



Database

SQL

Aggregate Queries

Case Study

► Game Store
Requirement
Design

Game Store Requirement



Game Store Requirement

Our company, **Apasaja Pte Ltd**, has been commissioned to develop an application to manage the data of an online app store. We want to store several items of information about our customers such as their **first name**, **last name**, **date of birth**, **e-mail**, **date** and **country of registration** to our online sales service and the **customer identifier** that they have chosen.

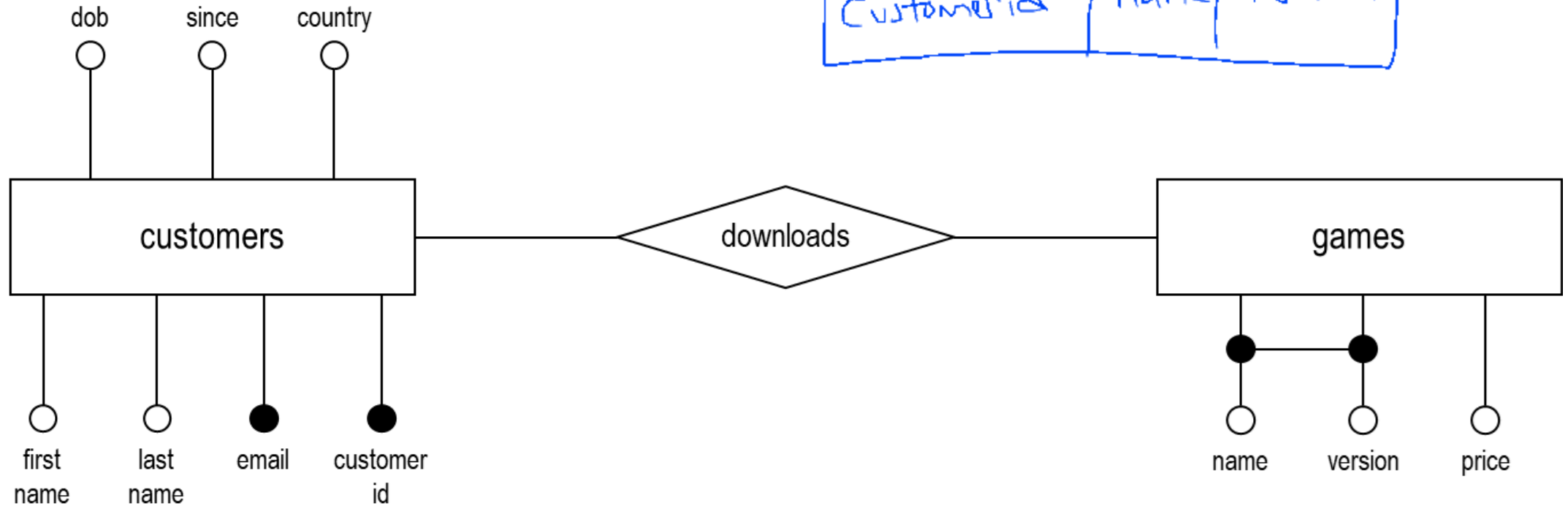
We also want to manage the list of our products, **games**, their **name**, their **version**, and their **price**. The price is fixed for each version of each game. Finally, our customers buy and **download** games. We record which version of which game each customer has downloaded. It is not essential to keep the download date for this application.

