SQL

Data Query Language

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Introduction

SQL

- Structured **Q**uery **L**anguage.
- A special purpose language to manage data stored in a **relational** database.
- Based on **relational algebra**.
- Pronounced *Sequel*

History

- Early 70's SEQUEL Developed at IBM
- 1986 SQL-86 and SQL-87 Ratified by ANSI and ISO.
- 1989 SQL-89
- 1992 SQL-92 Also know as SQL2.
- 1999 SQL:1999 Also known as SQL3 Includes regurlar expressions, recursive queries, triggers, non-scalar data types and some object-oriented expressions.
- 2003 SQL:2003 XML support and auto-generated values.
- 2006 SQL:2006 XQuery support.
- 2008 SQL:2008.
- 2011 SQL:2011.

Standard

- Although SQL is an ANSI/ISO standard, every database system implements it in a slightly different way.
- These slides will try to adhere to the standard as much as possible.
- Sometimes we'll deviate and talk specifically about **PostgreSQL**.

Selecting Data

SELECT and FROM

- **SELECT** and **FROM** are the most basic SQL query operators.
- They allows to specify which tables (FROM) and columns (SELECT) we want to retrieve from the database.
- The result of an SQL query is also a table.

Selecting all columns

To select all columns from a table we can use an *

```
SELECT * FROM employee;
```

id	name	salary	taxes	dep_num
1	John Doe	1000	200	1
2	Jane Doe	800	100	2
3	John Smith	1200	350	2
4	Jane Roe	1000	200	3
5	Richard Roe	900	0	NULL

? Selects all columns from table employee

Choosing columns

Choosing columns

We can select only some columns

```
SELECT id, name FROM employee;
```

id	name
1	John Doe
2	Jane Doe
3	John Smith
4	Jane Roe
5	Richard Roe

? Selects columns id and name from table employee

Column operations

We can also perform any operations between columns

```
SELECT id, name, salary - taxes FROM employee;
```

id	name	salary - taxes
1	John Doe	800
2	Jane Doe	700
3	John Smith	850
4	Jane Roe	800
5	Richard Roe	900

? Selects columns id, name and the difference between salary and taxes from table employee

Renaming columns

Any column can be renamed using the AS operator

```
SELECT id AS num, name, salary - taxes AS net_salary FROM employee;
```

num	name	net_salary
1	John Doe	800
2	Jane Doe	700
3	John Smith	850
4	Jane Roe	800
5	Richard Roe	900

? Renaming column id as num and the difference between salary and taxes to net_salary

Filtering Rows

WHERE

- The WHERE command allows us to filter which rows we want in our result table according to a condition.
- The condition can use any comparison operator (<, >, <=, <>, ...) and can be composed using AND, OR and NOT.

Example

```sql
SELECT * FROM employee WHERE dep_num = 2 OR salary <= 900;
```

id	name	salary	taxes	dep_num
2	Jane Doe	800	100	2
3	John Smith	1200	350	2
5	Richard Roe	900	0	NULL

? Employees from department 2 or a salary lower or equal to 900

Example

To test if a value is null, we have to use the special **IS NULL** operator.

```
SELECT * FROM employee WHERE dep_num IS NULL;
```

id	name	salary	taxes	dep_num
5	Richard Roe	900	0	NULL

? Employees from department 2 or a salary lower or equal to 900

Use **IS NOT NULL** to select rows where a certain attribute is not null.

