Database Designs

Section 3: Advanced Retrieving Data Queries

3.1 Aggregate Operators

Aggregate operators allows us to return more interesting information from our data. Below is an example Sales_Data table containing sales for two ASDA stores.

Sales_Data			
storeLocation	productName	salesDate	revenue
ASDA Coventry	Milk	November 02, 2020	1,233.32
ASDA Birmingham	Bread	November 02, 2020	5,434.74
ASDA Coventry	Coffee	November 02, 2020	3,855.96
ASDA Coventry	Coffee	November 02, 2020	2,280.90
ASDA Birmingham	Coffee	November 02, 2020	2,110.95
ASDA Coventry	Milk	November 01, 2020	4,558.24
ASDA Birmingham	Milk	November 01, 2020	6,849.99
ASDA Birmingham	Bread	November 01, 2020	2,543.57

The insights an analyst or business owner may be interested in retrieving from the above dataset are: Total Revenue, Best Performing Stores, Best Performing Products, Best Product-Store Combination that Sold Best.

We would like to find patterns in the data so that we can drive business decisions that would help the business to perform better. Below are some example Aggregate Operations which can help us retrieve more interesting data insights.

```sql
SELECT SUM(revenue) totalRevenue
FROM Sales_Data;
```

The **SUM** aggregate operator wraps the column in brackets for the column data we wish to apply the sum function. Whatever result is returned from the aggregate operator is then returned in a column we have decided to name as totalRevenue. By omitting the **WHERE** clause from the select statement means that it will sum over all data within the Sales_Data table.

The **SUM** is a function that operates over an entire column and not just a single cell and the result returned is a single value which can be named. The **SUM** can operate over an entire column or any subset of a column and does not necessarily have to be an entire column.

The reason SUM is called an aggregate function is because it acts on an aggregation of cells and not just a single cell.

```
SELECT AVG(revenue) averageRevenue
FROM Sales_Data;
```

The **AVG** aggregate operator is a function that operates over an entire column or a subset of a column and not just a single cell and returns a single value which can be named. This function averages all the values in the column. The syntax is the same as the **SUM** function above but it returns the average instead.

3.2 Group By Clause

The **GROUP BY** clause allows us to aggregate the returned data by grouping data in a certain logical unit. An example command using the **GROUP BY** clause would look like the below:

```
SELECT storeLocation, SUM(revenue) totalRevenue
FROM Sales_Data
GROUP BY storeLocation;
```

The result from the above query will return a table with two columns, storeLocation and totalRevenue, with a total sum of revenue for each store (i.e. a row per unique store).

The column we specify after the **GROUP BY** clause define what groups we would want to use and subtotal. Using the **SUM** aggregate operator with the **GROUP BY**, would define to what groups would we sum up i.e. what is the logical unit that we would run the **SUM** operation on. The **GROUP BY** can be used with other aggregate operators such as the **AVG** function.

We can visualise the **GROUP BY** as sorting the data before we perform the other operations i.e. before performing the **SUM** operation on the revenue column for every group. This will give a flatten result table demonstrated below:

Sales_Data			
storeLocation	productName	salesDate	revenue
ASDA Birmingham	Bread	November 02, 2020	5,434.74
ASDA Birmingham	Coffee	November 02, 2020	2,110.95
ASDA Birmingham	Milk	November 01, 2020	6,849.99
ASDA Birmingham	Bread	November 01, 2020	2,543.57
ASDA Coventry	Milk	November 02, 2020	1,233.32

ASDA Coventry	Coffee	November 02, 2020	3,855.96
ASDA Coventry	Coffee	November 02, 2020	2,280.90
ASDA Coventry	Milk	November 01, 2020	4,558.24

In the example query we can see that ASDA Birmingham is the best performing store based on total revenue.

Sales_Data Query Results	
storeLocation	totalRevenue
ASDA Birmingham	16,939.25
ASDA Coventry	11,928.42

The **SELECT** statement allows us to choose which columns we wish to display in our results after we have completed the thinning of the data using the **GROUP BY**. We can confidently remove the productName and salesDate columns from the results table without losing any information. However, we cannot **GROUP BY** any column that is not present in the select statement since the results would not make any sense. Therefore, any column specified in the **GROUP BY** statement must also be present in the **SELECT** statement i.e. it must be part of the final result.

Remember: The **WHERE** clause is generally used when we want to filter the number of rows that meet the **WHERE** clause condition. Therefore, if we want all rows we omit the **WHERE** clause. The **GROUP BY** clause on the other hand is used when we want to group our data in a logical unit. It is therefore possible to use both the **GROUP BY** and **WHERE** clauses at the same time for a more complex query.