Case Study

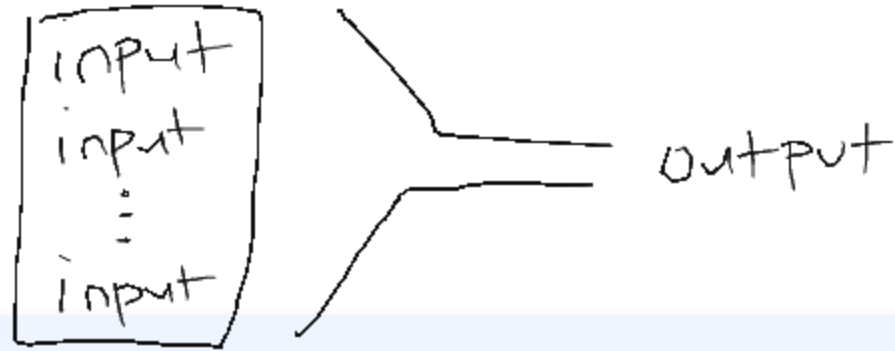
Requirement
» Design

Design

Entity-Relationship Diagram



Aggregation



Functions

Basic

Aggregation Functions

An **aggregate function** is a function that takes in a **set of values** and returns **a single value**.

The values of column can be aggregated using **aggregation functions** such as `COUNT()`, `SUM()`, `MAX()`, `MIN()`, `AVG()`, `STDDEV()`, *etc.*. PostgreSQL also allows user-defined aggregate functions.

```
SELECT COUNT(*)  
FROM customers c;
```

```
SELECT COUNT(c.customerid)  
FROM customers c;
```

count
1000

Note

`COUNT(*)` counts the total number of rows in the table.

```
SELECT COUNT(ALL c.country)  
FROM customers c;
```

Note

`ALL` is the default and often omitted. This counts duplicate entries.

Aggregation

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Distinct

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WHERE

Behavior

NULL

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Functions

Distinct

DISTINCT Keyword

We need to add the keyword **DISTINCT** inside the **COUNT()** aggregate function if we want to count the number of **different** countries in the column **country** of the table **customers**.

The keyword **DISTINCT** can be used in other aggregate functions similarly.

```
SELECT COUNT(DISTINCT c.country)
FROM customers c;
```

count
5

Aggregation

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.009 round → .01
trunc → .00

Aggregate Functions Example

The following query finds the **maximum**, **minimum**, **average**, and **standard deviation** prices of our games. These aggregate functions only works on **numerical data**.

It uses the arithmetic **TRUNC()** to display **two decimal places** for average and standard deviation.

```
SELECT MAX(g.price), MIN(g.price),  
       TRUNC(AVG(g.price), 2) AS avg,  
       TRUNC(STDDEV(g.price), 2) AS std  
FROM games g;
```

max	min	avg	std
12	1.99	6.97	3.96

Aggregation

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WHERE

Aggregate with WHERE Clause

We can first remove the unwanted rows before aggregating by using the **WHERE** clause. The following query finds the **maximum, minimum, and average price for "Aerified"**.

Currently, there is only one single big group to be aggregated.

```
SELECT MAX(g.price), MIN(g.price),  
       TRUNC(AVG(g.price), 2)  
FROM games g  
WHERE name = 'Aerified';
```

max	min	avg
12	1.99	6.49

Aggregation

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Functions Behavior

Basic Interpretation

Let **R** be a **non-empty** table with attribute **A**.

...	A	...
...	3	...
...	NULL	...
...	42	...
...	0	...
...	3	...

Query	Interpretation	Result
SELECT MIN(A) FROM R;	The smallest non-null value in A	0
SELECT MAX(A) FROM R;	The largest non-null value in A	42
SELECT AVG(A) FROM R;	Average of non-null values in A	12
SELECT SUM(A) FROM R;	The sum of non-null values in A	48
SELECT COUNT(A) FROM R;	The count of non-null values in A	4
SELECT COUNT(*) FROM R;	The count of all rows in A	5
SELECT AVG(DISTINCT A) FROM R;	Average of distinct non-null values in A	15
SELECT SUM(DISTINCT A) FROM R;	The sum of distinct non-null values in A	45
SELECT COUNT(DISTINCT A) FROM R;	The count of distinct non-null values in A	3

