Lecture 8

Database Usage (and Construction)

More SQL Queries and Relational Algebra

Quiz!

What will the result of this query be?

```
SELECT 1
FROM   Courses;
```

Courses

code	*name*
TDA357	Databases
TIN090	Algorithms

1
1
1

For each row in Courses that passes the test (all rows since we have no test), project the value 1.

Constants

- Constants can be used in projections.

```
SELECT code, name,
       'Database course' AS comment
FROM   Courses
WHERE  name LIKE '%Database%';
```

code	*name*	*comment*
TDA357	Databases	Database course

Aggregation

- Aggregation functions are functions that produce a single value over a relation.
  - SUM, MAX, MIN, AVG, COUNT…

```
SELECT MAX(nrSeats)
FROM   Rooms;
```

MAX actually has Rooms as an implicit argument!

```
SELECT COUNT(*)
FROM   Lectures
WHERE  room = 'HC1';
```

Quiz!

List the room(s) with the highest number of seats, and its number of seats.

```
SELECT name, MAX(nrSeats)
FROM   Rooms;
```

NOT correct!

Error when trying to execute, why is it so?

Aggregate functions are special

- Compare the following:

```
SELECT nrSeats
FROM   Rooms;
```

```
SELECT MAX(nrSeats)
FROM   Rooms;
```

  - The ordinary selection/projection results in a relation with a single attribute nrSeats, and one row for each row in Rooms.
  - The aggregation results in a single value, not a relation.
  - We can't mix both kinds in the same query! (almost…more on this later)

name	*nrSeats*
HC1	105
HC2	115
VR	230
HA1	146
HA4	152

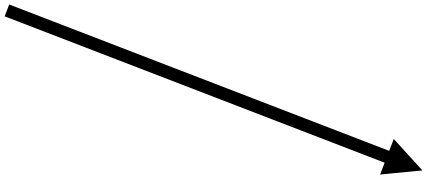
```
SELECT nrSeats
FROM   Rooms;
```

nrSeats
105
115
230
146
152

name	*nrSeats*
HC1	105
HC2	115
VR	230
HA1	146
HA4	152

```
SELECT MAX(nrSeats)
FROM   Rooms;
```

MAX(nrSeats)
230



```
SELECT MAX(nrSeats) AS nrSeats
FROM   Rooms;
```

nrSeats
230

Quiz! New attempt

List the room(s) with the highest number of seats, and its number of seats.

```
SELECT name,
       (SELECT MAX(nrSeats)
        FROM   Rooms)
FROM   Rooms;
```

Not correct either, will list all rooms, together with the highest number of seats in any room.

Let's try yet again…

name	*nrSeats*
HC1	105
HC2	115
VR	230
HA1	146
HA4	152

```
SELECT name,
   (SELECT MAX(nrSeats)
    FROM   Rooms)
FROM   Rooms;
```

name	*nrSeats*
HC1	230
HC2	230
VR	230
HA1	230
HA4	230

Quiz! New attempt

List the room(s) with the highest number of seats, and its number of seats.

```
SELECT name, nrSeats
FROM   Rooms
WHERE  nrSeats = MAX(nrSeats);
```

Still not correct, MAX(nrSeats) is not a test over a row so it can't appear in the WHERE clause!

Let's try yet again…

Quiz!

List the room(s) with the highest number of seats, and its number of seats.

```
SELECT name, nrSeats
FROM   Rooms
WHERE  nrSeats =
          (SELECT MAX(nrSeats)
           FROM   Rooms);
```

That's better!

Single-value queries

- If the result of a query is known to be a single value (like for MAX), the whole query may be used as a value.

```
SELECT name, nrSeats
FROM   Rooms
WHERE  nrSeats =
          (SELECT MAX(nrSeats)
           FROM   Rooms);
```

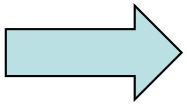
- Dynamic verification, so be careful…

NULL in aggregations

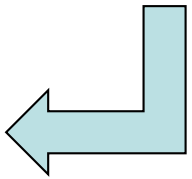
- NULL never contributes to a sum, average or count, and can never be the maximum or minimum value.
- If there are no non-null values, the result of the aggregation is NULL.