The **GROUP BY** clause allows us to group by multiple columns so that we can answer more complex questions that uses a combination of columns. An example query would look like the below:

```
SELECT productName, storeLocation, AVG(revenue) averageRevenue
FROM Sales_Data
GROUP BY productName, storeLocation;
```

The **GROUP BY** clause above groups based on the unique combination of the two columns specified in the statement. In the above example, this provides a unique combinations of: ASDA Birmingham Bread, ASDA Birmingham Coffee, ASDA Birmingham Milk, ASDA Coventry Coffee and ASDA Coventry Milk.
The **AVG** operation will then be performed on each unique **GROUP BY** unit combination to provide the averages of each unit groups.

The above example can help us answer the question of what is the worst performing product in which store.

3.3 Order By Clause

The **ORDER BY** clause allows us to order our results either in Ascending or Descending order. The ordering will depend on the data type i.e. numbers ordered smallest to largest in ascending order and vice versa for descending order while strings are ordered A-Z for ascending order and vice versa for descending. Below is an example of ordering the results of our query using the **ORDER BY** clause:

```
SELECT storeLocation, SUM(revenue) totalRevenue
FROM Sales_Data
GROUP BY storeLocation
ORDER BY storeLocation;
```

```
SELECT storeLocation, SUM(revenue) totalRevenue
FROM Sales_Data
GROUP BY storeLocation
ORDER BY totalRevenue DESC;
```

In the first example the column storeLocation column is forced to order the results in ascending order. In the second example, using the **DESC** keyword forced the results to order the column by descending order.

By default SQL does not order the results that are returned; therefore, using the **ORDER BY** clause there is no longer any ambiguity in the order of the result.

Whatever we specify in the **ORDER BY** clause must be present in the **SELECT** clause which is similar ruling as the **GROUP BY** clause. We can also **ORDER BY** more than one column as seen in the example below:

```
SELECT productName, storeLocation, AVG(revenue) averageRevenue
FROM Sales_Data
GROUP BY productName, storeLocation
ORDER BY storeLocation, productName DESC;
```

In the above example, SQL would order columns in the order they are specified in the query. Therefore, storeLocation will be ordered first in ascending order and then productName will be ordered second in descending order. Each column must be specified the type of ordering required and must be present in the **SELECT** clause.

It is important to note, a SQL query that contains both a **GROUP BY** and a **ORDER BY** clause, the ordering is applied after the grouping i.e. the grouping occurs first and then the ordering is performed on the results. There are many rules like this in SQL which we will see as we continue; for example, the **LIMIT** clause is the only clause that can apply after the **ORDER BY** clause.

3.4 Limit Clause

The **LIMIT** clause allows us to limit the number of results returned from our query results. This is another way of filtering our results once the query has run. Below is an example of using the **LIMIT** clause:

```
SELECT storeLocation, SUM(revenue) totalRevenue
FROM Sales_Data
GROUP BY storeLocation
ORDER BY totalRevenue
LIMIT 1;
```

The above example limits the results returned to the very first row in the results returned. This value can be any number and will limit the number of rows returned from the results. Therefore, if we chose to **LIMIT** up to 3 results and a query returned more than 3 results, the limit will return the first 3 results, whereas, if the query returned less than or equal to 3 results then the first few records up to the limit will be returned in the results.

This will help our query to automatically find the results, without requiring to manually check for the answer, within a single SQL query. For example, the above query allows us to answer the question of which is the worse performing store by revenue using a single query. Adding the **DESC** ordering on totalRevenue will answer which is the best performing store by revenue.

If we want to **LIMIT** the number of results from our SQL query but have an **ORDER BY** clause in the query, the **LIMIT** clause must always come after the **ORDER BY** clause. It is not needed to have the **ORDER BY** clause in order to use the **LIMIT** clause in a SQL query.

3.5 Count and Count Distinct

The **COUNT** operator is an aggregate operator similar to **SUM**, **AVG**, **MIN**, **MAX**, etc. The **COUNT** operator operates on the column(s) defined in the round brackets. The **DISTINCT** keywords is used to return unique values i.e. it tells SQL to ignore duplicates within the counting. An example syntax is provided below:

```
SELECT COUNT(storeLocations) uniqueStoreLocations
FROM Sales_Data
```

```
SELECT COUNT(DISTINCT storeLocations) uniqueStoreLocations
FROM Sales_Data
```

The first syntax example returns a count of all rows while the second syntax returns a count of unique values only.

