CS143: SQL Query (2)

Book Chapters

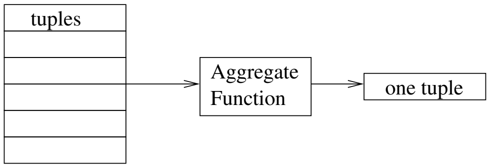
(5th) Chapter 3.5-8, 3.11, 4.7-8
(6th) Chapter 3.6, 3.7, 3.9, 4.1, 5.4-5
(7th) Chapter 3.6, 3.7, 3.9, 4.1, 5.4-5

Things to Learn

- Aggregate function
- Window function
- Case function
- ORDER BY and FETCH FIRST
- SQL data modifications
- Null and three-valued logic
- Outer join
- Bag semantics
- SQL expressive power

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 1:** Find the average GPA

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

Problems of Duplicates

- **Query 2:** The number of students taking CS classes

- **Query 3:** 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 4:** 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 5:** 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 6:** 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.

Window Function

- **Query 7:** Per each result row, return a student's name, their GPA, and the overall GPA average
  - Q: Will this work?

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

- *Window function*:

  - Syntax: `FTN() OVER()`
    - Append `OVER()` to convert an aggregate function to a window function
  - Introduced in SQL 2003
  - Aggregate function merges all input tuples into a *single* output tuple
  - Window function generates *one output tuple per each input tuple*, but the function is computed over all input tuples

- PARTITION BY:
  - **Query 8:** Per each result row, return a student's name, their GPA, and the average GPA within the student's age group

  - `OVER(PARTITION BY` *attr*`)`
  - With `PARTITION BY`, window function is applied only within the same partition

Case Function

- Limited support of if-then-else
  - Return different values depending on conditions
- Syntax:

```
CASE
          WHEN <condition> THEN <expr>
          WHEN <contidion> THEN <expr>
          ELSE <expr>
END
```

- Can be used anywhere a column name can be referenced
  - SELECT, WHERE, GROUP BY, ...
- **Query 9:** Average GPA of the child vs adult group

- Q: What if we want to show “child” and “adult” as part of the output?

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 DESC, sid ASC
  ```
  - All students and GPAs, in the descending order of their GPAs and the ascending order of sids. Default is ASC if omitted.
  - Does not change SQL semantics. Just makes the display easier to look at and understand

FETCH FIRST clause

- **Query 10:** Top-3 students ordered by GPA
  - Sometimes, we just want a few rows from the result. Is there a way to limit result size?
- SQL 2008 Syntax: `[ OFFSET` ⟨*offset*⟩ `ROWS ] FETCH FIRST` ⟨*count*⟩ `ROWS ONLY`
  - From the result, skip first *offset* rows and return the subsequent *count* rows
  - Unfortunately, this was standardized only in SQL 2008. Many systems use their own syntax, including MySQL.
- Variations:
  - MySQL: `LIMIT` ⟨*count*⟩ `OFFSET` ⟨*offset*⟩
  - Oracle used to use `rownum`, DB2 used to use `SELECT TOP`, but they both support `FETCH FIRST` now
  - MS SQL server requires `ORDER BY` clause *and* `OFFSET` to use `FETCH FIRST`

General SQL SELECT statement

-
  ```
  SELECT attributes, aggregates
  FROM relations
  WHERE conditions
  GROUP BY attributes
  HAVING conditions on aggregates
  ORDER BY attributes, aggregates
  FETCH FIRST n ROWS ONLY
  ```
- Evaluation order: FROM → WHERE → GROUP BY → HAVING → ORDER BY → FETCH FIRST → SELECT

Data Modification in SQL (INSERT/DELETE/UPDATE)

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

More Advanced SQL

We now go over a bit more esoteric yet important details of SQL

NULL and Three-valued logic

- **Arithmetic 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**

- **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.

- **`COALESCE()` function**

  - Return first non-NULL value in the list
  - Example: `COALESCE(phone, email, addr)`

OUTER join

- Q: 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 `FROM` 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?

- Other supported join syntax
  - `R NATURAL JOIN S`
  - `R (INNER) JOIN S ON R.A = S.A`

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`
    - MySQL supports only `UNION 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.

Expressive power of SQL

- **Example:** All ancestors

child	parent
Susan	John
John	Andy
Andy	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 SQL1999.
  - `WITH RECURSIVE R(A1, A2) AS ...`

    ```
    WITH RECURSIVE Ancestor(child, ancestor) AS (
       (SELECT child, parent AS ancestor FROM Parent)
        UNION
       (SELECT A.child, P.parent
        FROM Ancestor A, Parent P
        WHERE A.ancestor = P.child) )
    SELECT * FROM Ancestor WHERE Ancestor.child = 'Susan';
    ```

  - MySQL introduced support for recursive common table expression in v8.0