB 10.2.1 added (limited) CHECK constraint support
- Limited trigger: does not allow updating the table that caused the trigger event
  - Generates error and rejects the statement that caused the event

Things to Remember

Constraints and Trigger

- Key constraint: PRIMARY KEY, UNIQUE
- Referential Integrity
  - Referencing attribute (foreign key), referenced attribute
    - Referenced attribute should be PRIMARY KEY or UNIQUE
  - Violation at referencing attribute not allowed
  - Violation at referenced attribute can be fixed automatically
    - `ON DELETE/UPDATE SET NULL/SET DEFAULT/CASCADE`
- Tuple-based CHECK constraint
- Trigger