Xi'an Jiaotong-Liverpool University 西交利物浦大学

DTS207TC Database Development and Design

Lecture 2
Mid-level SQL

Di Zhang, Autumn 2025

Page titles with * will not be assessed

*SQL Interview Questions Website

- China Big Company
  - https://www.nowcoder.com/ta/sql
  - https://www.mianshiya.com/tag/SQL
- International Company
  - https://leetcode.cn/problemset/database/
  - https://www.stratascratch.com

-- You will be asked to be tested without AI and Internet in real interview…

*Tips on CW

- Correctness
- Efficiency
- Completeness
- Document quality

Joined Relations

- **Join operations** take two relations and return as a result another relation.
- A join operation is a Cartesian product which requires that tuples in the two relations match (under some condition). It also specifies the attributes that are present in the result of the join
- The join operations are typically used as subquery expressions in the **from** clause
- Three types of joins:
  - Natural join
  - Inner join
  - Outer join

Natural Join in SQL

- Natural join matches tuples with the same values for all common attributes, and retains only one copy of each common column.
- List the names of instructors along with the course ID of the courses that they taught
  - **select** *name*, *course_id*
    from *students, takes*
    where *student.ID* = *takes.ID*;
- Same query in SQL with "natural join" construct
  - **select** *name*, *course_id*
    from *student* **natural join** *takes*;

Natural Join in SQL (Cont.)

- The **from** clause can have multiple relations combined using natural join:

  select $A_1, A_2, \ldots A_n$
  from r_1 **natural join** r_2 **natural join .. natural join** r_n
  where P ;

Example: Student Relation

ID	*name*	*dept_name*	*tot_cred*
00128	Zhang	Comp. Sci.	102
12345	Shankar	Comp. Sci.	32
19991	Brandt	History	80
23121	Chavez	Finance	110
44553	Peltier	Physics	56
45678	Levy	Physics	46
54321	Williams	Comp. Sci.	54
55739	Sanchez	Music	38
70557	Snow	Physics	0
76543	Brown	Comp. Sci.	58
76653	Aoi	Elec. Eng.	60
98765	Bourikas	Elec. Eng.	98
98988	Tanaka	Biology	120

Takes Relation

ID	*course_id*	*sec_id*	*semester*	*year*	*grade*
00128	CS-101	1	Fall	2017	A
00128	CS-347	1	Fall	2017	A-
12345	CS-101	1	Fall	2017	C
12345	CS-190	2	Spring	2017	A
12345	CS-315	1	Spring	2018	A
12345	CS-347	1	Fall	2017	A
19991	HIS-351	1	Spring	2018	B
23121	FIN-201	1	Spring	2018	C+
44553	PHY-101	1	Fall	2017	B-
45678	CS-101	1	Fall	2017	F
45678	CS-101	1	Spring	2018	B+
45678	CS-319	1	Spring	2018	B
54321	CS-101	1	Fall	2017	A-
54321	CS-190	2	Spring	2017	B+
55739	MU-199	1	Spring	2018	A-
76543	CS-101	1	Fall	2017	A
76543	CS-319	2	Spring	2018	A
76653	EE-181	1	Spring	2017	C
98765	CS-101	1	Fall	2017	C-
98765	CS-315	1	Spring	2018	B
98988	BIO-101	1	Summer	2017	A
98988	BIO-301	1	Summer	2018	*null*