Aggregation

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Functions

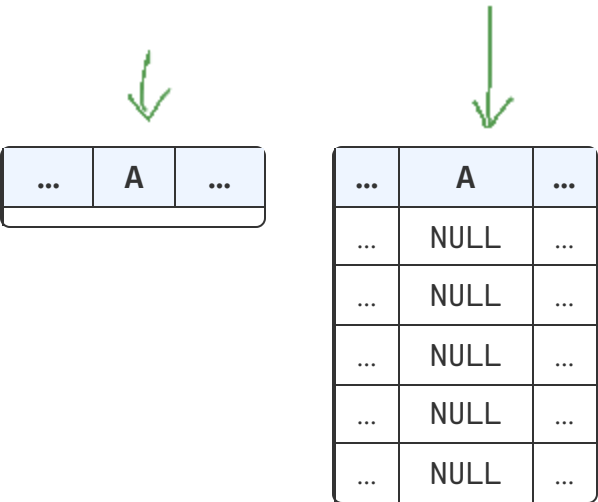
NULL



A	B
NULL	NULL
NULL	NULL
NULL	NULL


Basic Interpretation

Let **T** be empty relation. Let **R** be **non-empty** but contains only **NULL**.




...	A	...
...	NULL	...
...	NULL	...
...	NULL	...
...	NULL	...
...	NULL	...

Query	Result
SELECT MIN(A) FROM T	NULL
SELECT MAX(A) FROM T	NULL
SELECT AVG(A) FROM T	NULL
SELECT SUM(A) FROM T	NULL
SELECT COUNT(A) FROM T	0
SELECT COUNT(*) FROM T	0



Query	Result
SELECT MIN(A) FROM R	NULL
SELECT MAX(A) FROM R	NULL
SELECT AVG(A) FROM R	NULL
SELECT SUM(A) FROM R	NULL
SELECT COUNT(A) FROM R	0
SELECT COUNT(*) FROM R	5



Aggregation

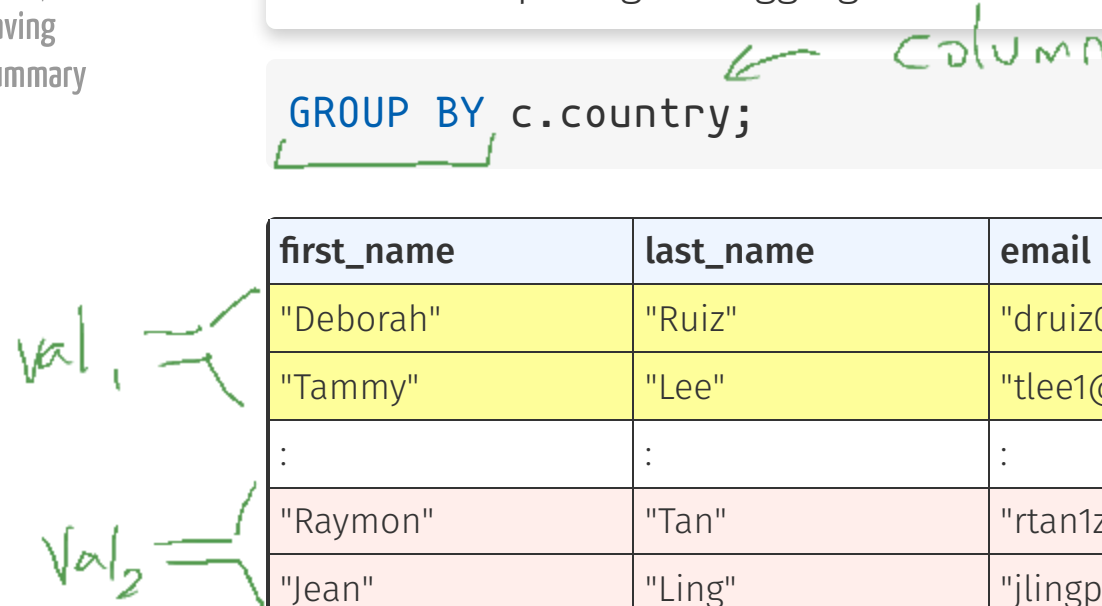
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Grouping Logical

GROUP BY

The **GROUP BY** clause creates **logical groups** of records that have the **same values for the specified fields** before computing the aggregate functions.

