COMP9120

Week 5: Advanced SQL

Semester 1, 2022

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THE UNIVERSITY OF SYDNEY

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Reminder

- **Quiz** next week (week 6)
  - Released on Thursday, 31 March at 23:59
  - Due date Friday, 1 April at 23:59
  - Quiz duration → 1.5 hours
    - Only one attempt is allowed
  - 10 MCQ questions (on week1 – week 5 contents)
  - 3 essay questions
    - ERD to logical design
    - Relational Algebra
    - SQL
  - Practice quiz is available in Canvas to familiarize yourself with the system

Acknowledgement of Country

I would like to acknowledge the Traditional Owners of Australia and recognise their continuing connection to land, water and culture. I am currently on the land of the Gadigal People of the Eora nation and pay my respects to their Elders, past, present and emerging.

I further acknowledge the Traditional Owners of the country on which you are on and pay respects to their Elders, past, present and future.

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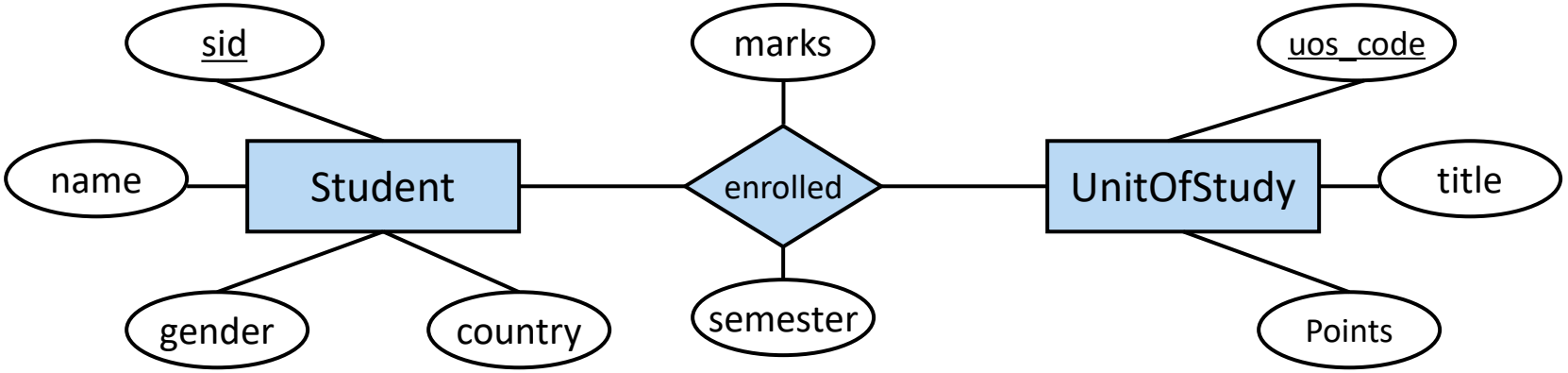
Running Example



Student			
sid	**name**	**gender**	**country**
1001	Adam	M	AUS
1002	Bob	M	ROK
1003	Lily	F	AUS
1004	Simon	M	GBR
1005	Jesse	F	CHN
1006	Adam	M	GER

Enrolled			
sid	**uos_code**	**semester**	**marks**
1001	COMP5138	2020-S2	72
1002	COMP5702	2020-S2	85
1003	COMP5138	2020-S2	67
1006	COMP5318	2020-S2	94
1003	ISYS3207	2020-S1	78
1006	ISYS3207	2020-S2	40

UnitOfStudy		
uos_code	**title**	**points**
COMP5138	Relational DBMS	6
COMP5318	Data Mining	6
INFO6007	IT Project Management	6
SOFT1002	Algorithms	12
ISYS3207	IS Project	4
COMP5702	MIT Research Project	18

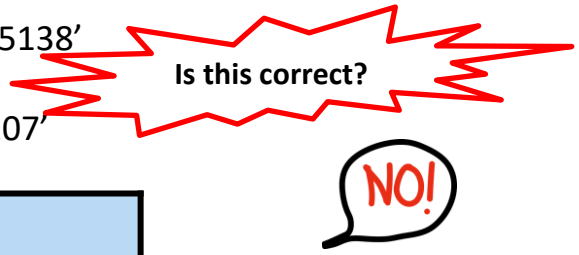
Review: Set Operations

› Find id of all students who are enrolled in both ‘COMP5138’ and ‘ISYS3207’.

```
SELECT sid FROM Enrolled WHERE uos_code='COMP5138'
INTERSECT
SELECT sid FROM Enrolled WHERE uos_code='ISYS3207'
```

