Aggregate functions and set operators

- The learning objectives for this week are:
  - Knowing what kind of query problems **aggregate functions** solve
  - Knowing how to use the aggregate functions `COUNT`, `SUM`, `AVG`, `MIN` and `MAX`
  - Knowing what kind of query problems **set operators** solve
  - Knowing how to combine result tables with `UNION`, `EXCEPT` and `INTERSECT` set operators

Aggregate functions

- Basic `SELECT` statement lets us retrieve specific columns from a table and filter rows with a `WHERE` clause
- However, when working with large datasets, we often need **summary information**, such as counts, averages, or totals, rather than individual rows
- That is, performing some calculation (such as sum or average) for **multiple rows** so that the end result is a **single summarized value** is a common query problem
- For example, *"what is the total number of courses?"*, or *"what is the sum of male teachers' salaries?"*
- Functions that perform such SQL operations are referred to as **aggregate functions**

The COUNT aggregate function

```
COUNT ( * | { [ DISTINCT ] column_expression } )
```

- The `COUNT` aggregate function returns the **total number of rows** that match the specified criteria
- The `COUNT` aggregate function and other aggregate functions are used to compute a value for a column in the `SELECT` statement

```
-- what's the number of courses in the Course table?
SELECT COUNT(*) as number_of_courses FROM Course
```

- The `COUNT` aggregate function operates on all the target table rows, leaving the result table with a single row:

number_of_courses
7

Using aggregate functions with a WHERE clause

- We can also filter the rows the aggregate function operates on using the `WHERE` clause:

```
-- what's the number of courses with more than 3 credits?
SELECT COUNT(*) as number_of_courses FROM Course
WHERE credits > 3
```

- Now the aggregate function operates on the target table rows, **which match the `WHERE` clause condition**, leaving the result table with a single row:

number_of_courses
2

Omitting NULL values with COUNT aggregate function

- We can also provide a column name for the `COUNT` aggregate function in which case the function returns the number of the **non-null values** of the given column:

```
-- what's the number of students with an email address?
SELECT COUNT(email) as number_of_students_with_email
FROM Student
```

Omitting NULL values with COUNT aggregate function

student_number	email
o354	0354@takkula.fi
o410	0410@takkula.fi
o473	NULL

```sql
-- count all rows, total_number_of_students is 3
SELECT COUNT(*) as total_number_of_students
FROM Student

-- count rows with non-null email column value, number_of_students_with_email is 2
SELECT COUNT(email) as number_of_students_with_email
FROM Student
```

The SUM aggregate function

```
SUM ( [ DISTINCT ] column_expression )
```

- The `SUM` aggregate function returns the **sum of all the non-null values** of a column:

```
-- what's the sum of salaries of female teachers?
SELECT SUM(salary) as sum_of_salaries FROM Teacher
WHERE gender = 'F'
```

- The `SUM` aggregate function operates on all the target table rows, leaving the result table with a single row:

sum_of_salaries
102273.00

The AVG aggregate function

$$\text{AVG}(column) = \frac{\text{SUM}(column)}{\text{COUNT}(column)}$$

```
AVG ( [ DISTINCT ] column_expression )
```

- The `AVG` aggregate function returns the **average of non-null values** of a column:

```
-- what's the average grade from course with code "a730"?
SELECT AVG(grade) as average_grade FROM CourseGrade
WHERE course_code = 'a730'
```

- The `AVG` aggregate function operates on all the target table rows, leaving the result table with a single row

average_grade
3

Rounding the AVG aggregate function result

- Calculating the average includes a division operation, which can produce decimal numbers
- To avoid losing the decimal part of the average, we need to cast integer column values to a `DECIMAL` type:

```
-- multiplying an integer with 1.0 will end up with a DECIMAL type
SELECT AVG(grade * 1.0) as average_grade FROM CourseGrade
WHERE course_code = 'a730'
```