Removing duplicates

We can remove duplicates from the final result by using the DISTINCT operator

```
SELECT DISTINCT salary FROM employee;
```

salary
1000
800
1200
900

? Selects the different salaries in the database

Set operators

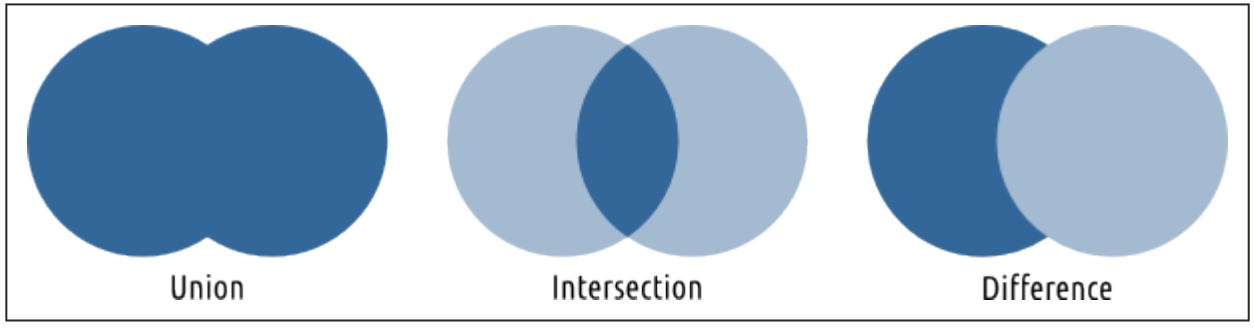
Set operators

Two tables are compatible for being used in a set operation if they have the same **number of columns** and the **type** of each column is **compatible**:

- The **UNION** between two tables (R1 and R2) is a table that includes all lines that are present in R1 or R2.
- The **INTERSECT**ion between two tables (R1 and R2) is a table that includes all lines that are present in R1 and R2.
- The difference (**EXCEPT**) between two tables (R1 and R2) is a table that includes all lines that are present in R1 but not in R2.

With all these operators, **duplicate** rows are **eliminated** automatically.

Union, Intersection and Difference



Example

```
SELECT * FROM employee WHERE salary >= 1000;
```

id	name	salary	taxes	dep_num
1	John Doe	1000	200	1
3	John Smith	1200	350	2
4	Jane Roe	1000	200	3

```
SELECT * FROM employee WHERE id_dep = 2;
```

id	name	salary	taxes	dep_num
2	Jane Doe	800	100	2
3	John Smith	1200	350	2

Union

```
SELECT * FROM employee WHERE salary >= 1000;
UNION
SELECT * FROM employee WHERE id_dep = 2;
```

id	name	salary	taxes	dep_num
1	John Doe	1000	200	1
2	Jane Doe	800	100	2
3	John Smith	1200	350	2
4	Jane Roe	1000	200	3

? Employees that have a salary larger or equal to 1000 or work on department 2

Intersection

```
SELECT * FROM employee WHERE salary >= 1000;
INTERSECT
SELECT * FROM employee WHERE id_dep = 2;
```

id	name	salary	taxes	dep_num
3	John Smith	1200	350	2

? Employees that have a salary larger or equal to 1000 and work on department 2

Difference

```sql
SELECT * FROM employee WHERE salary >= 1000;
EXCEPT
SELECT * FROM employee WHERE id_dep = 2;
```

id	name	salary	taxes	dep_num
1	John Doe	1000	200	1
4	Jane Roe	1000	200	3

? Employees that have a salary larger or equal to 1000 and do not work on department 2

Joining Tables

Cartesian product

- The cartesian product allows us to combine rows from **different tables**.
- To use it, we just have to indicate which tables we want to combine using commas to separate them.
- The result is a table containing the columns of all tables and **all possible combinations** of rows.
- Also known as **CROSS JOIN**.

