CS143: Query and Update in SQL

Book Chapters

(4th) Chapter 4.1-6, 4.8-10, 3.3.4
(5th) Chapter 3.1-8, 3.10-11
(6th) Chapter 3.1-9, 4.1, 4.3

Things to Learn

- DML for SQL

SQL

- Structured Query Language
- The standard language for all commericial RDBMS
- SQL has many aspects
  - DDL: schema definition, constraints, index, ...
  - DML: query, update, ...
  - triggers, transaction, authorization, ...
- In this lecture, we cover the DML aspect of SQL
  - How to query and modify exsiting databases
- SQL and DBMS
  - SQL is high-level description of user's query
    - No concrete procedure for query execution is given
  - The beauty and success of DBMS
    - The system understands the query and find the best way possible to execute it *automatically*

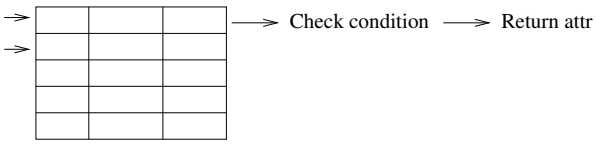
Example to Use in the Class

- School information
  - Student(sid, name, age, GPA, address, ...)
  - Class(dept, cnum, sec, unit, title, instructor, ...)
  - Enroll(sid, dept, cnum, sec)

Basic SELECT statement

- **Query 1:** Find the titles and instructors of all CS courses

- **Semantics**
  - Interpret and write FROM → WHERE → SELECT
    - FROM: the list of tables to look up
    - WHERE: conditions to meet
    - SELECT: the attributes to return
  - *Conceptual* execution (table cursor diagram)



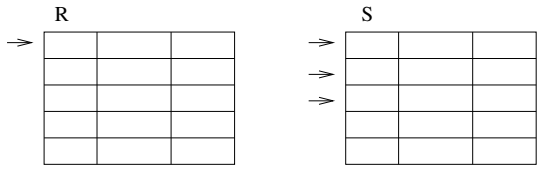
General SQL statement

- `SELECT A1, ..., An`
  `FROM R1, ..., Rm`
  `WHERE C`
  $\equiv \pi_{A_1,\ldots,A_n}(\sigma_C(R_1 \times \cdots \times R_m))$
- `SELECT *`: all attributes
- `SELECT` is "projection" not "selection": can be confusing
- SQL does not remove duplicates: Major difference between SQL and relational algebra
  - More examples will follow

SQL join

- **Query 2:** Find the names and GPAs of all students taking CS classes

  - Conceptually `WHERE R, S`
    (Table join diagram)



- For every pair of tuples from R and S, we check condition and produce output

Notes:

- S, E: tutple variable
  - renaming operator
  - We can consider that S and E are variables that bind to every pair of tuples
- Attribues can also be renamed
  - `GPA (AS) grade`
- `DISTINCT`: remove duplicates in the results

WHERE conditions

- **Query 3:** All student names and GPAs who live on Wilshire

- `%`: any length (0–∞) string
  _: one character
  `'%Wilshire%'`: Any string containing Wilshire

Q: What does `'___%'` mean?

Set operators

- $\cap$: `INTERSECT`, $\cup$: `UNION`, $-$: `EXCEPT`
- Can be applied to the result of SELECT statements or to relations
- **Query 4:** All names of students and instructors

- **Important points to note**
  - Set operators should have the same schema for operands
    - In practice, it is okay to have just compatible types
  - Set operators follow *set* semantics and remove duplicates
    - Set semantics is well understood for set operations. Not many people know bag semantics.
    - Efficiency
  - To keep duplicates, use `UNION ALL, INSERSECT ALL, EXCEPT ALL`
- **Query 5:** Find ids of all students who are not taking any CS courses.

Subqueries

- `SELECT` statement may appear in `WHERE` clause
  - Treated the same as regular relations
  - If the result is one-attribute one-tuple relation, the result can be used like a 'value'

Scalar-value subqueries

- **Query 6:** Find the student ids who live at the same addr as the student with id 301

- **Q:** Can we rewrite it without subquery?

- **Notes:**
  - There is a whole theory about whether/how to rewite a subquery to non-subquery SQL
  - The basic result is we can rewrite subqueries as long as we do not have negation.
  - With negation, we need `EXCEPT`
  - One of the reasons why relational model has been so successful
    - Because it is easy to understand and model, we can design and prove elegant theorems.
    - Many efficient and provable algorithms.

Set membership (IN, NOT IN)

- **Query 7:** Find all student names who take CS classes.

  Idea: Find the set of sids that take CS classes first. Then check whether any student's id belong to that set or not.

  - `IN` is a set membership operator
    - `(a IN R)` is `TRUE` if `a` appears in `R`

Q: Can we write the same query without subqueries?