average_grade
3.333333

Rounding the AVG aggregate function result

- We can limit the number of decimal places in the result by using casting the result to a `DECIMAL` type with specific precision (the total number of decimal digits stored) and scale (the number of decimal digits stored to the right of the decimal point):

```
-- use scale of 2 in the DECIMAL type to round to two decimals places
SELECT CAST(AVG(grade * 1.0) AS DECIMAL(5, 2)) as average_grade
FROM CourseGrade
WHERE course_code = 'a730'
```

$$\text{DECIMAL}(5, 2) \quad \Rightarrow \quad \underbrace{999}_{5 - 2 = 3 \text{ digits left}} \; . \; \underbrace{99}_{2 \text{ digits right}}$$

average_grade
3.33

The MIN aggregate function

```
MIN ( column_expression )
```

- The `MIN` function returns the **smallest value** of a column

```
-- what's the lowest grade from course with code "a730"?
SELECT MIN(grade) as lowest_grade FROM CourseGrade
WHERE course_code = 'a730'
```

- The `MIN` aggregate function operates on all the target table rows, leaving the result table with a single row

lowest_grade
1

The MAX aggregate function

```
MAX ( column_expression )
```

- The `MAX` function returns the **largest value** of a column

```
-- what's the highest grade from course with code "a730"?
SELECT MAX(grade) as highest_grade FROM CourseGrade
WHERE course_code = 'a730'
```

- The `MAX` aggregate function operates on all the target table rows, leaving the result table with a single row

highest_grade
5

Multiple aggregate functions in a single query

- We can have multiple aggregate functions in the same query:

```
-- what's the highest and lowest grade from course with code "a730"?
SELECT MAX(grade) as highest_grade, MIN(grade) as lowest_grade FROM CourseGrade
WHERE course_code = 'a730'
```

- The result table contains a single row with two columns:

highest_grade	lowest_grade
5	1

Only operating on distinct values

- The `COUNT`, `SUM` and `AVG` aggregate functions support the `DISTINCT` keyword for only operating on **distinct values**:

```
-- how many different grades have been given?
SELECT COUNT(DISTINCT grade) as number_of_different_grades FROM CourseGrade
```

Combining aggregate function and non-aggregate function columns

- If we use an aggregate function, we **can't include non-aggregate function columns** to the `SELECT` statement*:

```
-- ✅ only aggregate function columns, all good here
SELECT COUNT(*) as number_of_courses FROM Course

-- ❌ combintation of aggregate function and non-aggregate function columns, this won't work
SELECT course_name, COUNT(*) as number_of_courses FROM Course
```

- * That is, unless the non-aggregate function columns are included in a `GROUP BY` clause, but we will cover that later

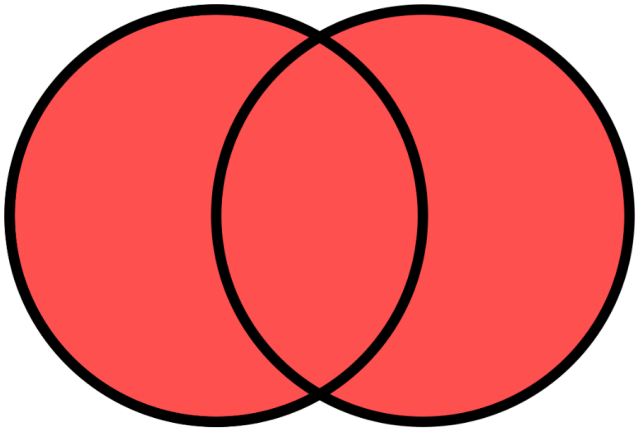
Combining aggregate function and non-aggregate function columns

- If it would be possible, how would the RDMS know, which `course_name` to display in the result table?

```
-- ❌ combintation of aggregate function and non-aggregate function columns, this won't work
SELECT course_name, COUNT(*) as number_of_courses FROM Course
```

course_name	number_of_courses
?	2

Combining results tables with set operators



- We can use the results from **multiple result tables** using the `UNION`, `EXCEPT`, and `INTERSECT` **set operators**
- For example, the `UNION` operator returns **all** the rows from two or more result tables **without duplicate values**:

```
-- what are all the surnames among teachers and students?
SELECT surname FROM Teacher
UNION
SELECT surname FROM Student
```