3.6 Introduction to SQL Joins

SQL Provides many ways to combine information from two or more tables in order to query the new combined table information. The way we combine a table is called a “Join” and there are a while variety of joins.

In the previous sections we have seen a Sales_Data table containing a lot of information within a single table. In a real life scenario the table would actually be split into multiple tables. The Sales_Data table would look something like the below tables:

Stores_Data		
storeID	storeLocation	city
1	ASDA Small Heath	Birmingham
2	ASDA Binley	Coventry
3	ASDA Wilmslow	Manchester
4	ASDA Stratford	London
5	ASDA Bebington	Liverpool

Products_Data	
productID	productName
1	Bread
2	Biscuits
3	Coffee
4	Milk
5	Instant Noodles

Sales_Data			
storeID	productID	salesDate	revenue
2	4	November 02, 2020	1,233.32
1	1	November 02, 2020	5,434.74
2	3	November 02, 2020	3,855.96
2	3	November 02, 2020	2,280.90

1	3	November 02, 2020	2,110.95
2	4	November 01, 2020	4,558.24
2	4	November 01, 2020	6,849.99
1	1	November 01, 2020	2,543.57

The Stores_Data table stores data that relate to store information only while the Product_Data table stores data related to product information. The Sales_Data makes reference to both the Stores_Data and Products_Data tables using the IDs.
This in one potential way of designing and splitting the tables. This is to ensure the data about an entity fits into a single table. This allows table data to be more flexible to changes by splitting the information by entities into its own tables.

In Section 2.5 and 2.6 we briefly saw examples of joining tables using a match on the id columns for example:

```
SELECT s.studentID, subjectName, currentGrade
FROM STUDENTS AS s, SUBJECTS AS c
WHERE (gender = 'F')
            AND s.studentID = c.studentID;
```

In the example above we had to match the id columns from the students table and the subjects table in order to return a results set from both tables where the criteria match.

SQL Joins indicate connections between two or more tables and is a very useful way to connect tables and query them as a unit. There are many different ways to join tables:

- **Cross** Join (a.k.a cartesian join)
- **Inner** Join
- **Outer** Join
- **Natural** Join

The **Outer** Join can be split into sub-categories of:

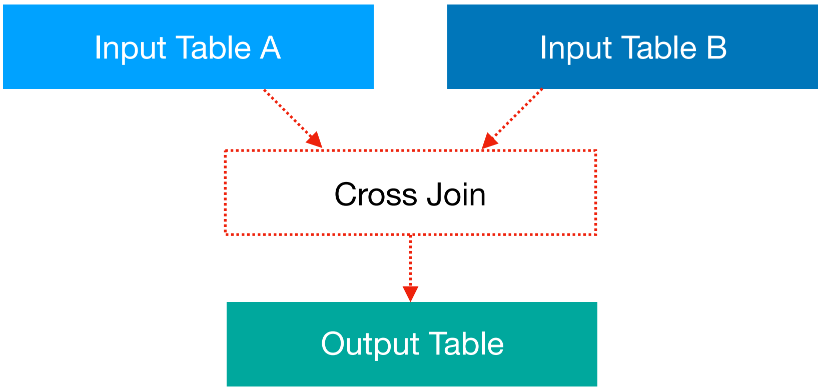
- **Left** Outer Join
- **Right** Outer Join
- **Full** Outer Join

These are all the different ways in which we can join tables and we will explore each joins and how they operate in the next couple of sections.

3.7 Cross Joins (Cartesian Joins)

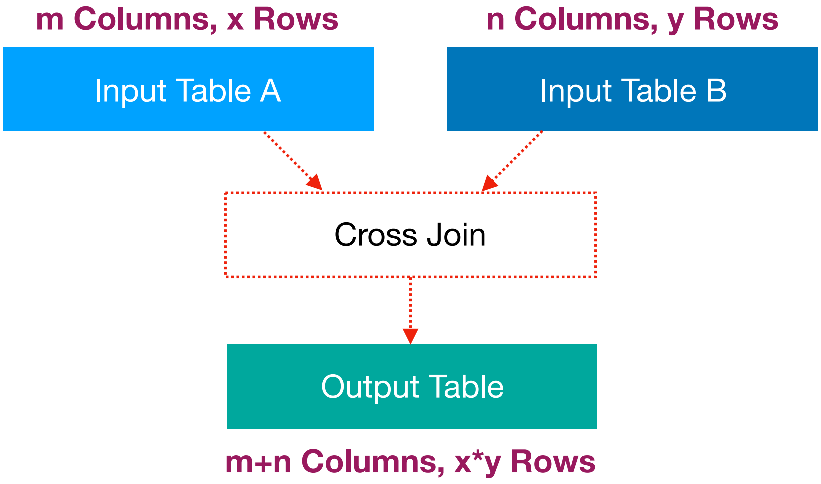
The Cross Join (Cartesian Join) is the most intuitive and easiest to understand join but is also a join that is not as widely/typically used. When joining tables we must always consider the input tables as well as the output tables. What do we mean by this?