› How about listing the **names** of students who are enrolled in both ‘COMP5138’ and ‘ISYS3207’?

```
SELECT name FROM Student NATURAL JOIN Enrolled WHERE uos_code='COMP5138'
INTERSECT
SELECT name FROM Student NATURAL JOIN Enrolled WHERE uos_code='ISYS3207'
```



Student			
sid	**name**	**gender**	**country**
1001	Adam	M	AUS
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Enrolled			
sid	**uos_code**	**Semester**	**marks**
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Outline

- **Nested Queries**
- Aggregation and Grouping
- NULL Values and Three-valued Logic

Nested Queries

› How about listing the names of students who enrolled in both ‘COMP5138’ and ‘ISYS3207’?

```
SELECT name FROM Student NATURAL JOIN Enrolled WHERE uos_code='COMP5138'
INTERSECT
SELECT name FROM Student NATURAL JOIN Enrolled WHERE uos_code='ISYS3207'
```

- Correct SQL using nested queries

```
SELECT name
  FROM Student
 WHERE sid IN (
            SELECT sid FROM Enrolled WHERE uos_code='COMP5138'
            INTERSECT
            SELECT sid FROM Enrolled WHERE uos_code='ISYS3207'
            )
```

This subquery lists the id of all students who are enrolled in both ‘COMP5138’ and ‘ISYS3207’

Nested Queries

- SQL provides a mechanism for the nesting of queries to formulate complex queries
  - SQL is **compositional**: everything (inputs/outputs) is represented as multisets, the output of one query can thus be used as the input to another (nesting!)

- A Select-From-Where expression that is nested within another query is called a **subquery**
  - Typically appear in the **WHERE** clause
  - But also, can appear in the **FROM** clause, **SELECT** clause, or **HAVING** clause

- A common use of subqueries is to perform tests for *set membership*, *set comparisons*, and *set cardinality*.

Example: Nested Queries

› Find the names of students who are enrolled in 'COMP5138'?

```
SELECT name
  FROM Student
 WHERE sid IN ( SELECT sid
                FROM Enrolled
                WHERE uos_code='COMP5138' )
```

The **IN** operator will test to see if the sid value of a row is included in the list returned from the subquery

Subquery is embedded in parentheses. In this case it returns a list that will be used in the **WHERE** clause of the outer query

Set Comparison Operators in SQL

v set-comparison R: v is a value in the outer query, R is the result of a subquery

- v **[NOT] IN** R
  - tests whether v is in (or not in, if **NOT** is specified) R: **true** $\Leftrightarrow$ v $\in$ R
- **[NOT] EXISTS** R
  - tests whether a set R is not (is, if **NOT** is specified) empty: **true** $\Leftrightarrow$ R $\neq \emptyset$ (**true** $\Leftrightarrow$ R = $\emptyset$)
- v op **ALL** R
  - op can be $<$, $\leq$, $>$, $\geq$, $=$, $\neq$
  - tests whether a predicate is true for the whole set: **true** $\Leftrightarrow \forall$ t $\in$ R : (v op t)
- v op **SOME** R
  - the same as v op **ANY** R
  - tests whether a predicate is true for at least one set element: **true** $\Leftrightarrow \exists$ t $\in$ R : (v op t)

Example: Nested Queries

› Find the id of the student with the highest mark

```
SELECT sid
FROM Enrolled
WHERE marks >= ALL ( SELECT marks
                     FROM Enrolled )
```

› Find name of the students who did not enroll in 2020-S2 semester.

```
SELECT name
FROM Student
WHERE sid NOT IN( SELECT sid
                  FROM Enrolled
                  WHERE semester = '2020-S2')
```

Views

- A view is a virtual table
  - Defined through an SQL query, used as a table in other queries
  - Normally evaluated on each use
    - Not evaluated once and stored
  - Convenient way of encapsulating queries as tables

```
CREATE VIEW student_enrollment AS
        SELECT sid, name, title, semester
        FROM student NATURAL JOIN Enrolled NATURAL JOIN unitofstudy

SELECT *
FROM student_enrollment
ORDER BY name;
```