The UNION operator

> *"What are all the surnames among teachers and students?"*

```
SELECT surname FROM Teacher
```

surname
Huhta
Hellerus

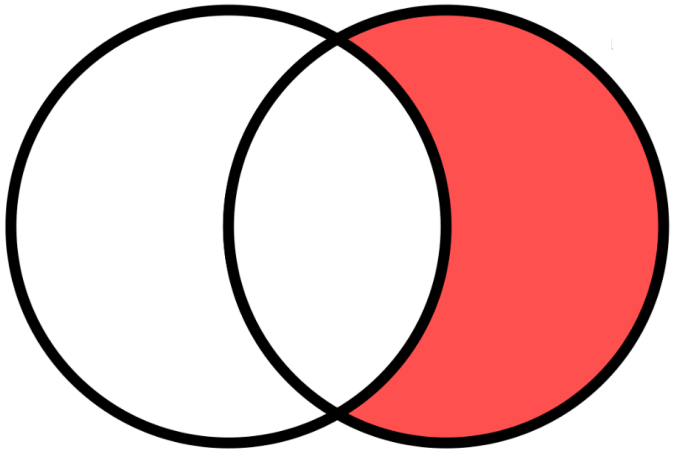
```
SELECT surname FROM Student
```

surname
Kokki
Kuikka

```
SELECT surname FROM Teacher
UNION
SELECT surname FROM Student
```

surname
Huhta
Hellerus
Kokki
Kuikka

The EXCEPT operator



- The `EXCEPT` operator returns only the rows from the first result table that are **not included** in the second result table **without duplicate values**:

```
-- what are the campus cities that no student lives in?
SELECT city FROM Campus
EXCEPT
SELECT city FROM Student
```

The EXCEPT operator

> *"What are the campus cities that no student lives in?"*

```
SELECT city FROM Campus
```

city
Helsinki
Vantaa

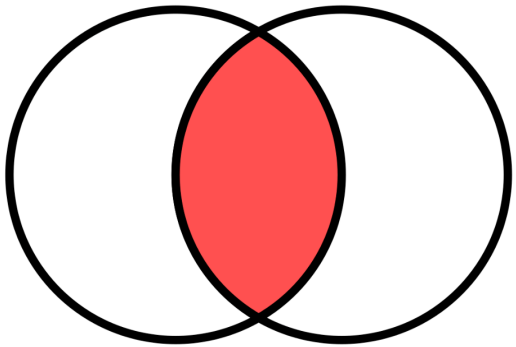
```
SELECT city FROM Student
```

city
Helsinki
Espoo

```
SELECT city FROM Campus
EXCEPT
SELECT city FROM Student
```

city
Vantaa

The INTERSECT operator



- The `INTERSECT` operator returns only the rows that **exist in both** result tables **without duplicate values**:

```
-- what are the campus cities that have students living in them?
SELECT city FROM Campus
INTERSECT
SELECT city FROM Student
```

The EXCEPT operator

> *"What are the campus cities that have students living in them?"*

```
SELECT city FROM Campus
```

city
Helsinki
Vantaa

```
SELECT city FROM Student
```

city
Helsinki
Espoo

```
SELECT city FROM Campus
INTERSECT
SELECT city FROM Student
```

city
Helsinki

The set operators

- ⚠️ With set operators, the column names and data types of each `SELECT` statement **must match**:

```
-- ❌ first_name column is missing from the latter SELECT statement.
-- This will lead into an error.
SELECT surname, first_name FROM Teacher
UNION
SELECT surname FROM Student
```

Summary

- We can perform calculations on multiple rows so that the end result is a single row using **aggregate functions**
- The `COUNT` aggregate function returns the **total number of rows**
- The `SUM` aggregate function returns the **sum of all the values** of a column
- The `AVG` aggregate function returns the **average of values** of a column
- The `MIN` aggregate function returns the **minimum value** of a column
- The `MAX` aggregate function returns the **maximum value** of a column
- The `UNION`, `EXCEPT` and `INTERSECT` **set operators** can be used to combine results of multiple result tables