GROUP BY c.country;



first_name	last_name	email	...	country
"Deborah"	"Ruiz"	"druiz0@drupal.org"	...	"Singapore"
"Tammy"	"Lee"	"tlee1@barnesandnobles.com"	...	"Singapore"
:	:	:	...	:
"Raymon"	"Tan"	"rtan1z@nature.com"	...	"Thailand"
"Jean"	"Ling"	"jlingpn@walmart.com"	...	"Thailand"
:	:	:	...	:

*The table above is only a **potential representation**.

Aggregation

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Grouping

Aggregation

Aggregation Function Per Group

The aggregation functions are calculated for each **logical group**.

```
SELECT c.country, COUNT(*)  
FROM customers c  
GROUP BY c.country;
```

country	count
"Singapore"	391
"Thailand"	100
...	

...	country	count
...	"Singapore"	391
...	"Singapore"	
...	:	:
...	"Thailand"	100
...	"Thailand"	
...	:	:

Aggregation

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Grouping

Aggregation

Aggregation Function Per Group

The aggregation functions are calculated for each **logical group**.

```
SELECT c.country, COUNT(*)
FROM customers c
GROUP BY c.country;
```

country	count
"Singapore"	391
"Thailand"	100
...	

```
SELECT c.country, COUNT(*)
FROM customers c;
/* only one group created */
```

Error

This is actually an error as we cannot select only one value of `c.country`.

Aggregation

Functions

► Grouping

Logical

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Grouping

Where

After WHERE

Groups are formed (*logically*) **after** the rows have been filtered by the **WHERE** clause.

```
④ SELECT c.country, COUNT(*)  
① FROM customers c  
② WHERE c.dob >= '2006-01-01'  
③ GROUP BY c.country;
```

country	count
"Vietnam"	4
"Singapore"	25
"Thailand"	5
"Indonesia"	15
"Malaysia"	12

Aggregation

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Grouping

From

After FROM

Groups are formed (*logically*) **after** the tables have been joined in the **FROM** clause.

```
SELECT c.customerid, c.first_name, c.last_name, SUM(g.price)
FROM customers c, downloads d, games g
WHERE c.customerid = d.customerid
      AND d.name = g.name and d.version = g.version
GROUP BY c.customerid, c.first_name, c.last_name;
```

Note

Find the total spending of each customer.

Aggregation

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Grouping Select

SELECT Clause

It is recommended (*and required per SQL standard*) to **include attributes projected** in the **SELECT** clause by the **GROUP BY** clause.

```
SELECT c.customerid, c.first_name, c.last_name, SUM(g.price)
FROM customers c, downloads d, games g
WHERE c.customerid = d.customerid
      AND d.name = g.name and d.version = g.version
GROUP BY c.customerid;
```

Bad Practice

The above query works only because `first_name` and `last_name` are guaranteed unique.

Aggregation

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Grouping Select

Invalid Query

The following query **does not work** in PostgreSQL (*but works in SQLite with potentially incorrect result*). We will run all codes on PostgreSQL for testing.

```
SELECT c.customerid, c.first_name, c.last_name, SUM(g.price)
FROM customers c, downloads d, games g
WHERE c.customerid = d.customerid
      AND d.name = g.name and d.version = g.version
GROUP BY c.first_name, c.last_name;
```

Issue

If there are two customers with the same first and last name, which `customerid` is selected?

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Renamed Column

Renamed columns can be used in **GROUP BY** clause. The following query displays the number of downloads by country and year of birth (using *EXTRACT*).

```
SELECT c.country, EXTRACT(YEAR FROM c.since) AS regyear, COUNT(*) AS total
FROM customers c, downloads d
WHERE c.customerid = d.customerid
GROUP BY c.country, regyear
ORDER BY regyear ASC, c.country ASC;
```

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GROUP BY Reordering

The order of columns in **GROUP BY** clause does not change the meaning of the query. The logical groups remain the same.

```
SELECT c.country, EXTRACT(YEAR FROM c.since) AS regyear, COUNT(*) AS total
FROM customers c, downloads d
WHERE c.customerid = d.customerid
GROUP BY regyear, c.country
ORDER BY regyear ASC, c.country ASC;
```