Joins can be applied to two or more tables but for simplicity we will focus on joining two tables only.



The result of the join is also a table which we would call as the output table. The output table is not a real table that exists in the database. The input tables might exists in the database but the output table is a virtual table created by the join.

If Input Table A has m columns and x rows while the Input Table B has n columns and y rows. The output table from a cross join would have M+N columns and x*y rows.



The Cross Join will create an output table with 1 row for every combination of the input rows i.e. every row in Input Table A combines with every row in Input Table B. Therefore, for every combination of rows there is one row in the output table. Below is an example syntax using the stores and products table:

```
SELECT storeLocation, productName
FROM Stores_Data
CROSS JOIN Products_Data;
```

This query will return from the two tables a virtual output table results of the below. We can use this output table to query as though the table actually existed as a table in the database.

Stores_Data		
storeID	storeLocation	city
1	ASDA Small Heath	Birmingham
2	ASDA Binley	Coventry

Products_Data	
productID	productName
1	Bread
2	Biscuits
3	Coffee

The columns between the two tables are added together i.e. m + n columns.
The rows are all the possible combinations between the two table rows i.e. x*y rows.

CROSS_JOIN_OUTPUT_TABLE				
storeID	storeLocation	city	productID	productName
1	ASDA Small Heath	Birmingham	1	Bread
1	ASDA Small Heath	Birmingham	2	Biscuits
1	ASDA Small Heath	Birmingham	3	Coffee
2	ASDA Binley	Coventry	1	Bread
2	ASDA Binley	Coventry	2	Biscuits
2	ASDA Binley	Coventry	3	Coffee

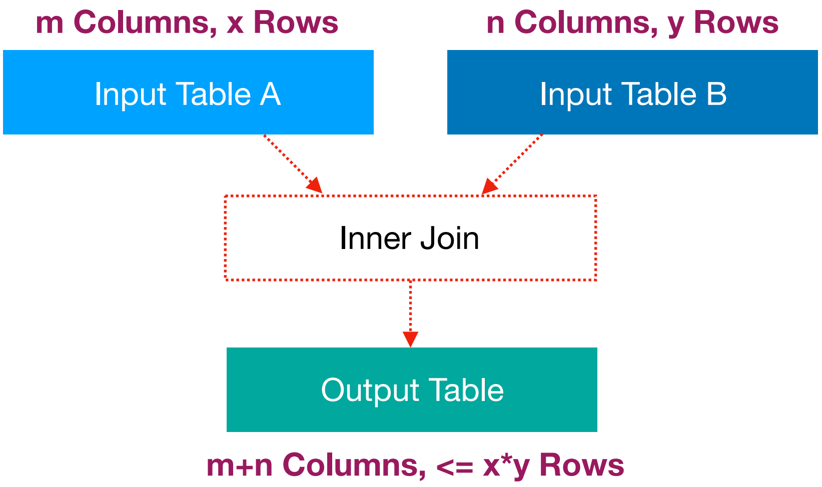
The select statement within the query will return the storeLocation and the productName columns from this virtual output table as the final result table for the query as seen below:

RESULTS_TABLE	
storeLocation	productName
ASDA Small Heath	Bread
ASDA Small Heath	Biscuits
ASDA Small Heath	Coffee
ASDA Binley	Bread
ASDA Binley	Biscuits
ASDA Binley	Coffee

Cross Joins are very resource-intensive because it puts a tremendous strain on the database when performing a cross join. The database will require a lot of processing power and time to create the virtual output table.
For example, if we had an Input Table A with 1000 rows and an Input Table B with 1000 rows, this will create an Output Table of 1million rows.
Therefore, it is not typically used Cross Joins unless it is certain that the output tables are very small e.g. less than a 100 rows. Doing this type of join can put strain on the database and potentially bring down the system as a result.

3.8 Inner Joins

The Inner Join also has input tables and produces a virtual output table. The output table has all columns of both tables but the total rows is always less than or equal to the number of row combinations. We can see this represented in the diagram below.

