SQL: Part II

CPS 116
Introduction to Database Systems

Announcements (September 20)

- ❖ Homework #2 assigned today
  - Due in 9 days (September 29)
- ❖ Homework #1 sample solution available
  - Hardcopies only
- ❖ Project Milestone #1 due in 23 days
  - Come to my office hours if you want to chat about project ideas

Incomplete information

- ❖ Example: *Student* (*SID*, *name*, *age*, *GPA*)
- ❖ Value unknown
  - We do not know Nelson's age
- ❖ Value not applicable
  - Nelson has not taken any classes yet; what is his GPA?

Solution 1

- ❖ A dedicated special value for each domain (type)
  - GPA cannot be –1, so use –1 as a special value to indicate a missing or invalid GPA
  - Leads to incorrect answers if not careful
    - `SELECT AVG(GPA) FROM Student;`
  - Complicates applications
    - `SELECT AVG(GPA) FROM Student WHERE GPA <> -1;`
  - Remember the Y2K bug?
    - "00" was used as a missing or invalid year value

Solution 2

- ❖ A valid-bit for every column
  - *Student* (*SID*, *name*, *name_is_valid*, *age*, *age_is_valid*, *GPA*, *GPA_is_valid*)
  - Complicates schema and queries
    - `SELECT AVG(GPA) FROM Student WHERE GPA_is_valid;`

SQL's solution

- ❖ A special value `NULL`
  - For every domain
  - Special rules for dealing with `NULL`'s
- ❖ Example: *Student* (*SID*, *name*, *age*, *GPA*)
  - ⟨ 789, "Nelson", `NULL`, `NULL` ⟩

Computing with `NULL`'s

- When we operate on a `NULL` and another value (including another `NULL`) using +, –, etc., the result is `NULL`
- Aggregate functions ignore `NULL`, except `COUNT(*)` (since it counts rows)

Three-valued logic

- `TRUE` = 1, `FALSE` = 0, `UNKNOWN` = 0.5
- x `AND` y = min(x, y)
- x `OR` y = max(x, y)
- `NOT` x = 1 – x
- When we compare a `NULL` with another value (including another `NULL`) using =, >, etc., the result is `UNKNOWN`
- `WHERE` and `HAVING` clauses only select rows for output if the condition evaluates to `TRUE`
  - `UNKNOWN` is not enough

Unfortunate consequences

-
  ```
  SELECT AVG(GPA) FROM Student;
  SELECT SUM(GPA)/COUNT(*) FROM Student;
  ```
  - Not equivalent
  - Although `AVG(GPA)` = `SUM(GPA)/COUNT(GPA)` still

-
  ```
  SELECT * FROM Student;
  SELECT * FROM Student WHERE GPA = GPA;
  ```
  - Not equivalent

☞ Be careful: `NULL` breaks many equivalences

Another problem

- Example: Who has `NULL` GPA values?
  - `SELECT * FROM Student WHERE GPA = NULL;`
    - Does not work; never returns anything

  -
    ```
    (SELECT * FROM Student)
    EXCEPT ALL
    (SELECT * FROM Student WHERE GPA = GPA)
    ```
    - Works, but ugly
  - Introduced built-in predicates `IS NULL` and `IS NOT NULL`
    - `SELECT * FROM Student WHERE GPA IS NULL;`

Outerjoin motivation

- Example: a master class list

  -
    ```
    SELECT c.CID, c.title, s.SID, s.name
    FROM Course c, Enroll e, Student s
    WHERE c.CID = e.CID AND e.SID = s.SID;
    ```
  - What if a class is empty?
  - It may be reasonable for the master class list to include empty classes as well
    - For these classes, SID and name columns would be `NULL`

Outerjoin flavors and definitions

- A full outerjoin between *R* and *S* (denoted *R* ⟗ *S*) includes all rows in the result of *R* ⋈ *S*, plus
  - "Dangling" *R* rows (those that do not join with any *S* rows) padded with `NULL`'s for *S*'s columns
  - "Dangling" *S* rows (those that do not join with any *R* rows) padded with `NULL`'s for *R*'s columns
- A left outerjoin (*R* ⟕ *S*) includes rows in *R* ⋈ *S* plus dangling *R* rows padded with `NULL`'s
- A right outerjoin (*R* ⟖ *S*) includes rows in *R* ⋈ *S* plus dangling *S* rows padded with `NULL`'s

Outerjoin examples

Course

CID	*title*
CPS199	Independent Study
CPS130	Analysis of Algorithms
CPS114	Computer Networks