Aggregation

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Having Condition



WHERE $x < \underline{\text{AVG}(x)}$

Aggregate Condition

Aggregate functions can be used in **conditions**, but not in **WHERE** clause. Aggregate functions can be evaluated after groups are formed (*which is after **WHERE** clause*).

```
SELECT c.country  
FROM customers c  
WHERE COUNT(*) >= 100  
GROUP BY c.country;
```

HAVING Clause

We need a new clause: **HAVING** clause. This clause is performed **after** GROUP BY clause.

HAVING clause can **only use** aggregate functions, columns listed in the GROUP BY clause, and subqueries.

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Aggregate Condition

Aggregate functions can be used in **conditions**, but not in **WHERE** clause. Aggregate functions can be evaluated after groups are formed (*which is after **WHERE** clause*).

```
SELECT c.country  
→ FROM customers c  
GROUP BY c.country  
HAVING COUNT(*) >= 100;
```

Handwritten underline

Note

The query on the left finds the countries in which there are more than 100 customers.

Aggregation

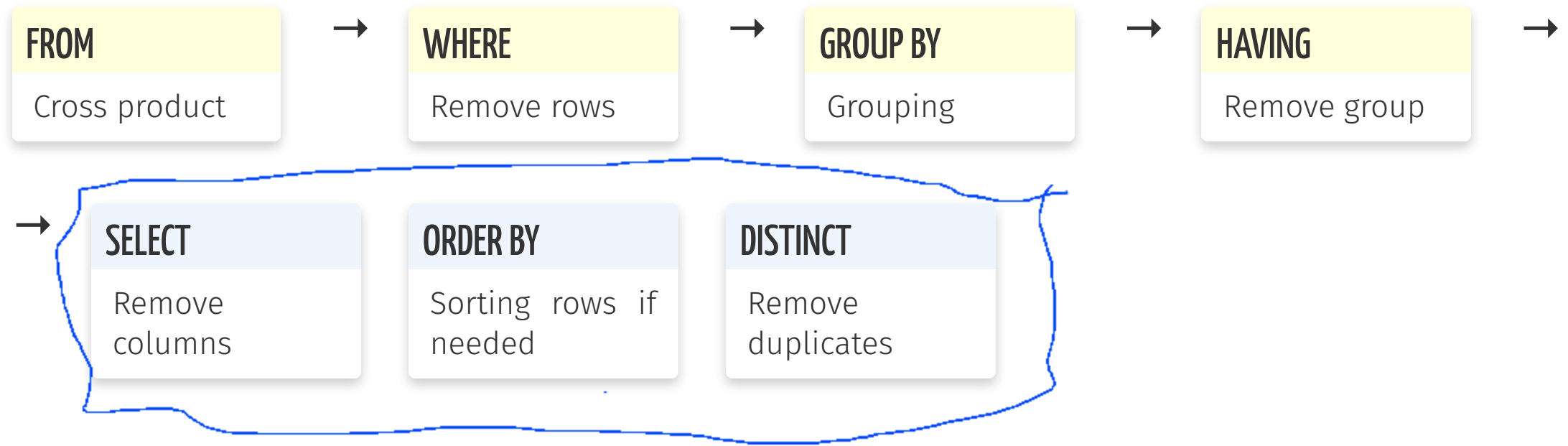
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Evaluation

Summary

Evaluation

Logical Evaluation

The **logical evaluation** of SQL query up to this point is the following.



Break

Back by 19:28

Joins

» Inner Join
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Inner Join

Basic

Expressiveness

While **inner join** is a popular construct, there is **no added expressiveness** or performance in **INNER JOIN**. The two queries below are **equivalent**.