Example

```
SELECT * FROM employee;
```

id	name	salary	taxes	dep_num
1	John Doe	1000	200	1
2	Jane Doe	800	100	2
3	John Smith	1200	350	2
4	Jane Roe	1000	200	3
5	Richard Roe	900	0	NULL

```
SELECT * FROM department;
```

num	name
1	Marketing
2	Sales
3	Production

Cartesian product

```
SELECT * FROM employee, department;
```

```
SELECT * FROM employee CROSS JOIN department;
```

id	name	salary	taxes	dep_num	num	name
1	John Doe	1000	200	1	1	Marketing
2	Jane Doe	800	100	2	1	Marketing
3	John Smith	1200	350	2	1	Marketing
4	Jane Roe	1000	200	3	1	Marketing
5	Richard Roe	900	0	NULL	1	Marketing
1	John Doe	1000	200	1	2	Sales
2	Jane Doe	800	100	2	2	Sales
3	John Smith	1200	350	2	2	Sales
4	Jane Roe	1000	200	3	2	Sales
5	Richard Roe	900	0	NULL	2	Sales
1	John Doe	1000	200	1	3	Production
2	Jane Doe	800	100	2	3	Production
3	John Smith	1200	350	2	3	Production
4	Jane Roe	1000	200	3	3	Production
5	Richard Roe	900	0	NULL	3	Production

Solving ambiguities

When selecting from more than one table, columns with the same name might lead to ambiguities.

```
SELECT id, name, name FROM employee, department;
```

To solve them we must use the table name before the column name.

```
SELECT id, employee.name, department.name FROM employee, department;
```

Solving ambiguities

```
SELECT id, employee.name, department.name FROM employee, department;
```

id	name	name
1	John Doe	Marketing
2	Jane Doe	Marketing
3	John Smith	Marketing
4	Jane Roe	Marketing
5	Richard Roe	Marketing
1	John Doe	Sales
2	Jane Doe	Sales
3	John Smith	Sales
4	Jane Roe	Sales
5	Richard Roe	Sales
1	John Doe	Production
2	Jane Doe	Production
3	John Smith	Production
4	Jane Roe	Production
5	Richard Roe	Production

Joining using WHERE

```
SELECT * FROM employee, department WHERE dep_num = num;
```

id	name	salary	taxes	dep_num	num	name
1	John Doe	1000	200	1	1	Marketing
~~2~~	~~Jane Doe~~	~~800~~	~~100~~	~~2~~	~~1~~	~~Marketing~~
~~3~~	~~John Smith~~	~~1200~~	~~350~~	~~2~~	~~1~~	~~Marketing~~
~~4~~	~~Jane Roe~~	~~1000~~	~~200~~	~~3~~	~~1~~	~~Marketing~~
~~5~~	~~Richard Roe~~	~~900~~	~~0~~	~~NULL~~	~~1~~	~~Marketing~~
~~1~~	~~John Doe~~	~~1000~~	~~200~~	~~1~~	~~2~~	~~Sales~~
2	Jane Doe	800	100	2	2	Sales
3	John Smith	1200	350	2	2	Sales
~~4~~	~~Jane Roe~~	~~1000~~	~~200~~	~~3~~	~~2~~	~~Sales~~
~~5~~	~~Richard Roe~~	~~900~~	~~0~~	~~NULL~~	~~2~~	~~Sales~~
~~1~~	~~John Doe~~	~~1000~~	~~200~~	~~1~~	~~3~~	~~Production~~
~~2~~	~~Jane Doe~~	~~800~~	~~100~~	~~2~~	~~3~~	~~Production~~
~~3~~	~~John Smith~~	~~1200~~	~~350~~	~~2~~	~~3~~	~~Production~~
4	Jane Roe	1000	200	3	3	Production
~~5~~	~~Richard Roe~~	~~900~~	~~0~~	~~NULL~~	~~3~~	~~Production~~

Joining using WHERE

```
SELECT * FROM employee, department WHERE dep_num = num;
```

id	name	salary	taxes	dep_num	num	name
1	John Doe	1000	200	1	1	Marketing
2	Jane Doe	800	100	2	2	Sales
3	John Smith	1200	350	2	2	Sales
4	Jane Roe	1000	200	3	3	Production