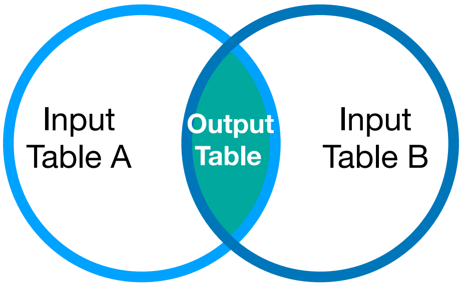


The Inner Join is logically equivalent to doing a Cross (Cartesian) Join and then applying a filter condition on the results of the Cross (Cartesian) Join. This is a logical equivalence and not what actually occurs under the hood when performing a Inner Join. This is the reason for why the output table of an Inner Join always has less than or equal to the number of rows in an output table of a Cross Join.

The filter condition almost always involves linking two columns of the two joined tables. If the condition tests for equality the join is called an Equi-Join (i.e. the value of a column in Table A is the same/equal to the value in the column of Table B).

When using an Inner Join, never actually write an Inner Join as a Cross Join with a filter. This is purely to logically visualise what an inner join is doing, furthermore, Cross Joins are very resource intensive. When using Inner Joins the DBMS performs some internal optimisation under the hood to not receive all the necessary columns which is why it is much faster than performing a Cross Join with a filter.

Below is the more commonly used diagram to represent an Inner Join. Where the inner parts of the two input tables columns match on the condition, this forms the data rows for the virtual output table of the Inner Join.



Below is an example Inner Join SQL query syntax joining two tables:

```
SELECT storeLocation, salesDate, revenue
FROM Stores_Data AS s
        INNER JOIN Sales_Data AS rev
        ON s.storeID = rev.storeID AND s.storeLocation = ‘ASDA Binley’;
```

The **SELECT** clause selects some columns from the output table while the **FROM** clause has a whole bunch of things going on to perform the Join to create the output table. First we specify in the **FROM** clause the first input table to involve in the Inner Join. The **INNER JOIN** keyword is used followed by the name of the second input table. This will indicate to the DBMS to perform an inner join using the two input tables specified in the SQL query. Finally, the keyword **ON** is used to specify the filter condition. The **INNER JOIN** keyword is always used with the **ON** keyword.

In the example above there are two filter conditions separated by the **AND** keyword. The first condition is an Equi-Join since it is linking the two columns from both input tables via an equality check. The second condition checks for the storeLocation from the Stores_Data is equal to ASDA Binley. This query will provide the following result:

Stores_Data		
storeID	storeLocation	city
1	ASDA Small Heath	Birmingham
2	ASDA Binley	Coventry

Sales_Data			
storeID	productID	salesDate	revenue
2	4	November 02, 2020	1,233.32
1	1	November 02, 2020	5,434.74
2	3	November 02, 2020	3,855.96
2	3	November 02, 2020	2,280.90

The columns between the two tables are added together i.e. m + n columns.
The rows are all the possible combinations between the two table rows i.e. x*y rows.
(Remember that the DBMS does not actually perform a Cross Join under the hood, but this allows us to logically visualise what an Inner Join does to grasp the concept).

CROSS_JOIN_OUTPUT_TABLE

storeID	storeLocation	city	storeID	productID	salesDate	revenue
1	ASDA Small Heath	Birmingham	2	4	November 02, 2020	1,233.32
1	ASDA Small Heath	Birmingham	…	…	…	…
2	ASDA Binley	Coventry	2	4	November 02, 2020	1,233.32
2	ASDA Binley	Coventry	…	…	…	…

The rows are then filtered based on the condition i.e. <= x*y rows.

INNER_JOIN_OUTPUT_TABLE

storeID	storeLocation	city	storeID	productID	salesDate	revenue
~~1~~	~~ASDA Small Heath~~	~~Birmingham~~	~~2~~	~~4~~	~~November 02, 2020~~	~~1,233.32~~
~~1~~	~~ASDA Small Heath~~	~~Birmingham~~	~~…~~	~~…~~	~~…~~	~~…~~
2	ASDA Binley	Coventry	2	4	November 02, 2020	1,233.32
~~2~~	~~ASDA Binley~~	~~Coventry~~	~~1~~	~~1~~	~~November 02, 2020~~	~~5,434.74~~
2	ASDA Binley	Coventry	2	3	November 02, 2020	3,855.96
2	ASDA Binley	Coventry	2	3	November 02, 2020	2,280.90

The select statement within the query will return the storeLocation, salesDate and revenue columns from this virtual Inner Join output table as the final result table as seen below:

RESULTS_TABLE

storeLocation	salesDate	revenue
ASDA Binley	November 02, 2020	1,233.32
ASDA Binley	November 02, 2020	3,855.96
ASDA Binley	November 02, 2020	2,280.90
ASDA Binley	…	…