Inner Join

```
SELECT *  
FROM customers c  
  INNER JOIN downloads d  
    ON d.customerid = c.customerid  
  INNER JOIN games g  
    ON d.name = g.name  
   AND d.version = g.version;
```

Cross Join

```
SELECT *  
FROM customers c, downloads d,  
      games g  
WHERE d.customerid = c.customerid  
      AND d.name = g.name  
      AND d.version = g.version;
```



Joins

» Inner Join

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Inner Join

JOIN

Synonym

JOIN is **synonymous** with **INNER JOIN**. We do **NOT** recommend either as **CROSS JOIN** (or *comma*) is typically easier to read and will be optimized by DBMS.

Join

```
SELECT *  
FROM customers c  
  JOIN downloads d  
    ON d.customerid = c.customerid  
  JOIN games g  
    ON d.name = g.name  
   AND d.version = g.version;
```

Cross Join

```
SELECT *  
FROM customers c, downloads d, games g  
WHERE d.customerid = c.customerid  
   AND d.name = g.name  
   AND d.version = g.version;
```


Joins

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Inner Join Condition

Order of Condition

In **JOIN**, the **order of condition matters**. We cannot easily reorder the conditions unlike in **CROSS JOIN**. That is why we recommend simply using **comma**.

Join

```
SELECT *  
FROM customers c  
  JOIN downloads d  
    ON d.name = g.name -- what is g?  
    AND d.version = g.version  
  JOIN games g  
    ON d.customerid = c.customerid;
```

Cross Join

```
SELECT *  
FROM customers c, downloads d, games g  
WHERE d.customerid = c.customerid  
      AND d.name = g.name  
      AND d.version = g.version;
```

Joins

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Natural Join

What is Natural?

Automatic Equality

If we managed to give the same name to columns with the same meaning across the tables, we can use **natural join**. `NATURAL JOIN` joins rows that have the **same values** for columns with the **same name**. It also **prints only one** of the two columns.

Natural Join

```
SELECT *  
FROM customers c  
    NATURAL JOIN downloads d  
    NATURAL JOIN games g;
```

Question

Can you write the equivalent of the query on the left using `CROSS JOIN`?

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Natural Join

Design Impact

Universal Relation

If we want to use **NATURAL JOIN** more easily, we need to ensure that **columns with the same should have the same meaning**. Otherwise, we cannot use **NATURAL JOIN** and we have to use **CROSS JOIN** or **INNER JOIN**. This condition is called **universal relation**.

Natural Join

```
SELECT *  
FROM customers c  
    NATURAL JOIN downloads d  
    NATURAL JOIN games g;
```

Issue

The SQL query on the left does not work if the attributes are different such as the following (e.g., we change **customerid** to **id** in **customers** table only).

Joins

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Outer Join

Basic

What is Outer?

The **outer join** keeps the columns of the rows in the left (*left outer join*), the right (*right outer join*), or in both (*full outer join*) tables that **do not match** anything in the other table according to the join condition (*i.e., dangling rows*). The remaining values are **padded** with **NULL** values.

Warning

It is better to **avoid outer joins** whenever possible as they introduce **NULL** values. They can sometimes be justified for efficiency reasons. However, this course does not care about efficiency as long as the query can finish within reasonable time.

Note

There are also the **natural** variant of outer joins. For instance, **NATURAL LEFT OUTER JOIN** is a natural version of **left join**.

The meaning is the **combination** of natural join (*i.e., automatic equality*) and left join (*i.e., keeps unmatched column, padded with NULL*).

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Difficulty of Dangle

We cannot easily obtain dangling rows by using **INNER JOIN**. A row is included in the result of an inner join if the condition is true and the condition can only look at the current row.

```
SELECT *  
FROM customers c, downloads d  
WHERE c.customerid <> d.customerid;
```

Result

This finds all customer and the games downloaded by **other customers**.

What we need is a way to say that **c.customerid** is not equal to **ALL** other **d.customerid**.

This is not possible without nested queries or **outer join**.