student natural join *takes*

ID	*name*	*dept_name*	*tot_cred*	*course_id*	*sec_id*	*semester*	*year*	*grade*
00128	Zhang	Comp. Sci.	102	CS-101	1	Fall	2017	A
00128	Zhang	Comp. Sci.	102	CS-347	1	Fall	2017	A-
12345	Shankar	Comp. Sci.	32	CS-101	1	Fall	2017	C
12345	Shankar	Comp. Sci.	32	CS-190	2	Spring	2017	A
12345	Shankar	Comp. Sci.	32	CS-315	1	Spring	2018	A
12345	Shankar	Comp. Sci.	32	CS-347	1	Fall	2017	A
19991	Brandt	History	80	HIS-351	1	Spring	2018	B
23121	Chavez	Finance	110	FIN-201	1	Spring	2018	C+
44553	Peltier	Physics	56	PHY-101	1	Fall	2017	B-
45678	Levy	Physics	46	CS-101	1	Fall	2017	F
45678	Levy	Physics	46	CS-101	1	Spring	2018	B+
45678	Levy	Physics	46	CS-319	1	Spring	2018	B
54321	Williams	Comp. Sci.	54	CS-101	1	Fall	2017	A-
54321	Williams	Comp. Sci.	54	CS-190	2	Spring	2017	B+
55739	Sanchez	Music	38	MU-199	1	Spring	2018	A-
76543	Brown	Comp. Sci.	58	CS-101	1	Fall	2017	A
76543	Brown	Comp. Sci.	58	CS-319	2	Spring	2018	A
76653	Aoi	Elec. Eng.	60	EE-181	1	Spring	2017	C
98765	Bourikas	Elec. Eng.	98	CS-101	1	Fall	2017	C-
98765	Bourikas	Elec. Eng.	98	CS-315	1	Spring	2018	B
98988	Tanaka	Biology	120	BIO-101	1	Summer	2017	A
98988	Tanaka	Biology	120	BIO-301	1	Summer	2018	*null*

Dangerous in Natural Join

- Beware of unrelated attributes with same name which get equated incorrectly
- Example -- List the names of students instructors along with the titles of courses that they have taken
  - Correct version

    select *name*, *title*
    from *student* **natural join** *takes*, *course*
    where *takes*.*course_id* = *course*.*course_id*;

  - Incorrect version

    select *name*, *title*
    from *student* **natural join** *takes* **natural join** *course*;

    - This query omits all (student name, course title) pairs where the student takes a course in a department other than the student's own department.
    - The correct version (above), correctly outputs such pairs.

Natural Join with Using Clause

- To avoid the danger of equating attributes erroneously, we can use the “**using**” construct that allows us to specify exactly which columns should be equated.

- Query example

select *name*, *title*
from (*student* **natural join** *takes*) **join** *course* **using** (*course_id*)

Joined Types and Conditions

- **Join operations** take two relations and return as a result another relation.
- These additional operations are typically used as subquery expressions in the **from** clause
- **Join condition** – defines which tuples in the two relations match.
- **Join type** – defines how tuples in each relation that do not match any tuple in the other relation (based on the join condition) are treated.

Join types
inner join
left outer join
right outer join
full outer join

Join conditions
natural
on <predicate>
using $(A_1, A_2, \ldots, A_n)$

Join Condition

- The **on** condition allows a general predicate over the relations being joined
- This predicate is written like a **where** clause predicate except for the use of the keyword **on**
- Query example

  select *
  from *student* **join** *takes* **on** *student_ID* = *takes_ID*

  - The **on** condition above specifies that a tuple from *student* matches a tuple from *takes* if their *ID* values are equal.

- Equivalent to:

  select *
  from *student* , *takes*
  where *student_ID* = *takes_ID*

Join Condition (Cont.)

- The **on** condition allows a general predicate over the relations being joined.
- This predicate is written like a **where** clause predicate except for the use of the keyword **on**.
- Query example

  select *
  from *student* **join** *takes* **on** *student_ID* = *takes_ID*

  - The **on** condition above specifies that a tuple from *student* matches a tuple from *takes* if their *ID* values are equal.

- Equivalent to:

  select *
  from *student* , *takes*
  where *student_ID* = *takes_ID*

Outer Join

An extension of the join operation that avoids loss of information.

Computes the join and then adds tuples form one relation that does not match tuples in the other relation to the result of the join.