Exercise

› Find male students name who are enrolled in units that has the lowest credit point

Solution: [Without view and step-by-step nested query]

```
SELECT name
FROM  Student
WHERE gender = 'M' AND sid IN (SELECT sid
                               FROM  Enrolled
                               WHERE uos_code IN (SELECT uos_code
                                                  FROM UnitOfStudy
                                                  WHERE points <= ALL (SELECT points
                                                                       FROM UnitOfStudy)));
```

Exercise

› Find male students name who are enrolled in units that has the lowest credit point

Solution: [Using View]

```
CREATE VIEW MaleStudents AS
        SELECT sid, name
        FROM  Student
        WHERE gender = 'M';
```

```
CREATE VIEW LowestCreditPointUnit AS
        SELECT uos_code
        FROM UnitOfStudy
        WHERE points <= ALL (SELECT points
                             FROM UnitOfStudy);
```

```
SELECT name
FROM  MaleStudents
WHERE sid IN (SELECT sid
              FROM  Enrolled
              WHERE uos_code IN (SELECT uos_code
                                 FROM LowestCreditPointUnit));
```

Outline

- Nested Queries
- **Aggregation and Grouping**
- NULL Values and Three-valued Logic

Aggregation

- Besides retrieving data, SQL supports several **aggregation** operations
  - **COUNT**, **SUM**, **AVG**, **MAX**, **MIN** (also called aggregate functions)
  - Except **COUNT**, all aggregations apply to a single attribute
  - These operations apply to duplicates, unless **DISTINCT** is specified

Example

- How many courses are there?
  - **SELECT COUNT**(*) **FROM** unitofstudy
- Find the highest mark for ‘COMP5138’?
  - **SELECT MAX**(marks) **FROM** Enrolled

    WHERE uos_code = ‘COMP5138’
- Find the average mark of ‘COMP5138’?
  - **SELECT AVG**(marks) **FROM** Enrolled

    WHERE uos_code = ‘COMP5138’
- How many students are enrolled?
  - **SELECT COUNT**(**DISTINCT** sid) **FROM** Enrolled

Enrolled			
sid	**uos_code**	**Semester**	**marks**
1001	COMP5138	2020-S2	72
1002	COMP5702	2020-S2	85
1003	COMP5138	2020-S2	67
1006	COMP5318	2020-S2	94
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UnitOfStudy		
uos_code	**title**	**points**
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COMP5318	Data Mining	6
INFO6007	IT Project Management	6
SOFT1002	Algorithms	12
ISYS3207	IS Project	4
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Example

› Find the id of the student who has got the highest mark in COMP5138

Enrolled			
sid	**uos_code**	**Semester**	**marks**
1001	COMP5138	2020-S2	72
1002	COMP5702	2020-S2	85
1003	COMP5138	2020-S2	67
1006	COMP5318	2020-S2	94
1003	ISYS3207	2020-S1	78
1006	ISYS3207	2020-S2	40

```
SELECT sid
FROM enrolled
WHERE uos_code = 'COMP5138' AND
        marks = (SELECT MAX(marks)
                 FROM enrolled
                 WHERE uos_code = 'COMP5138');
```

Example

› Find the name of the student who has got the highest mark in ‘Relational DBMS’ course

```
SELECT name FROM student
WHERE sid IN (
        SELECT sid FROM enrolled NATURAL JOIN unitofstudy
        WHERE title = ‘Relational DBMS’ and marks =(SELECT MAX(marks)
                                                    FROM enrolled NATURAL JOIN unitofstudy
                                                    WHERE title = ‘Relational DBMS’))
```

Student

sid	name	gender	country
1001	Adam	M	AUS
1002	Bob	M	ROK
1003	Lily	F	AUS
1004	Simon	M	GBR
1005	Jesse	F	CHN
1006	Adam	M	GER

Enrolled

sid	uos_code	Semester	marks
1001	COMP5138	2020-S2	72
1002	COMP5702	2020-S2	85
1003	COMP5138	2020-S2	67
1006	COMP5318	2020-S2	94
1003	ISYS3207	2020-S1	78
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UnitOfStudy

uos_code	title	points
COMP5138	Relational DBMS	6
COMP5318	Data Mining	6
INFO6007	IT Project Management	6
SOFT1002	Algorithms	12
ISYS3207	IS Project	4
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Grouping

› Instead of aggregating all (qualifying) tuples into a single value, sometimes we want to apply aggregation to each of several *groups* of tuples.