Joins

Inner Join
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Outer Join

Example

Left Outer Join

In the example below, the customers --from the left table-- who never downloaded a game are combined with **NULL** values to replace missing values for the columns of the **downloads** table. Columns from the right table are padded with **NULL** values.

```
SELECT c.customerid, c.email, d.customerid, d.name, d.version  
FROM customers c LEFT OUTER JOIN downloads d ON c.customerid = d.customerid;
```

c.customerid	c.email	d.customerid	d.name	d.version
...				
"Willie90"	"wlongjj@moonfruit.com"	"Willie90"	"Ronstring"	"1.1"
"Willie90"	"wlongjj@moonfruit.com"	"Willie90"	"Veribet"	"2.1"
"Al8"	"ahansenp3@webnode.com"	NULL	NULL	NULL
"Johnny1997"	"jstevensb0@un.org"	NULL	NULL	NULL

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Right Outer Join

In the example below, the games --*from the right table*-- that have never been downloaded are combined with **NULL** values to replace missing values for the columns of the **downloads** table. Columns from the left table are padded with **NULL** values.

```
SELECT *  
FROM downloads d RIGHT OUTER JOIN games g ON g.name = d.name AND g.version = d.version;
```

Full Outer Join

A **full outer join** pads missing values with **NULL** for both the tables on the left and on the right.

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Outer Join Condition

Condition Matters

Dangling rows is defined only with respect to the **condition** on the **ON clause**. Moving the condition to **WHERE clause** will result in different output.

```
SELECT *  
FROM downloads d RIGHT OUTER JOIN games g  
ON g.name = d.name  
AND g.version = d.version;
```

d.customerid	d.name	d.version	g.name	g.version	g.price
Adam1983	Biodex	1.0	Biodex	1.0	2.99
Adam1983	Domainer	2.1	Domainer	2.1	2.99
:	:	:	:	:	:
NULL	NULL	NULL	Overhold	2.0	12
NULL	NULL	NULL	Andalax	1.0	12

```
SELECT *  
FROM downloads d RIGHT OUTER JOIN games g  
ON g.name = d.name  
WHERE g.version = d.version;
```

d.customerid	d.name	d.version	g.name	g.version	g.price
Adam1983	Biodex	1.0	Biodex	1.0	2.99
Adam1983	Domainer	2.1	Domainer	2.1	2.99
:	:	:	:	:	:
Willie90	Ronstring	1.1	Ronstring	1.1	3.99
Willie90	Veribet	2.1	Veribet	2.1	2.99

Joins

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Anti Join

Only Missing Value

Find customers who never downloaded a game.

```
SELECT c.customerid
FROM customers c
      LEFT OUTER JOIN downloads d
        ON c.customerid = d.customerid
WHERE d.customerid IS NULL;
```

Further Restriction

Further restriction should be on **WHERE** clause and not **ON** clause.

```
SELECT c.customerid
FROM customers c
      LEFT OUTER JOIN downloads d
        ON c.customerid = d.customerid
WHERE d.customerid IS NULL
      AND c.country = 'Singapore';
-- try moving the AND above
```

Joins

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Outer Join Closing

Warning

Outer joins are not easy to write as conditions in the **ON** clause are not equivalent to conditions in the **WHERE** clause (*as it was the case with **INNER JOIN***). Conditions in the **ON** clause determines which rows are **dangling**.

Synonyms

- | | | |
|--------------|----------------|------------------|
| • LEFT JOIN | is synonym for | LEFT OUTER JOIN |
| • RIGHT JOIN | is synonym for | RIGHT OUTER JOIN |
| • FULL JOIN | is synonym for | FULL OUTER JOIN |