- Uses *null* values.
- Three forms of outer join:
  - left outer join
  - right outer join
  - full outer join

Outer Join Examples

- Relation *course*

course_id	*title*	*dept_name*	*credits*
BIO-301	Genetics	Biology	4
CS-190	Game Design	Comp. Sci.	4
CS-315	Robotics	Comp. Sci.	3

- Relation *prereq*

course_id	*prereq_id*
BIO-301	BIO-101
CS-190	CS-101
CS-347	CS-101

- Observe that

  course information is missing CS-347

Left Outer Join

- *course* **natural left outer join** *prereq*

course_id	*title*	*dept_name*	*credits*	*prereq_id*
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-315	Robotics	Comp. Sci.	3	*null*

Right Outer Join

- *course* **natural right outer join** *prereq*

course_id	*title*	*dept_name*	*credits*	*prereq_id*
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-347	*null*	*null*	*null*	CS-101

Full Outer Join

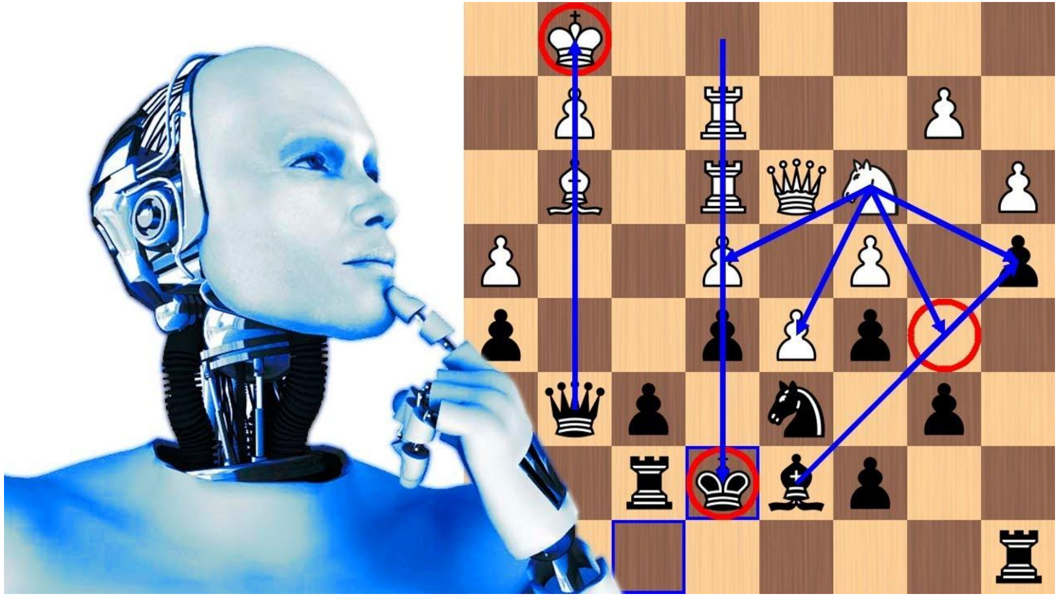
- *course* **natural full outer join** *prereq*

course_id	*title*	*dept_name*	*credits*	*prereq_id*
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-315	Robotics	Comp. Sci.	3	*null*
CS-347	*null*	*null*	*null*	CS-101

*The impact of different writing methods on Join efficiency (chpt. 16)

- The following minimalist but real-world example demonstrates how different approaches can lead to explosive intermediate results and vastly different computational effort, yet the final answer remains the same.
  - See '3_compare_join.txt'
- In most cases, PostgreSQL will automatically optimize. However, if you write the JOIN conditions as complex expressions or use views/CTEs, the optimizer may not be able to see the filter conditions, resulting in performance degradation.

*Optimal path to execute ‘Join’



- Similar approach to playing chesses with AI
  - Define legal moves
  - Define an evaluation function
  - Search for the best solution（can be solved by various methods, such as Paper）

Views

- In some cases, it is not desirable for all users to see the entire logical model (that is, all the actual relations stored in the database.)
- Consider a person who needs to know an instructors name and department, but not the salary. This person should see a relation described, in SQL, by

  select *ID*, *name*, *dept_name*
  from *instructor*

- A **view** provides a mechanism to hide certain data from the view of certain users.
- Any relation that is not of the conceptual model but is made visible to a user as a "virtual relation" is called a **view**.

View Definition

- A view is defined using the **create view** statement which has the form

  create view *v* **as** < query expression >

  where <query expression> is any legal SQL expression. The view name is represented by *v.*

- Once a view is defined, the view name can be used to refer to the virtual relation that the view generates.