› Example: Find the total sales amount of each company

Sales Table

id	company	amount
1	IBM	5500
2	DELL	4500
3	IBM	6500

SELECT company, **SUM**(amount)
FROM Sales

company	amount
IBM	16500
DELL	16500
IBM	16500

SELECT company, **SUM**(amount)
FROM Sales
GROUP BY company

company	amount
IBM	12000
DELL	4500

Group By Queries

- In SQL, we can "partition" a relation into *groups* according to the value(s) of one or more attributes:

SELECT target-list
FROM relation-list
WHERE qualification
GROUP BY grouping-list
HAVING group-qualification

SELECT company, **SUM**(amount)
FROM Sales
GROUP BY company

- A *group* is a set of tuples that have the same value for all attributes in grouping-list.
- NOTE: Attributes in the **SELECT** / **HAVING** clause must be either in aggregate functions or from the grouping-list
  - Intuitively, each result tuple corresponds to a *group,* and these attributes must have a single value per group.

Group By Overview

```
SELECT company, SUM(amount)
FROM Sales
GROUP BY company
```

Sales Table

id	company	amount
1	IBM	5500
2	DELL	4500
3	IBM	6500

company	amount
IBM	5500
IBM	6500
DELL	4500

company	amount
IBM	12000
DELL	4500

Exercise

- Find the total number of student from each country

```
SELECT country, COUNT(*)
FROM student
GROUP BY country;
```

- Find the total number of Male and Female student

```
SELECT gender, COUNT(*)
FROM student
GROUP BY gender;
```

Student			
sid	**name**	**gender**	**country**
1001	Adam	M	AUS
1002	Bob	M	ROK
1003	Lily	F	AUS
1004	Simon	M	GBR
1005	Jesse	F	CHN
1006	Adam	M	GER

Filtering Groups with HAVING Clause

- Group By Example:
  - List courses and their average marks

```
SELECT uos_code, AVG(marks)
FROM enrolled
GROUP BY uos_code
```

- **HAVING** clause can further filter groups to fulfil a predicate
  - Example: Find courses that have average mark > 60, and their average marks

```
SELECT uos_code, AVG(mark)
FROM enrolled
GROUP BY uos_code
HAVING AVG(mark) > 60
```

  - NOTE: Predicates in the **HAVING** clause are applied after the formation of groups, whereas predicates in the **WHERE** clause are applied before forming groups