Q: Are the above two queries equivalent?

Q: Why we care about duplicates so much?

- **Query 8:** Find the names of students who take no CS classes

Q: Can we rewrite it without subqueries?

Set comparison operator ($>$ ALL, $<$ SOME, ...)

- **Query 9:** Find the ids of students whose GPA is greater than all students taking CS classes

  - `ALL` is the universial quantifier $\forall$

- **Query 10:** Find the names of students whose GPA is better than at least one other student
  ≡ All students except the worst GPA

  - `SOME` is the existential quantifier ∃

  Other Set comparison operators: `> ALL, <= SOME, = SOME, ...`, etc.

  - `(<> ALL)` ≡ `(NOT IN)`, `(= SOME)` ≡ `IN`

EXISTS and Correlated subqueries

- **Query 11:** Find the names of the students who take CS courses

  - **EXISTS:** `WHERE EXISTS(SELECT ... FROM ... WHERE)`
    - True if `SELECT .. FROM .. WHERE` returns at least one tuple
  - **Correlated subquery interpretation:**
    - Outer query looks at one tuple at a time and binds the tuple to `S`
    - For each `S`, we execute the inner query and check the condition
    - This is just interpretation. ***DBMS executes it more efficiently but get the same result.***

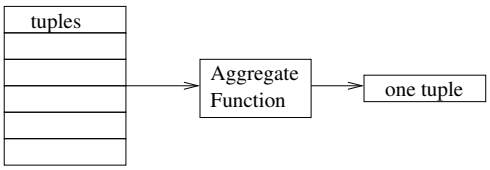
  ### Subqueries in FROM clause

  - Considered as a regular relation
  - **Example:**
    ```
    SELECT name
    FROM (SELECT name, age FROM Student) S
    WHERE age > 17
    ```
    - A subquery inside FROM **MUST** be renamed
    - Student names with age > 17

- **Q:** Do subqueries make SQL more expressive than relational algebra?

Aggregates

- The operators so far check the condition "tuple-by-tuple"
- They never "summarize" multiple tuples into one.
  For example, 'SUM', 'AVG' of GPA is not possible.
- Aggregate function (aggregate diagram)



- **Query 12:** Find the average GPA

- Common aggregate functions: `SUM, AVG, COUNT, MIN, MAX` on single attribute or `COUNT(*)`.

Problems of Duplicates

- **Query 13:** The number of students taking CS classes

- **Query 14:** The average GPA of the students taking CS classes

GROUP BY clause

- Sometimes, we want to get separate statistics for each group of tuples

Example:

Age	AVG(GPA)
17	3.7
19	2.1
20	3.1

But `AVG()` takes average over *all* tuples.

- **Query 15:** Find the average GPA for each age group

  Q: Is the following query meaningful?

  ```
  SELECT sid, age, AVG(GPA)
  FROM Student
  GROUP BY age
  ```

  – SELECT can have only attributes that have a single value in each group or *aggregates*

- **Query 16:** Find the number of classes each student is taking

  Q: What about the students who take no classes?

  Comments: We will learn about outer join that can address this issue later.

HAVING clause

- **Query 17:** Find students who take two or more classes

  – Conditions on aggregates should appear in the HAVING clause.

  Q: Can we rewrite the query without HAVING clause?

- In general, we can rewrite a query not to have a HAVING clause.

ORDER BY clause

- Sometimes we may want to display tuples in a certain order. For example order all students by their GPA
- ```
  SELECT sid, GPA
  FROM Student
  ORDER BY GPA [ASC/DESC]
  ```
  - All students and GPAs, in the acsending/descending order of their GPAs
  - Does not change SQL semantics. Just makes the display easier to look at and understand
  - Default: ASC

General SQL SELECT statement

- ```
  SELECT attributes, aggregates
  FROM relations
  WHERE conditions
  GROUP BY attributes
  HAVING conditions on aggregates
  ORDER BY attributes, aggregates
  ```
- Evaluation order: FROM → WHERE → GROUP BY → HAVING → ORDER BY → SELECT

NULL and Three-valued logic

- **Aggregates**

  - **Q:**

ID	GPA
1	3.0
2	3.6
3	2.4
4	NULL

```
SELECT AVG(GPA)
FROM Student
```

What should be the result?
What about `COUNT(*)`? `COUNT(GPA)`?

  - Rule: Aggregates are computed ignoring `NULL` value, except `COUNT(*)`.
    - Too much information is lost otherwise.
    - `COUNT(*)` considers a `NULL` tuple as a valid tuple
    - When the input to an aggregate is empty, COUNT returns 0; all others return NULL.

- **Set operators** ($\cup, \cap, -$)

  - **Q:** What should be {2.4, 3.0, `NULL`} $\cup$ {3.6, `NULL`}?