- View definition is not the same as creating a new relation by evaluating the query expression
  - Rather, a view definition causes the saving of an expression; the expression is substituted into queries using the view.

View Definition and Use

- A view of instructors without their salary

  create view ***faculty*** **as**
  select *ID*, *name*, *dept_name*
  from *instructor*

- Find all instructors in the Biology department

  select *name*
  from ***faculty***
  where *dept_name* = 'Biology'

- Create a view of department salary totals

  create view ***departments_total_salary(dept_name, total_salary)*** **as**
  select *dept_name*, **sum** (*salary*)
  from *instructor*
  group by *dept_name*;

Views Defined Using Other Views

- One view may be used in the expression defining another view
- A view relation v_1 is said to ***depend directly*** on a view relation v_2 if v_2 is used in the expression defining v_1
- A view relation v_1 is said to ***depend on*** view relation v_2 if either v_1 depends directly to v_2 or there is a path of dependencies from v_1 to v_2
- A view relation v is said to be ***recursive*** if it depends on itself.

Views Defined Using Other Views

- **create view** ***physics_fall_2017*** **as**
  select *course.course_id*, *sec_id*, *building*, *room_number*
  from *course*, *section*
  where *course.course_id* = *section.course_id*
  and *course.dept_name* = 'Physics'
  and *section.semester* = 'Fall'
  and *section.year* = '2017';

- **create view** ***physics_fall_2017****_watson* **as**
  select *course_id*, *room_number*
  from ***physics_fall_2017***
  where *building*= 'Watson';

View Expansion

- Expand the view :

```
create view physics_fall_2017_watson as
   select course_id, room_number
   from physics_fall_2017
   where building= 'Watson'
```

- To:

```
create view physics_fall_2017_watson as
   select course_id, room_number
   from (select course.course_id, building, room_number
         from course, section
         where course.course_id = section.course_id
              and course.dept_name = 'Physics'
              and section.semester = 'Fall'
              and section.year = '2017')
   where building= 'Watson';
```

View Expansion (Cont.)

- A way to define the meaning of views defined in terms of other views.
- Let view v_1 be defined by an expression e_1 that may itself contain uses of view relations.
- View expansion of an expression repeats the following replacement step:

  repeat
  Find any view relation v_i in e_1
  Replace the view relation v_i by the expression defining v_i
  until no more view relations are present in e_1

- As long as the view definitions are not recursive, this loop will terminate

Materialized Views

- Certain database systems allow view relations to be physically stored.
  - Physical copy created when the view is defined.
  - Such views are called **Materialized view**:
- If relations used in the query are updated, the materialized view result becomes out of date
  - Need to **maintain** the view, by updating the view whenever the underlying relations are updated.

Update of a View

- Add a new tuple to *faculty* view which we defined earlier

  insert into *faculty*

  values ('30765', 'Green', 'Music');

- This insertion must be represented by the insertion into the *instructor* relation
  - Must have a value for salary.
- Two approaches
  - Reject the insert
  - Insert the tuple

    ('30765', 'Green', 'Music', null)

  into the *instructor* relation

Some Updates Cannot be Translated Uniquely

- **create view** *instructor_info* **as**
  select *ID*, *name*, *building*
  from *instructor*, *department*
  where *instructor.dept_name* = *department.dept_name*;
- **insert into** *instructor_info*

  values ('69987', 'White', 'Taylor');
- Issues
  - Which department, if multiple departments in Taylor?
  - What if no department is in Taylor?

And Some Not at All

- **create view** *history_instructors* **as**
  select *
  from *instructor*
  where *dept_name*= 'History';

- What happens if we insert

  ('25566', 'Brown', 'Biology', 100000)

  into *history_instructors?*

View Updates in SQL

- Most SQL implementations allow updates only on simple views
  - The **from** clause has only one database relation.
  - The **select** clause contains only attribute names of the relation, and does not have any expressions, aggregates, or **distinct** specification.
  - Any attribute not listed in the **select** clause can be set to null
  - The query does not have a **group** by or **having** clause.