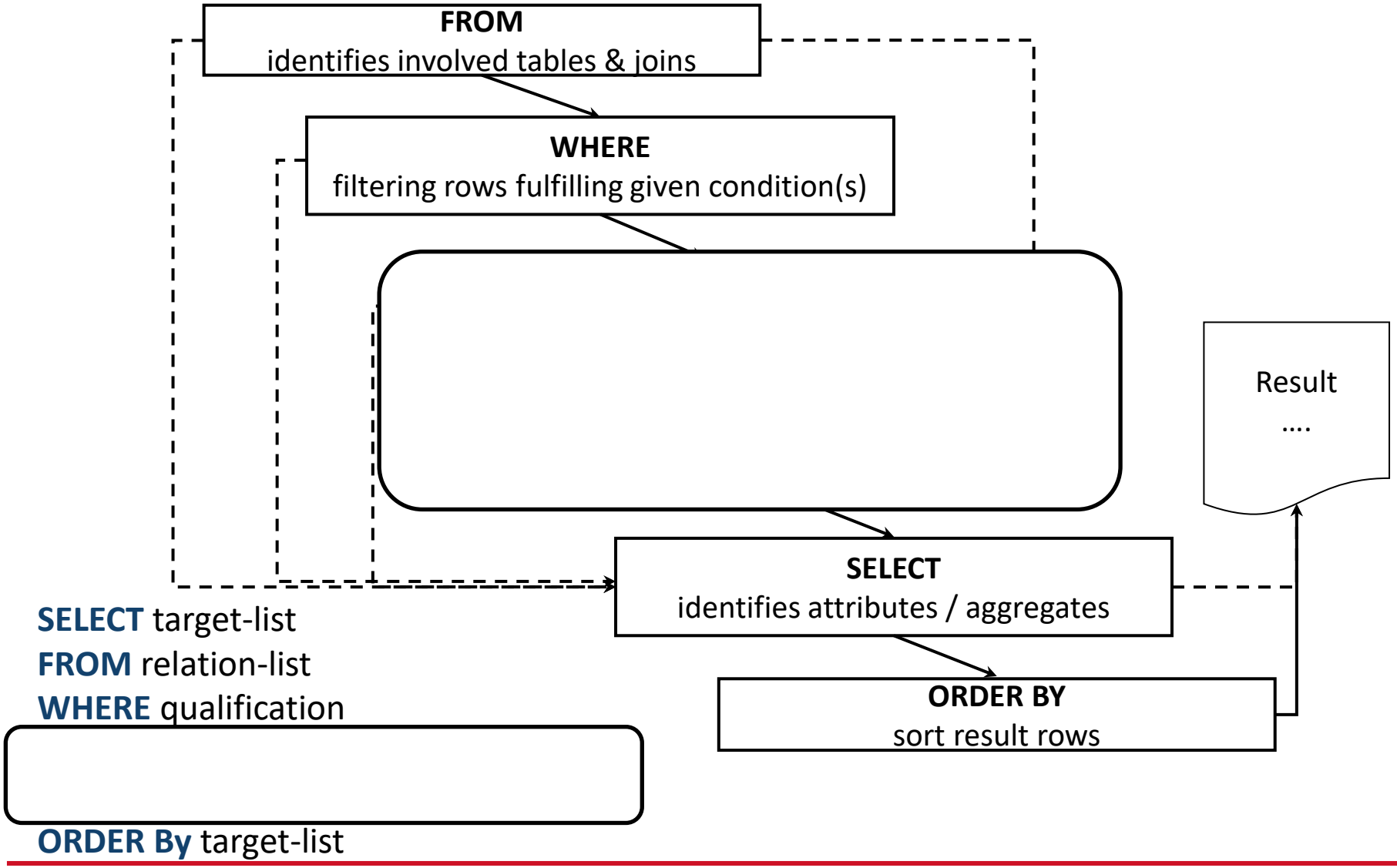
Exercise

› Select the country name with more than 1 student

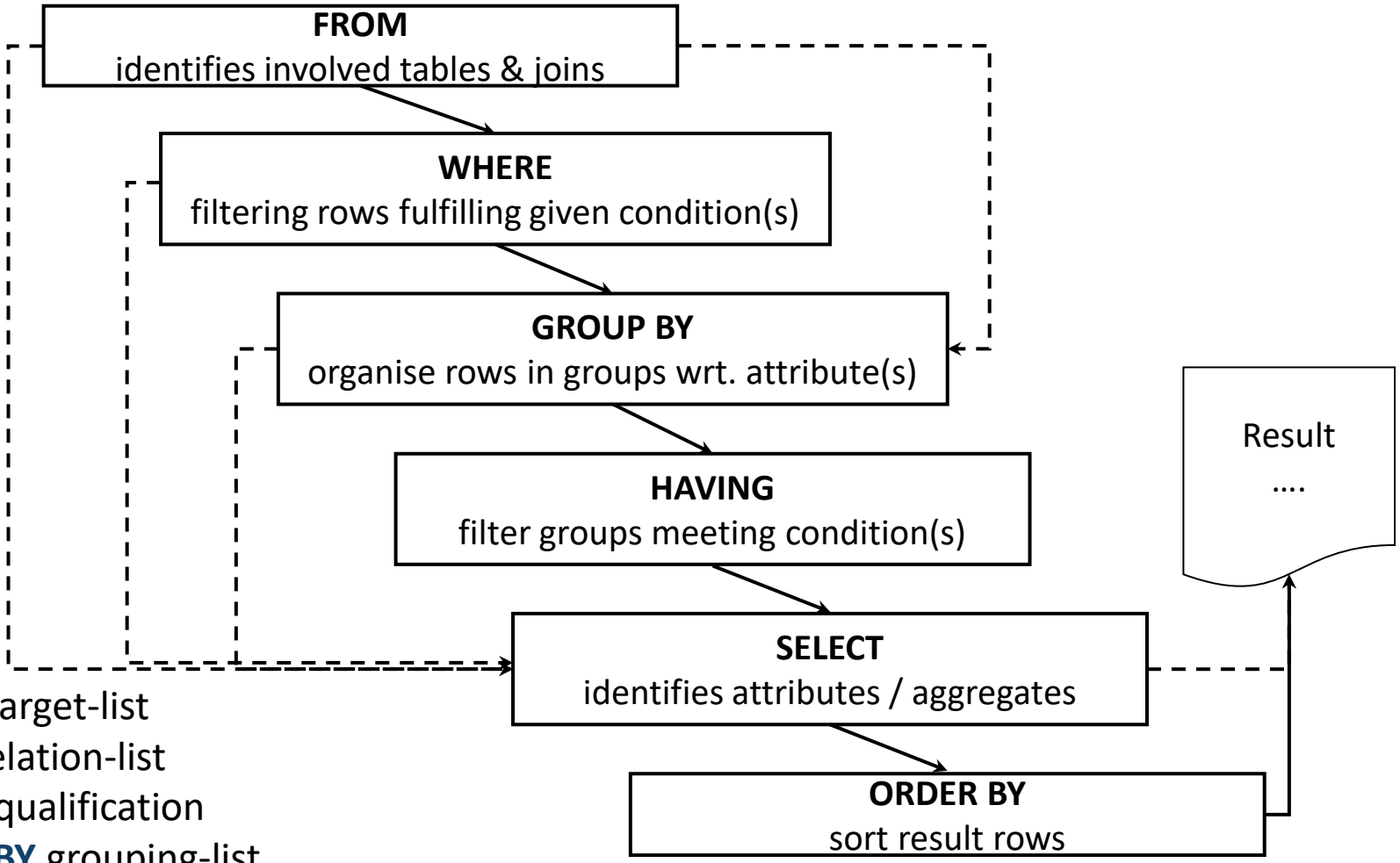
```
SELECT country
 FROM student
 GROUP BY country
 HAVING COUNT(*) > 1;
```

Student			
sid	**name**	**gender**	**country**
1001	Adam	M	AUS
1002	Bob	M	ROK
1003	Lily	F	AUS
1004	Simon	M	GBR
1005	Jesse	F	CHN
1006	Adam	M	GER

Query-Clause Evaluation Order



Query-Clause Evaluation Order



SELECT target-list
FROM relation-list
WHERE qualification
GROUP BY grouping-list
HAVING group-qualification
ORDER By target-list

Evaluation Example

› Find the maximum marks of 6-credit point courses with at least 2 students

```
SELECT uos_code, MAX(marks)
FROM enrolled NATURAL JOIN UnitOfStudy
WHERE points = 6
GROUP BY uos_code
HAVING COUNT(*) >= 2
```

1. enrolled and UnitOfStudy are joined

   FROM enrolled **NATURAL JOIN** UnitOfStudy

2. Tuples that fail the **WHERE** condition are discarded

   WHERE credit_points = 6