Set Operations

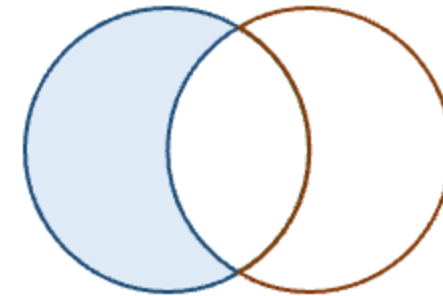
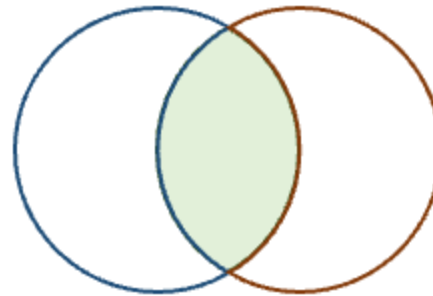
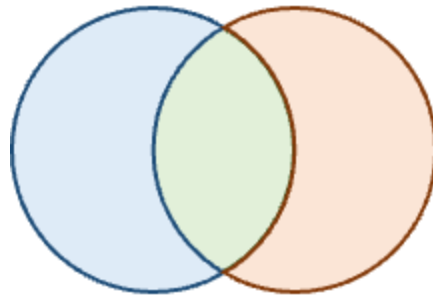
INT U STR

› Set
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Set Basic

Operators

The set operators **UNION**, **INTERSECT**, and **EXCEPT** return the **union**, **intersection**, and **non-symmetric difference** of the results of two queries respectively.



Deduplication

Union, intersection, and non-symmetric difference **eliminate duplicates** unless annotated with the keyword **ALL**.

Set Operations

› Set
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Set Compatible

Union-Compatible

Two queries must be **union-compatible** to be used with UNION, INTERSECT, or EXCEPT. They must return the same **number of columns** with the **same domain** in the **same order**.

Compatible

student.name (VARCHAR(32))

department.department (VARCHAR(32))

Incompatible

student.year (DATE)

department.department (VARCHAR(32))

Note

Just because they are **union-compatible** does not mean it is **meaningful** to perform set operations on the two tables.

Set Operations

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Union

Question

Find the `customerid` of all the **customers** who **downloaded** **version 1.0 or 2.0** of the game **Aerified**.

```
SELECT d.customerid
FROM downloads d
WHERE d.name = 'Aerified' AND d.version = '1.0'
UNION
SELECT d.customerid
FROM downloads d
WHERE d.name = 'Aerified' AND d.version = '2.0';
```

Set Operations

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Union

Question

Find the **name** and **versions** of all the games after GST is applied. GST of 9% is applied if it is **more than 30 cents**.

```
SELECT g.name || ' ' || g.version AS game, ROUND(g.price * 1.09) AS price
FROM games g
WHERE g.price * 0.09 >= 0.3
UNION
SELECT g.name || ' ' || g.version AS game, g.price
FROM games g
WHERE g.price * 0.09 < 0.3;
```

Set Operations

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► Examples

Union

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Intersection

Question

Find the `customerid` of all the **customers** who **downloaded** both **version 1.0 and 2.0** of the game **Aerified**.

```
SELECT d.customerid
FROM downloads d
WHERE d.name = 'Aerified' AND d.version = '1.0'
INTERSECT
SELECT d.customerid
FROM downloads d
WHERE d.name = 'Aerified' AND d.version = '2.0';
```

Set Operations

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Difference

Question

Find the `customerid` of the **customers** who **downloaded version 1.0 but not version 2.0** of the game **Aerified**.

```
SELECT d.customerid
FROM downloads d
WHERE d.name = 'Aerified' AND d.version = '1.0'
EXCEPT
SELECT d.customerid
FROM downloads d
WHERE d.name = 'Aerified' AND d.version = '2.0';
```


Conclusion

► Reading

Reading

What Does This Query Find?

```
SELECT c.email, SUM(g.price)
FROM customers c, downloads d, games g
WHERE c.customerid = d.customerid AND g.name = d.name
      AND g.version = d.version AND c.country = 'Indonesia' AND g.name= 'Fixflex'
GROUP BY c.email
UNION
SELECT c.email, 0
FROM customers c LEFT JOIN
  (downloads d INNER JOIN games g
    ON g.name = d.name AND g.version = d.version AND g.name = 'Fixflex')
  ON c.customerid = d.customerid
WHERE c.country = 'Indonesia' AND d.name IS NULL;
```

```
postgres=# exit
```

```
Press any key to continue . . .
```