Enroll

SID	*CID*
142	CPS196
142	CPS114
123	CPS196
857	CPS196
857	CPS130
456	CPS114

Course ⟕ *Enroll*

CID	*title*	*SID*
CPS199	Independent Study	NULL
CPS130	Analysis of Algorithms	857
CPS114	Computer Networks	142
CPS114	Computer Networks	456

Course ⟖ *Enroll*

CID	*title*	*SID*
CPS196	NULL	142
CPS114	Computer Networks	142
CPS196	NULL	123
CPS196	NULL	857
CPS130	Analysis of Algorithms	857
CPS114	Computer Networks	456

Course ⟗ *Enroll*

CID	*title*	*SID*
CPS199	Independent Study	NULL
CPS130	Analysis of Algorithms	857
CPS114	Computer Networks	142
CPS114	Computer Networks	456
CPS196	NULL	142
CPS196	NULL	123
CPS196	NULL	857

Outerjoin syntax

-
  ```
  SELECT * FROM Course LEFT OUTER JOIN Enroll
                ON Course.CID = Enroll.CID;
  ```

-
  ```
  SELECT * FROM Course RIGHT OUTER JOIN Enroll
                ON Course.CID = Enroll.CID;
  ```

-
  ```
  SELECT * FROM Course FULL OUTER JOIN Enroll
                ON Course.CID = Enroll.CID;
  ```

☞ These are theta joins rather than natural joins

- Return all columns in *Course* and *Enroll*
- Equivalent to *Course* ⟕$_{Course.CID = Enroll.CID}$ *Enroll*, *Course* ⟖$_{Course.CID = Enroll.CID}$ *Enroll*, and *Course* ⟗$_{Course.CID = Enroll.CID}$ *Enroll*

☞ You can write regular ("inner") joins using this syntax too:

```
SELECT * FROM Course JOIN Enroll ON Course.CID = Enroll.CID;
```

Summary of SQL features covered so far

- SELECT-FROM-WHERE statements
- Set and bag operations
- Table expressions, subqueries
- Aggregation and grouping
- Ordering
- NULL's and outerjoins

☞ Next: data modification statements, constraints

INSERT

- Insert one row
  - `INSERT INTO Enroll VALUES (456, 'CPS116');`
    - Student 456 takes CPS116
- Insert the result of a query

  -
    ```
    INSERT INTO Enroll
    (SELECT SID, 'CPS116' FROM Student
     WHERE SID NOT IN (SELECT SID FROM Enroll
                       WHERE CID = 'CPS116'));
    ```
    - Force everybody to take CPS116

DELETE

- Delete everything
  - `DELETE FROM Enroll;`
- Delete according to a WHERE condition

  Example: Student 456 drops CPS116

  -
    ```
    DELETE FROM Enroll
    WHERE SID = 456 AND CID = 'CPS116';
    ```

  Example: Drop students from all CPS classes with GPA lower than 1.0

  -
    ```
    DELETE FROM Enroll
    WHERE SID IN (SELECT SID FROM Student
                  WHERE GPA < 1.0)
    AND CID LIKE 'CPS%';
    ```

UPDATE

- Example: Student 142 changes name to "Barney"

  -
    ```
    UPDATE Student
    SET name = 'Barney'
    WHERE SID = 142;
    ```
- Example: Let's be "fair"?

  -
    ```
    UPDATE Student
    SET GPA = (SELECT AVG(GPA) FROM Student);
    ```
    - But update of every row causes average GPA to change!
    - Average GPA is computed over the old Student table

Constraints

- Restrictions on allowable data in a database
  - In addition to the simple structure and type restrictions imposed by the table definitions
  - Declared as part of the schema
  - Enforced by the DBMS
- Why use constraints?
  - Protect data integrity (catch errors)
  - Tell the DBMS about the data (so it can optimize better)

Types of SQL constraints

- `NOT NULL`
- Key
- Referential integrity (foreign key)
- General assertion
- Tuple- and attribute-based `CHECK`'s

`NOT NULL` constraint examples

```
❖ CREATE TABLE Student
  (SID INTEGER NOT NULL,
   name VARCHAR(30) NOT NULL,
   email VARCHAR(30),
   age INTEGER,
   GPA FLOAT);
❖ CREATE TABLE Course
  (CID CHAR(10) NOT NULL,
   title VARCHAR(100) NOT NULL);
❖ CREATE TABLE Enroll
  (SID INTEGER NOT NULL,
   CID CHAR(10) NOT NULL);
```

Key declaration

- At most one `PRIMARY KEY` per table
  - Typically implies a primary index
  - Rows are stored inside the index, typically sorted by the primary key value ⇒ best speedup for queries
- Any number of `UNIQUE` keys per table
  - Typically implies a secondary index
  - Pointers to rows are stored inside the index ⇒ less speedup for queries

Key declaration examples