	uos_code character (8)	sid integer	semester character varying	marks integer	title character varying (30)	points integer
1	COMP5138	1001	2020-S2	72	Relational DBMS	6
~~2~~	~~COMP5702~~	~~1002~~	~~2020-S2~~	~~85~~	~~MIT Research Project~~	~~18~~
3	COMP5138	1003	2020-S2	67	Relational DBMS	6
4	COMP5318	1006	2020-S2	94	Data Mining	6
~~5~~	~~ISYS3207~~	~~1003~~	~~2020-S2~~	~~78~~	~~IS Project~~	~~4~~
~~6~~	~~ISYS3207~~	~~1006~~	~~2020-S1~~	~~40~~	~~IS Project~~	~~4~~

Evaluation Example (cont'd)

3. Remaining tuples are partitioned into groups by the value of attributes in the grouping-list (uos_code).

GROUP BY uos_code

4. Groups which fail the **HAVING** condition are discarded.

HAVING COUNT(*) >= 2

uos_code character (8)	sid integer	semester character varying	marks integer	title character varying (30)	points integer
COMP5138	1001	2020-S2	72	Relational DBMS	6
COMP5138	1003	2020-S2	67	Relational DBMS	6
~~COMP5318~~	~~1006~~	~~2020-S2~~	~~94~~	~~Data Mining~~	~~6~~