  - Rule: `NULL` is treated like other values in set operators

- **Checking** `NULL`

  - IS NULL or `IS NOT NULL` to check if the value is null.

- **Arithmatic operators and comparison**

Q:
```
SELECT name
FROM Student
WHERE GPA * 100/4 > 90
```
What should we do if GPA is `NULL`?

  - **Q:** What should be the value for `GPA * 100/4`?

- Rule: Arithmatic operators with `NULL` input returns `NULL`
- **Q:** What should be `NULL > 90`?
- Rule: Arithmatic comparison with `NULL` value return `Unknown`
  * SQL is **Three-valued logic:** `True, False, Unknown`
  * SQL returns only `True` tuples
  * `GPA * 100/4 > 90` does not return a tuple if `GPA` is `NULL`

- **Three-valued logic**
  - **Q:** `GPA > 3.7 AND age > 18`. What if `GPA` is `NULL` and age < 18?
  - **Q:** `GPA > 3.7 OR age > 18`. What if `GPA` is `NULL` and age < 18?
  - Truth table
    * AND: U AND T = U, U AND F = F, U AND U = U
    * OR: U OR T = T, U OR F = U, U OR U = U
  - `NOT Unknwon = Unknown`. It's not known
  - **SQL returns only `True` tuples**

SQL and bag semantics

- What is a bag (multiset)?
  - A set with duplicate elements
  - Order does not matter
  - **Example:** $\{a, a, b, c\} = \{a, c, b, a\} \neq \{a, b, c\}$
- **SQL and bag semantics**
  - Default SQL statements are based on bag semantics
    - We already learned the bag semantics
    - **Except set operators (`UNION, INTERSECT, EXCEPT`)**, which use set semantics
  - We can enforce set semantics by using `DISTINCT` keyword
- **Bag semantics for set operators**
  - `UNION ALL, INTERSECT ALL, EXCEPT ALL`
  - **Q:** $\{a, a, b\} \cup \{a, b, c\}$?
  - **Q:** $\{a, a, a, b, c\} \cap \{a, a, b\}$?
  - **Q:** $\{a, a, b, b\} - \{a, b, b, c\}$?
- **What rules still hold for Bag?**
  - **Q:** Under bag semantics, $R \cup S = S \cup R$? $R \cap S = S \cap R$?
    $R \cap (S \cup T) = (R \cap S) \cup (R \cap T)$?
    - Under bag semantics, some rules still hold, some do not
    - Consider, $R = \{a\}, S = \{a\}, T = \{a\}$ to check the distributive rule.

OUTER join

- **Query 18:** How many classes does each student take?

  - **Q:** What about student 208, Esther? What should we print? What is the problem?

  - **Q:** Anyway to preserve dangling tuples?

- `OUTER JOIN` operator in `WHERE` clause:
  - `R LEFT OUTER JOIN S ON R.A = S.A`
    - Keep all dangling tuples from R by padding S attributes with NULL.
  - `R RIGHT OUTER JOIN S ON R.A = S.A`
    - keep all dangling tuples from S by padding R attributes with NULL
  - `R FULL OUTER JOIN S ON R.A = S.A`
    - keep all dangling tuples both from R and S with appropriate padding

- **Q:** How to rewrite the above query to include Esther?

Data Modification in SQL (INSERT/DELETE/UPDATE)

- **Insertion**: `INSERT INTO` *Relation Tuples*
  - **Query 19:** Insert tuple `(301, CS, 201, 01)` to `Enroll`?
  - **Query 20:** Populate `Honors` table with students of GPA > 3.7?
- **Deletion**: `DELETE FROM` *R* `WHERE` *Condition*
  - **Query 21:** Delete all students who are not taking classes
- **Update**:
```
Update R
SET A1 = V1, A2 = V2, ..., An = Vn
WHERE Condition
```
  - **Query 22:** Increase all CS course numbers by 100

Expressive power of SQL

- **Example:** All ancestors

child	parent
Susan	John
John	James
James	Elaine
...	...

  - **Q:** Can we find all ancestors of Susan using SQL?

- **Example:** All reachable destination

city 1	city 2
A	B
B	D
A	C
E	F
G	H
...	...

  - **Q:** Find all cities reachable from A?

- **Comments:** SQL92 does not support "recursion" and thus cannot compute the *transitive closure*.
  - Recursion is supported in SQL3.
  - `WITH RECURSIVE R(A1, A2) AS ...`
  - e.g.,
```
WITH RECURSIVE Ancestor(child, ancestor) AS (
                          (SELECT * FROM Parent)
              UNION
                          (SELECT P.child, A.ancestor
                           FROM Parent P, Ancestor A
                           WHERE P.parent = A.child) )
    SELECT * FROM Ancestor
```
  - IBM DB2 supports it, while Oracle does not. Read Book 5.2 for detail