```
❖ CREATE TABLE Student
  (SID INTEGER NOT NULL PRIMARY KEY,
   name VARCHAR(30) NOT NULL,
   email VARCHAR(30) UNIQUE,
   age INTEGER,
   GPA FLOAT);
❖ CREATE TABLE Course
  (CID CHAR(10) NOT NULL PRIMARY KEY,
   title VARCHAR(100) NOT NULL);
❖ CREATE TABLE Enroll
  (SID INTEGER NOT NULL,
   CID CHAR(10) NOT NULL,
   PRIMARY KEY(SID, CID));
```

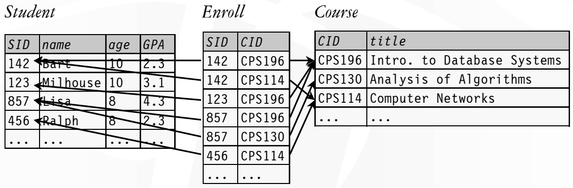
Works on Oracle but not DB2: DB2 requires `UNIQUE` key columns to be `NOT NULL`

This form is required for multi-attribute keys

Referential integrity example

- *Enroll.SID* references *Student.SID*
  - If an SID appears in *Enroll*, it must appear in *Student*
- *Enroll.CID* references *Course.CID*
  - If a CID appears in *Enroll*, it must appear in *Course*

☞ That is, no "dangling pointers"



Student

SID	*name*	*age*	*GPA*
142	Bart	10	2.3
123	Milhouse	10	3.1
857	Lisa	8	4.3
456	Ralph	8	2.3
...	...	...	...

Enroll

SID	*CID*
142	CPS196
142	CPS114
123	CPS196
857	CPS196
857	CPS130
456	CPS114
...	...

Course

CID	*title*
CPS196	Intro. to Database Systems
CPS130	Analysis of Algorithms
CPS114	Computer Networks
...	...

Referential integrity in SQL

- Referenced column(s) must be `PRIMARY KEY`
- Referencing column(s) form a `FOREIGN KEY`
- Example

  -
    ```
    CREATE TABLE Enroll
     (SID INTEGER NOT NULL
       REFERENCES Student(SID),
      CID CHAR(10) NOT NULL,
      PRIMARY KEY(SID, CID),
      FOREIGN KEY CID REFERENCES Course(CID));
    ```

Enforcing referential integrity

Example: *Enroll.SID* references *Student.SID*

- Insert or update an *Enroll* row so it refers to a non-existent SID
  - Reject
- Delete or update a *Student* row whose SID is referenced by some *Enroll* row
  - Reject
  - Cascade: ripple changes to all referring rows
  - Set `NULL`: set all references to `NULL`
  - All three options can be specified in SQL

Deferred constraint checking

- No-chicken-no-egg problem

  -
    ```
    CREATE TABLE Dept
    (name CHAR(20) NOT NULL PRIMARY KEY,
     chair CHAR(30) NOT NULL REFERENCES Prof(name));
    CREATE TABLE Prof
    (name CHAR(30) NOT NULL PRIMARY KEY,
     dept CHAR(20) NOT NULL REFERENCES Dept(name));
    ```
  - The first `INSERT` will always violate a constraint
- Deferred constraint checking is necessary
  - Check only at the end of a transaction
  - Allowed in SQL as an option
- Curious how the schema was created in the first place?
  - `ALTER TABLE ADD CONSTRAINT` (read the manual!)

General assertion

- `CREATE ASSERTION` *assertion_name*
  `CHECK` *assertion_condition*`;`
- *assertion_condition* is checked for each modification that could potentially violate it
- Example: *Enroll.SID* references *Student.SID*

  -
    ```
    CREATE ASSERTION EnrollStudentRefIntegrity
    CHECK (NOT EXISTS
           (SELECT * FROM Enroll
            WHERE SID NOT IN
            (SELECT SID FROM Student)));
    ```

☞ In SQL3, but not all (perhaps no) DBMS supports it

Tuple- and attribute-based `CHECK`'s

- Associated with a single table
- Only checked when a tuple or an attribute is inserted or updated
- Example:

  -
    ```
    CREATE TABLE Enroll
    (SID INTEGER NOT NULL
         CHECK (SID IN (SELECT SID FROM Student)),
     CID ...);
    ```
  - Is it a referential integrity constraint?
  - Not quite; not checked when *Student* is modified

Summary of SQL features covered so far

- Query
  - `SELECT-FROM-WHERE` statements
  - Set and bag operations
  - Table expressions, subqueries
  - Aggregation and grouping
  - Ordering
  - Outerjoins
- Modification
  - `INSERT/DELETE/UPDATE`
- Constraints

☞ Next: triggers, views, indexes