? Employees and their departments

Join using JOIN ... ON

- Instead of using a cartesian product followed by the WHERE keyword, we can use the more specific keywords: **JOIN ON**.
- These keywords allow us to specify simultaneously **which tables** to join and with which joining **condition**.
- Separates regular row filtering from joining conditions.
- Makes joining lots of tables **easier** to understand.

```
SELECT * FROM employee, department WHERE dep_num = num;
```

Same as:

```
SELECT * FROM employee JOIN department ON dep_num = num;
```

Join using JOIN ... ON

```
SELECT * FROM employee JOIN department ON dep_num = num;
```

id	name	salary	taxes	dep_num	num	name
1	John Doe	1000	200	1	1	Marketing
2	Jane Doe	800	100	2	2	Sales
3	John Smith	1200	350	2	2	Sales
4	Jane Roe	1000	200	3	3	Production

Join using JOIN ... USING

If the columns used in the join operation have the same name, we can join them using in a simpler way with JOIN USING.

```
SELECT * FROM employee;
```

id	name	salary	taxes	num
1	John Doe	1000	200	1
2	Jane Doe	800	100	2
3	John Smith	1200	350	2
4	Jane Roe	1000	200	3
5	Richard Roe	900	0	NULL

```
SELECT * FROM department;
```

num	name
1	Marketing
2	Sales
3	Production

Join using JOIN ... USING

```
SELECT * FROM employee JOIN department USING(num);
```

id	name	salary	taxes	num	name
1	John Doe	1000	200	1	Marketing
2	Jane Doe	800	100	2	Sales
3	John Smith	1200	350	2	Sales
4	Jane Roe	1000	200	3	Production

Renaming tables

- We can also rename tables.
- This might be useful if we need to use the **same table twice** in the same query.
- Or if we want to make the table names **simpler** in a complicated query.

```
SELECT * FROM employee;
```

id	name	sup_id
1	John Doe	NULL
2	Jane Doe	1
3	John Smith	1
4	Jane Roe	NULL
5	Richard Roe	4

Renaming tables

```
SELECT * FROM employee JOIN employee AS supervisor ON employee.sup_id = supervidor.id;
```

id	name	sup_id	id	name	sup_id
2	Jane Doe	1	1	John Doe	NULL
3	John Smith	1	1	John Doe	NULL
5	Richard Roe	4	4	Jane Roe	NULL

Aggregating Data

Aggregate Functions

There are **five** special aggregate functions defined in the SQL language:

```
MIN, MAX, SUM, AVG and COUNT
```

value
1
2
NULL
3

```
SELECT MIN(value)   FROM table; -- 1
SELECT MAX(value)   FROM table; -- 3
SELECT SUM(value)   FROM table; -- 6
SELECT AVG(value)   FROM table; -- 2
SELECT COUNT(value) FROM table; -- 3 (counts non null values)
SELECT COUNT(*)     FROM table; -- 4 (counts lines)
```

Aggregate Functions

When using aggregate functions, all rows are grouped into a single row.

id	name	salary	taxes	num	d_name
1	John Doe	700	200	1	Marketing
2	Jane Doe	800	100	2	Sales
3	John Smith	1500	350	2	Sales
4	Jane Roe	1000	200	3	Production

```
SELECT AVG(salary)       FROM employees; -- 1000
SELECT name, AVG(salary) FROM employees; -- Does not work
```

? You can no longer refer to columns without an aggregate function.

GROUP BY

Groups the rows into sets based on the value of a specific column or columns.

id	name	salary	taxes	num	d_name
1	John Doe	700	200	1	Marketing
2	Jane Doe	800	100	2	Sales
3	John Smith	1500	350	2	Sales
4	Jane Roe	1000	200	3	Production

```
SELECT AVG(salary) FROM employees GROUP BY num;
```

- All rows with same value in the *num* column get grouped together.
- The aggregate functions are used inside each group.