Built-in Data Types in SQL

- **date:** Dates, containing a (4 digit) year, month and date
  - Example: **date** '2005-7-27'
- **time:** Time of day, in hours, minutes and seconds.
  - Example: **time** '09:00:30'   **time** '09:00:30.75'
- **timestamp:** date plus time of day
  - Example: **timestamp** '2005-7-27 09:00:30.75'
- **interval:** period of time
  - Example: interval '1' day
  - Subtracting a date/time/timestamp value from another gives an interval value
  - Interval values can be added to date/time/timestamp values

Large-Object Types

- Large objects (photos, videos, CAD files, etc.) are stored as a *large object*:
  - **blob**: binary large object -- object is a large collection of uninterpreted binary data (whose interpretation is left to an application outside of the database system)
  - **clob**: character large object -- object is a large collection of character data
- When a query returns a large object, a pointer is returned rather than the large object itself.

User-Defined Types

- **create type** construct in SQL creates user-defined type

  create type *Dollars* **as numeric (12,2) final**

- Example:

  create table *department*
  (*dept_name* **varchar** (20),
  building **varchar** (15),
  budget Dollars);

Domains

- **create domain** construct in SQL-92 creates user-defined domain types

create domain *person_name* **char**(20) **not null**

- Types and domains are similar. Domains can have constraints, such as **not null**, specified on them.
- Example:

create domain *degree_level* **varchar**(10)
constraint *degree_level_test*
check (**value in** ('Bachelors', 'Masters', 'Doctorate'));

*Data Cleaning

- Extract, transform, load – Wikipedia
- Benefits
  - 1. The original table remains unchanged, allowing for rollback at any time.
  - 2. The cleaning logic is entirely contained within the VIEW, allowing version control with a SQL file.
  - 3. If you want to add new rules, simply wrap it in another VIEW; the old VIEW remains available for historical tasks.
  - 4. If you want to materialize the data later, simply create a materialized view mv_clean AS select * from v2_orders_valid; to speed things up.
  - This is the typical "using VIEWs for data cleaning" in PostgreSQL: dirty data remains in place, while clean data is "projected" as needed.

*Comparison of Tools

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	Easy to use	Performance	Memory	Scalability
Linux Command Line	Not good	Good	Based on disks	No
Python/Pandas	Not bad	Slow	Based on main mem	No
SQL/DB	Good	Slower than Linux, faster than Pandas	Based on disks	Hadoop can do it best
GUI Tools	Great for small tasks	Depends on the underlying implementation	Depends on the underlying implementation	Depends on the underlying implementation

**Mathematical thinking in DB (chpt. 2.6)

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- What is 'legal moves'?
  - Where a and where b ⇔ Where b and where a : **commutative law**
  - Nature Join satisfy **association law**
  - Exchange join and where: **distributive law**
  - …
- It is similar to what we have learned in math…

**Modeling with a kind of… *Algebra*??

- Informally speaking, algebra usually refers to something supporting ‘add’ and ‘multiply’, as well as their inversion (‘subtract’ and ‘divide’)

	+	×
Elementary algebra (for children)	add	multiply
Polynomial Algebra	add	multiply

- How many algebras do you know?

**Relational Algebra

	+	×
Boolean algebra (in computer science)	or	and
Linear algebra	add	product
Sigma algebra (in probilitstic theory)	union	interset
Relational Algebra	Union	Join

- Example (Not strictly speaking)
  - Two tables with the same schema can be united
  - Two tables with common keys can be Joined

***Application

- Find all equivalent queries
  - Traverse the equivalent form of an expression according to the transformation rules. Then a selection of the best form can be conducted.
- Query = Solve Boolean equations
  - Combined with other types of equations (such as linear equations), more complex queries can be implemented, such as: Q: Under what conditions can Alice receive a scholarship? A: improve GPA at least 0.3.
- Automatic normal form conversion
  - Polynomial factorization minimizes redundancy under a multiplication structure; database normal form decomposition minimizes redundancy under a connection structure. The normal form can be converted automatically.