Capacity per campus?

name	*capacity*	*campus*
HB2	186	Johanneberg
HC1	105	Johanneberg
HC2	115	Johanneberg
Jupiter44	64	Lindholmen
Svea239	60	Lindholmen
VR	300	Neverland



name	*capacity*	*campus*
HB2	186	Johanneberg
HC1	105 (406)	Johanneberg
HC2	115	Johanneberg
Jupiter44	64	Lindholmen
Svea239	60 (124)	Lindholmen
VR	300	Neverland



SUM(capacity)	*campus*
406	Johanneberg
124	Lindholmen
300	Neverland

```
SELECT SUM(capacity), campus FROM Rooms GROUP BY campus;
```

Grouping

- Grouping intuitively means to partition a relation into several groups, based on the value of some attribute(s).
  - ”All courses with this teacher go in this group, all courses with that teacher go in that group, …”
- Each group is a sub-relation, and aggregations can be computed over them.
- Within each group, all rows have the same value for the attribute(s) grouped on, and therefore we can project that value as well!

Grouping

- Grouping = given a relation R, a set of attributes X, and a set of aggregation expressions G; partition R into groups $R_1 \ldots R_n$ such that all rows in R_i have the same value on all attributes in X, and project X and G for each group.

$$\gamma_{X,G}(R)$$

```
SELECT   X,G
FROM     R
GROUP BY X;
```

  - ”For each X, compute G”
  - γ = gamma = greek letter **g** = **g**rouping

Example: List the average number of students that each teacher has on his or her courses.

course	*per*	*teacher*	*nrSt.*
TDA357	2	Mickey	130
DIT952	3	Mickey	70
TIN090	1	Tweety	62

SQL?

Result?

Relational Algebra?

Example: List the average number of students that each teacher has on his or her courses.

course	*per*	*teacher*	*nrSt.*
TDA357	2	Mickey	130
DIT952	3	Mickey	70
TIN090	1	Tweety	62

SQL?

teacher	*AVG(nrSt.)*
Mickey	100
Tweety	62

Relational Algebra?

Example: List the average number of students that each teacher has on his or her courses.

course	*per*	*teacher*	*nrSt.*
TDA357	2	Mickey	130
DIT952	3	Mickey	70
TIN090	1	Tweety	62

```
SELECT teacher,
  AVG(nrStudents)
FROM GivenCourses
GROUP BY teacher;
```

teacher	*AVG(nrSt.)*
Mickey	100
Tweety	62

Relational Algebra?

Example: List the average number of students that each teacher has on his or her courses.

course	*per*	*teacher*	*nrSt.*
TDA357	2	Mickey	130
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```
SELECT teacher,
  AVG(nrStudents)
FROM GivenCourses
GROUP BY teacher;
```

teacher	*AVG(nrSt.)*
Mickey	100
Tweety	62

$$\gamma_{\text{teacher, AVG(nrStudents)}}(\text{GivenCourses})$$

Specialized renaming of attributes

- We've seen the general renaming operator already: $\rho_{A(X)}(R)$
  - Rename R to A and its attributes to X.
- Can be akward to use, so we are allowed an easier way to rename attributes:

$$\gamma_{X,G\rightarrow B}(R)$$

  - E.g. $\gamma_{\text{teacher, AVG(nrStudents)}\rightarrow\text{avgStudents}}(\text{GivenCourses})$
  - Works in normal projection (π) as well.

Tests on groups

- Aggregations can't be put in the WHERE clause – they're not functions on rows but on groups.
- Sometimes we want to perform tests on the result of an aggregation.
  - Example: List all teachers who have an average number of students of >100 in their courses.
- SQL allows us to put such tests in a special HAVING clause after GROUP BY.

Example

```
SELECT    teacher
FROM      GivenCourses
GROUP BY  teacher
HAVING    AVG(nrStudents) > 100;
```

code	*period*	*teacher*	*#students*
TDA357	2	Mickey	130
~~TIN090~~	~~1~~	~~Tweety~~	~~95~~
TDA357	3	Donald	135
TDA283	2	Donald	70

AVG(nrSt.)
130
95
102.5

Quiz!

- There is no correspondence in relational algebra to the HAVING clause of SQL. Why?
  - Because we can express it with an extra renaming and a selection. Example:

```
SELECT   teacher
FROM     GivenCourses
GROUP BY teacher
HAVING   AVG(nrStudents) > 100;
```

$$\sigma_{avgSt > 100}(\gamma_{teacher,\ AVG(nrStudents) \rightarrow avgSt}(GivenCourses))$$

Sorting relations

- Relations are unordered by default.
- Operations could potentially change any existing ordering.

$\tau_X(R)$ **`ORDER BY X [DESC]`**

  - Sort relation R on attributes X.
  - Ordering only makes sense at the top level, or if only a given number of rows are sought, e.g. the top 5.
  - (For top 5: Append ”LIMIT 5”)
- τ = tau = greek letter t = sort (s is taken)

Example

```
SELECT   *
FROM     Courses
ORDER BY name;
```

code	*name*
TIN090	Algorithms
TDA590	Compiler Construction
TDA357	Databases

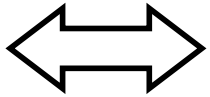
SELECT-FROM-WHERE-GROUPBY-HAVING-ORDERBY

- Full structure of an SQL query:

```
SELECT    attributes
FROM      tables
WHERE     tests over rows
GROUP BY  attributes
HAVING    tests over groups
ORDER BY  attributes
```

Only the SELECT and FROM clauses must be included.

```
SELECT    X,G
FROM      T
WHERE     C
GROUP BY  Y
HAVING    D
ORDER BY  Z;
```



What?

SELECT-FROM-WHERE-GROUPBY-HAVING-ORDERBY

- Full structure of an SQL query:

```
SELECT    attributes
FROM      tables
WHERE     tests over rows
GROUP BY  attributes
HAVING    tests over groups
ORDER BY  attributes
```

Only the SELECT and FROM clauses must be included.

```
SELECT    X,G
FROM      T
WHERE     C
GROUP BY  Y
HAVING    D
ORDER BY  Z;
```

$\Leftrightarrow$

$$\tau_{Z'}(\pi_{X,G'}(\sigma_{D'}(\gamma_{Y,G'}(\sigma_{C}(T)))))$$

X must be a subset of Y.
Primes ' mean we need some renaming.

Example:

```
SELECT   name, AVG(nrStudents) AS avSt
FROM     Courses, GivenCourses
WHERE    code = course
GROUP BY code, name
HAVING   AVG(nrStudents) > 100
ORDER BY avSt;
```

Courses

code	*name*
TDA357	Databases
TIN090	Algorithms

GivenCourses

course	*per*	*teacher*	*nrSt*
TDA357	2	Mickey	130
TDA357	3	Donald	95
TIN090	1	Tweety	62

$$\tau_{avSt}(\pi_{name,\ avSt}(\sigma_{avSt\ >\ 100}(\gamma_{code,\ name,\ AVG(nrStudents)\rightarrow avSt}(\sigma_{code\ =\ course}(Courses \times GivenCourses)))))$$

Example:

```
SELECT   name, AVG(nrStudents) AS avSt
FROM     Courses, GivenCourses
WHERE    code = course
GROUP BY code, name
HAVING   AVG(nrStudents) > 100
ORDER BY avSt;
```

code	*name*	*course*	*per*	*teacher*	*nrSt*
TDA357	Databases	TDA357	2	Mickey	130
TDA357	Databases	TDA357	3	Donald	95
TDA357	Databases	TIN090	1	Tweety	62
TIN090	Algorithms	TDA357	2	Mickey	130
TIN090	Algorithms	TDA357	3	Donald	95
TIN090	Algorithms	TIN090	1	Tweety	62

$\tau_{avSt}(\pi_{name,avSt}(\sigma_{avSt>100}(\gamma_{code,name,AVG(nrStudents)\rightarrow avSt}(\sigma_{code=course}(\textbf{Courses x GivenCourses})))))$

Example:

```
SELECT   name, AVG(nrStudents) AS avSt
FROM     Courses, GivenCourses
WHERE    code = course
GROUP BY code, name
HAVING   AVG(nrStudents) > 100
ORDER BY avSt;
```

code	*name*	*course*	*per*	*teacher*	*nrSt*
TDA357	Databases	TDA357	2	Mickey	130

code	*name*	*course*	*per*	*teacher*	*nrSt*
TDA357	Databases	TDA357	2	Mickey	130
TDA357	Databases	TDA357	3	Donald	95
TIN090	Algorithms	TIN090	1	Tweety	62
TIN090	Algorithms	TIN090	1	Tweety	62

$\tau_{avSt}(\pi_{name,avSt}(\sigma_{avSt>100}(\gamma_{code,name,AVG(nrStudents)\rightarrow avSt}(\sigma_{code=course}(\text{Courses x GivenCourses})))))$

Example:

```
SELECT   name, AVG(nrStudents) AS avSt
FROM     Courses, GivenCourses
WHERE    code = course
GROUP BY code, name
HAVING   AVG(nrStudents) > 100
ORDER BY avSt;
```

code	*name*	*course*	*per*	*teacher*	*nrSt*
TDA357	Databases	TDA357	2	Mickey	130
TDA357	Databases	TDA357	3	Donald	95
TIN090	Algorithms	TIN090	1	Tweety	62

AVG(nrSt)
112.5
62

$\tau_{avSt}(\pi_{name,avSt}(\sigma_{avSt>100}(\gamma_{code,name,AVG(nrStudents)\rightarrow avSt}(\sigma_{code=course}(Courses \times GivenCourses)))))$

Example:

```
SELECT   name, AVG(nrStudents) AS avSt
FROM     Courses, GivenCourses
WHERE    code = course
GROUP BY code, name
HAVING AVG(nrStudents) > 100
ORDER BY avSt;
```

code	name	AVG(nrSt)
TDA357	Databases	112.5
TIN090	Algorithms	62

$\tau_{avSt}(\pi_{name,avSt}(\sigma_{avSt>100}(\gamma_{code,name,AVG(nrStudents)\rightarrow avSt}(\sigma_{code=course}(Courses \times GivenCourses)))))$

Example:

```
SELECT name, AVG(nrStudents) AS avSt
FROM     Courses, GivenCourses
WHERE    code = course
GROUP BY code, name
HAVING   AVG(nrStudents) > 100
ORDER BY avSt;
```

code	*name*	*avSt*	*G(nrSt)*
TDA357	Databases	112.5	12.5

$\tau_{avSt}(\Pi_{name,avSt}(\sigma_{avSt>100}(\gamma_{code,name,AVG(nrStudents)\rightarrow avSt}(\sigma_{code=course}(Courses \times GivenCourses)))))$

Example:

```
SELECT   name, AVG(nrStudents) AS avSt
FROM     Courses, GivenCourses
WHERE    code = course
GROUP BY code, name
HAVING   AVG(nrStudents) > 100
ORDER BY avSt;
```

name	*avSt*
Databases	112.5

$$\tau_{avSt}(\pi_{name,avSt}(\sigma_{avSt>100}(\gamma_{code,name,AVG(nrStudents)\rightarrow avSt}(\sigma_{code=course}(Courses \times GivenCourses)))))$$

Break

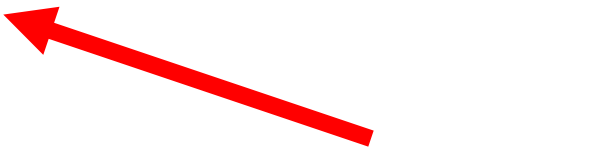
Why not simply this?