AVG(salary)
700
1150
1000

GROUP BY

Only columns used in **GROUP BY** expressions can be selected without using an aggregate function.

id	name	salary	taxes	num	d_name
1	John Doe	700	200	1	Marketing
2	Jane Doe	800	100	2	Sales
3	John Smith	1500	350	2	Sales
4	Jane Roe	1000	200	3	Production

```
SELECT num, AVG(salary) FROM employees GROUP BY num;
```

num	AVG(salary)
1	700
2	1150
3	1000

GROUP BY

Only columns used in **GROUP BY** expressions can be selected without using an aggregate function.

id	name	salary	taxes	num	d_name
1	John Doe	700	200	1	Marketing
2	Jane Doe	800	100	2	Sales
3	John Smith	1500	350	2	Sales
4	Jane Roe	1000	200	3	Production

```
SELECT num, d_name, AVG(salary) FROM employees GROUP BY num, d_name;
```

d_name	AVG(salary)
Marketing	700
Sales	1150
Production	1000

HAVING

Grouped rows can be filtered using the **HAVING** clause.

id	name	salary	taxes	num	d_name
1	John Doe	700	200	1	Marketing
2	Jane Doe	800	100	2	Sales
3	John Smith	1500	350	2	Sales
4	Jane Roe	1000	200	3	Production

```
SELECT num, d_name, AVG(salary) FROM employees
GROUP BY num, d_name HAVING AVG(salary) >= 1000;
```

d_name	AVG(salary)
Sales	1150
Production	1000

Sorting Rows

ORDER BY

- The order in which rows are sorted in a query result is unpredictable.
- You can sort the end result using the **ORDER BY** clause.

id	name	salary	taxes	num	d_name
1	John Doe	700	200	1	Marketing
2	Jane Doe	800	100	2	Sales
3	John Smith	1500	350	2	Sales
4	Jane Roe	1000	200	3	Production

```
SELECT * FROM employees ORDER BY salary;
```

id	name	salary	taxes	num	d_name
1	John Doe	**700**	200	1	Marketing
2	Jane Doe	**800**	100	2	Sales
4	Jane Roe	**1000**	200	3	Production
3	John Smith	**1500**	350	2	Sales

ORDER BY

- By default values are sorted in **ascending** order.
- We can change the default order using the **ASC** and **DESC** clauses.

```
SELECT * FROM employees ORDER BY salary ASC; -- default
```

id	name	salary	taxes	num	d_name
1	John Doe	**700**	200	1	Marketing
2	Jane Doe	**800**	100	2	Sales
4	Jane Roe	**1000**	200	3	Production
3	John Smith	**1500**	350	2	Sales

```
SELECT * FROM employees ORDER BY salary DESC; -- default
```

id	name	salary	taxes	num	d_name
3	John Smith	**1500**	350	2	Sales
4	Jane Roe	**1000**	200	3	Production
2	Jane Doe	**800**	100	2	Sales
1	John Doe	**700**	200	1	Marketing

ORDER BY

- We can also sort by more than one column.
- When this happens, we first sort using the first column and if there is a tie we use the next column.

```
SELECT * FROM employees ORDER BY taxes DESC, salary ASC;
SELECT * FROM employees ORDER BY taxes DESC, salary;     -- equivalent
```

id	name	salary	taxes	num	d_name
3	John Smith	**1500**	350	2	Sales
1	John Doe	**700**	200	1	Marketing
4	Jane Roe	**1000**	200	3	Production
2	Jane Doe	**800**	100	2	Sales

Limiting Data

LIMIT

The number of rows returned by a query can be limited using the **LIMIT** clause.

```
SELECT * FROM employees ORDER BY salary LIMIT 2;
```

id	name	salary	taxes	num	d_name
3	John Smith	**1500**	350	2	Sales
4	Jane Roe	**1000**	200	3	Production

OFFSET

When using the **LIMIT** clause, we can also indicate how many rows to skip using the **OFFSET** clause.

```
SELECT * FROM employees ORDER BY salary LIMIT 2 OFFSET 1;
```

id	name	salary	taxes	num	d_name
4	Jane Roe	**1000**	200	3	Production
2	Jane Doe	**800**	100	2	Sales

? Here the first line (with a salary of 1500) was skipped.