5. ONE result tuple is generated per group

SELECT uos_code, **MAX**(mark)

uos_code	MAX(mark)
COMP5138	72

Exercise

› Find the uos code in which students have got the lowest average mark

Solution:

```
SELECT uos_code
FROM enrolled
GROUP BY uos_code
HAVING AVG(marks) <= ALL (SELECT AVG (marks)
                          FROM enrolled
                          GROUP BY uos_code);
```

NOTE: aggregate function calls cannot be nested

Outline

- Nested Queries
- Aggregation and Grouping
- **NULL Values and Three-valued Logic**

NULL Values

- It is possible for tuples to have a null value, denoted by **NULL**, for some of their attributes
  - **NULL** signifies that a value *does not exist* or *not applicable*, it does *not mean "0" or "blank"*!
  - Integral part of SQL to handle missing / unknown information

- The predicate **IS NULL** or **IS NOT NULL** can be used to check for null values
  - e.g. Find students who don't have a mark for an assessment yet.

```
SELECT sid
FROM enrolled
WHERE marks IS NULL
```

NULL Values

- The result of any arithmetic expression involving NULL is NULL
  - e.g. 5 + NULL returns NULL

- Any comparison with NULL returns **unknown**
  - e.g. 5 < NULL or NULL <> NULL or NULL = NULL

- Result of **WHERE** clause predicate is treated as **false** if it evaluates to **unknown**
  - e.g: **SELECT** sid **FROM** enrolled **WHERE** marks < 50
    ignores all students without a mark so far

Three-valued Logic

- Three-valued logic for Boolean operations
  - OR: (**unknown** OR **true**) = **true**, (**unknown** OR **false**) = **unknown**
    (**unknown** OR **unknown**) = **unknown**
  - AND: (**true** AND **unknown**) = **unknown**, (**false** AND **unknown**) = **false**,
    (**unknown** AND **unknown**) = **unknown**
  - NOT: (NOT **unknown**) = **unknown**

- It is equivalent to the following

true = 1	B1 AND B2 = min(B1, B2)
unknown = 0.5	B1 OR B2 = max(B1, B2)
false = 0	NOT B1 = 1 – B1

Unexpected Behavior of NULL Values

```
SELECT *
FROM enrolled
WHERE marks < 25 OR marks >= 25
```

The students whose marks are unknown will not be returned!

```
SELECT *
FROM enrolled
WHERE marks < 25 OR marks >= 25 OR marks IS NULL
```

This SQL now lists all students!

NULL Values and Aggregation

- Aggregate functions ignore NULL values on the aggregated attributes
- Result of an aggregate function is NULL if there is no non-null rows
- Examples:
  - Minimum mark of all courses

```
SELECT MIN(marks)      -- ignores tuples with nulls on mark
FROM enrolled
```

  - Number of all courses

```
SELECT COUNT(*)        -- counts all tuples
FROM enrolled
```

  - Number of all courses with a mark

```
SELECT COUNT(marks)    -- ignores tuples with nulls on mark
FROM enrolled
```

You should now be able to…

- **…formulate even complex SQL Queries**
  - Including multiple joins with correct join conditions
  - Aggregate functions
  - Grouping and Having conditions
  - Handling NULL values

References

- Kifer/Bernstein/Lewis (2nd edition)
  - **Chapter 5**
- Ramakrishnan/Gehrke (3rd edition - the ‘Cow’ book)
  - Chapter 5
- Ullman/Widom (3rd edition)
  - Sections 6.3 and 6.4
- Silberschatz/Korth/Sudarshan (5th edition - ‘sailing boat’)
  - Sections 3.1-3.6
- Elmasri/Navathe (5th edition)
  - Sections 8.4 and 8.5.1

Next Week

- Database Application Development
  - SQL in Client Code
  - Call-level Database APIs
  - Server-Side Application Development with Stored Procedures

- Readings:
  - Kifer/Bernstein/Lewis book, Chapter 8
  - Ramakrishnan/Gehrke (Cow book), Chapter 6
  - Ullman/Widom, Chapter 9

See you next Week!