```
SELECT    name, AVG(nrStudents) AS avSt
FROM      Courses, GivenCourses
WHERE     code = course, avSt > 100
GROUP BY  code, name
HAVING    AVG(nrStudents) > 100
ORDER BY  avSt;
```

Because at the time of “WHERE”,
aggregates have not been computed yet!

Remember: If “GROUP BY” is used, then aggregates are computed over each “GROUP BY” group, not over all entries

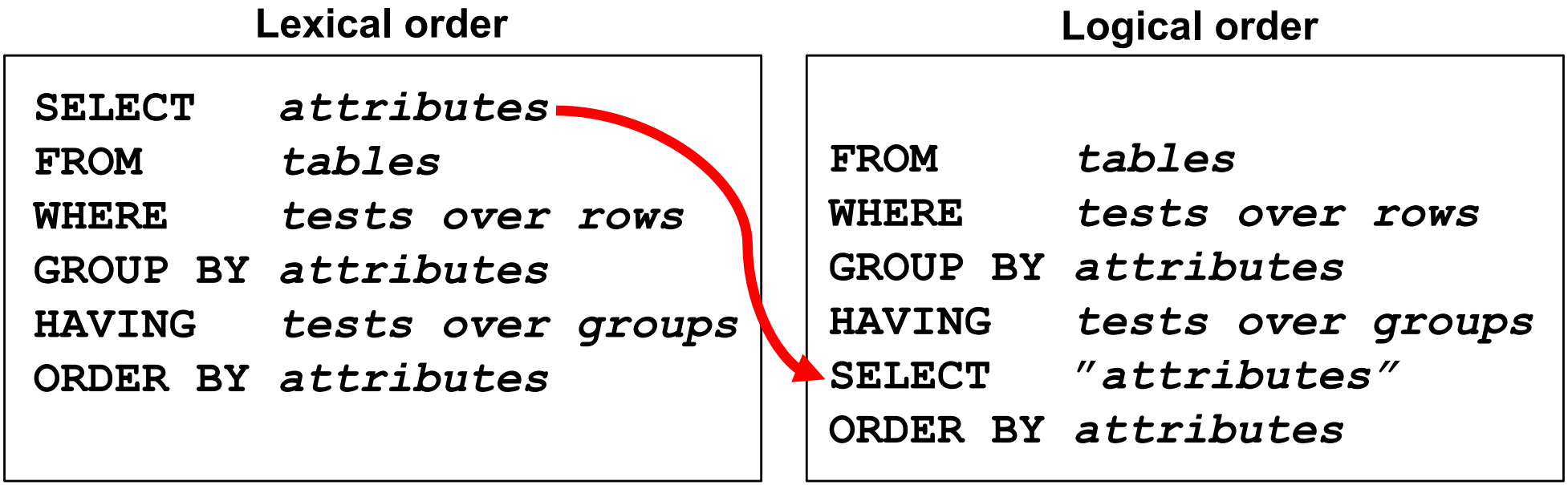
```
SELECT    name, AVG(nrStudents) AS avSt
FROM      Courses, GivenCourses
WHERE     code = course,
GROUP BY  code, name
HAVING    AVG(nrStudents) > 100
ORDER BY  avSt;
```



What about this then!?!?

Lexical vs logical ordering

- Lexical order: the way it's written in SQL
- Logical order: the way the query executes



Available attributes in SELECT

- Aggregate functions “summarize” values per group
  - Without GROUP BY, the group is the entire table
- If aggregate functions are used, then only attributes can be selected that make sense in a grouping

```
SELECT   campus, MAX(capacity)
FROM     Rooms
```

Invalid! Group = table, MAX returns 1 value, but 3 different campuses

```
SELECT   MAX(capacity)
FROM     Rooms
```

Valid! Group = table, MAX returns 1 value

```
SELECT   campus, MAX(capacity)
FROM     Rooms
GROUP BY campus
```

Valid! Grouped per campus, MAX returns 1 value per campus, there is 1 campus name per group

SQL Exercises

Music Website

Tracks(trackId,title, length)
length > 0

Artists(artistId, name)

Albums(albumId,title, yearReleased)

TracksOnAlbum(album,trackNr,track)
album -> Albums.albumId
track -> Tracks.trackId
(album,track) unique
trackNr > 0

Participates(track, artist)
track -> Tracks.trackId
artist -> Artists.artistId

Users(username, email, name)
email unique

Playlists(user, playlistName)
user -> Users.username

InList(user, playlist, number,track)
(user, playlist) -> Playlists.(user, playlistName)
track -> Tracks.trackId

PlayLog(user,time,track)
user -> Users.username
track -> Tracks.trackId
(user,time) unique

Music Website – Ex1

- Write an SQL query that lists all artists appearing on any album released from 2016

```
SELECT *
FROM Artists
WHERE artistId IN (
    SELECT artist
    FROM Participates WHERE track IN (
       SELECT track
       FROM TracksOnAlbum
       WHERE album IN (
              SELECT albumId
              FROM Albums
              WHERE yearReleased >= '1/1/2016')
    )
);
```

Music Website – Ex2

- Write an SQL query that lists, for each user, how many playlists that user has.

```
SELECT username, COUNT(playlistname)
FROM PlayLists
GROUP BY (username);
```

Music Website – Ex3

- Write an SQL query that lists, for each track, its ``trackId`` and title, together with the number of times that track has been played, and the number of distinct users that have played it.

```
SELECT trackId, title, COUNT(username) AS timesplayed,
   COUNT(DISTINCT username) AS differentUsers
FROM PlayLog
NATURAL JOIN Tracks
GROUP BY trackId, title;
```

Next time, Lecture 9

More on SQL and Relational Algebra