Pagination

LIMIT and OFFSET can be used to paginate our results.

? Example for page 3 with 10 results per page.

```
SELECT * FROM employees ORDER BY id LIMIT 10 OFFSET 20;
```

? Generically for page N with R results per page.

```
SELECT * FROM employees ORDER BY id LIMIT R OFFSET R * (N - 1);
```

A Complete Query

A Complete Query

- A query will always start with the SELECT clause.
- All the other clauses are optional.
- But they always follow the same order.

```
SELECT c1, c2, SUM(c3), AVG(c4) AS c5
FROM t1 JOIN
     t2 ON t1.foreign_key = t2.primary_key JOIN
     t3 USING (join_column)
WHERE condition_1 AND (condition_2 OR condition_3)
GROUP BY c1, c2
HAVING AVG(c4) > 10
ORDER BY AVG(c4)
LIMIT 5 OFFSET 10
```

Text Operators

LIKE

The LIKE operator can be used to compare strings using simple patterns.

- The **%** particle means zero or more characters
- The _ character means exactly one character.

id	name
1	John Doe
2	Jane Doe
3	Jean Doe
4	Jennifer Doe
5	William Doe

```
SELECT * FROM people WHERE name LIKE '% Doe'    -- All five rows
SELECT * FROM people WHERE name LIKE 'J% Doe'   -- John, Jane, Jean and Jennifer
SELECT * FROM people WHERE name LIKE 'J___ Doe' -- John, Jane and Jean
SELECT * FROM people WHERE name LIKE '_e%'      -- Jean and Jennifer
```

? The ILIKE operator is similar but also ignores case.

SIMILAR TO

To be done

POSIX Regular Expressions

To be done

Nested Queries

Queries as Tables

The result of a query is a table. This allows us to use queries in the same places we use tables.

```
SELECT *
FROM (SELECT * FROM
        employees JOIN
        department USING(d_num)
      WHERE department.name = 'Logistics') AS logistic_employees JOIN
     works ON logistic_employees.id = works.id
WHERE works.hours > 10
```

? *Subqueries* must be named using the AS particle.

Subquery Expressions

Subquery expressions can be used to combine two queries in the **WHERE** or **HAVING** clauses.

There are several subquery expressions:

```
expression IN subquery
expression NOT IN subquery
expression operator ANY (subquery) -- Same as SOME
expression operator ALL (subquery)
```

IN and NOT IN

```
expression IN subquery
expression NOT IN subquery
```

These expressions test if a value (or values) exist (or not) in the subquery.

```
SELECT *                -- Employees whose id exists in the subquery
FROM employees
WHERE employee.id IN (
    SELECT emp_id       -- The ids of employees that work more
    FROM works          -- than 10 hours in projects
    GROUP BY emp_id
    HAVING SUM(hours) > 10
)
```

ANY

```
expression operator ANY (subquery) -- Same as SOME
```

The **ANY** expression compares a value with every row of the subquery and returns true if **at least one** of the comparisons returns true.

```
SELECT *                -- Employees that have a larger salary than at least
FROM employees          -- one logistics department employee
WHERE salary >= ANY (
    SELECT salary       -- All the salaries from logistic department employees
    FROM employees JOIN
      departments ON employees.d_num = department.num
)
```

? = ANY is the same as IN

ALL

```
expression operator ALL (subquery)
```

The ALL expression compares a value with every row of the subquery and only returns true if **all** of the comparisons returns true.

```
SELECT *                -- Employees that have a larger salary than all of
FROM employees          -- the logistics department employees
WHERE salary >= ALL (
    SELECT salary       -- All the salaries from logistic department employees
    FROM employees JOIN
      departments ON employees.d_num = department.num
)
```

? <> ALL is the same as NOT IN