Lecture 5

Database Construction and Usage

SQL DDL and DML
Relational Algebra

Announcement

- Attributes on ER relationships are allowed
  – But boolean “flag” attributes are discouraged

- Sign up to the Google Group for updates!
    - https://groups.google.com/forum/#!forum/tda357-ht2016
- Fill in the doodles
  – No-one signed up == no TA attending
  – More rooms are added if needed

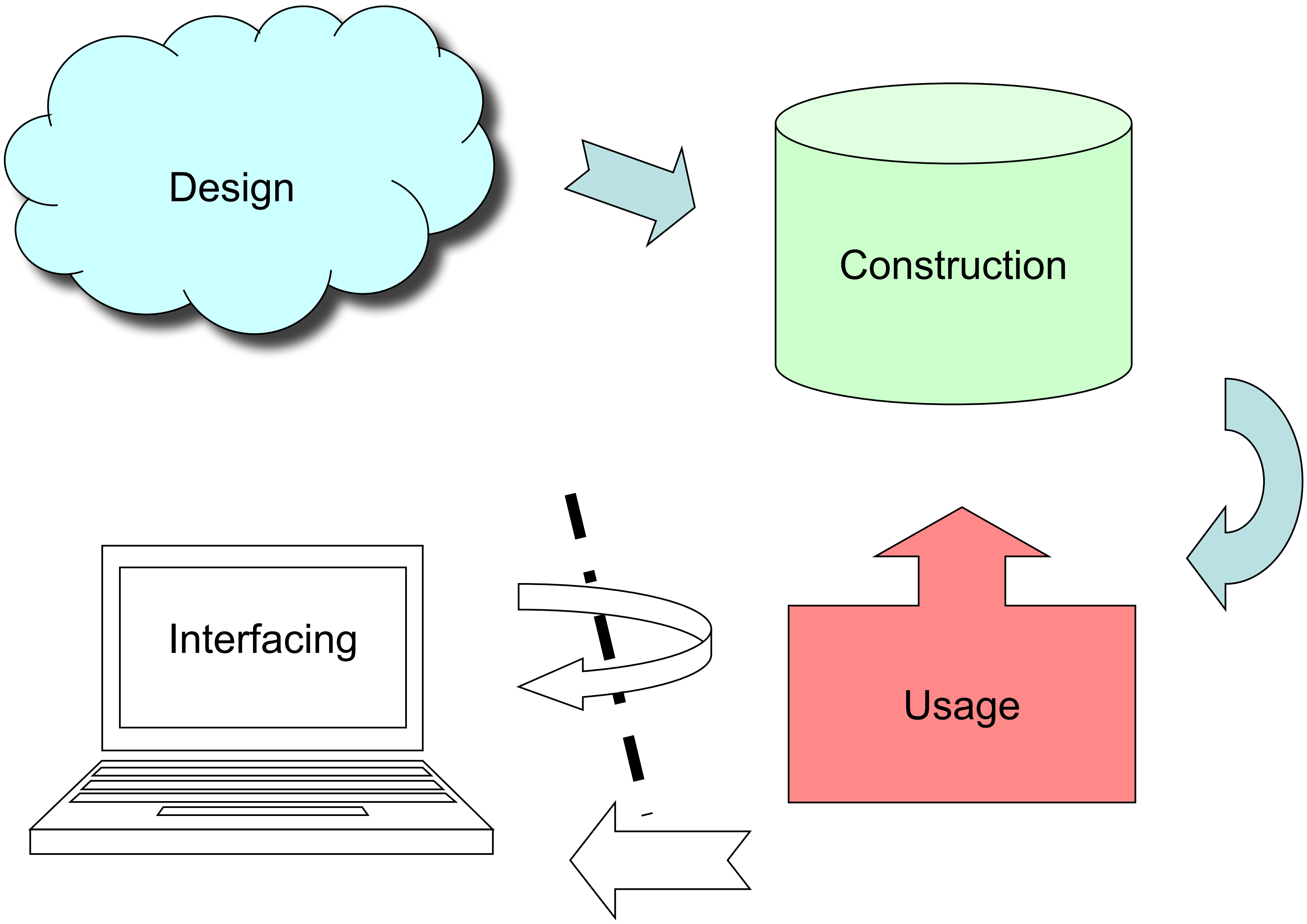
Example

	Room A	Room B
Alice	✓	
Bob	✓	
Charlie	✓	
	3	0

Alice, Bob and Charlie signed up for room A
No-one signed up for room B

In this case, there will be NO teaching assistant in room B!!

Course Objectives



Connecting to PostgreSQL

- Chalmers postgresql server (check Fire for your credentials):

```
psql -h ate.ita.chalmers.se -U <username> <dbname>
```

- Local postgresql server:

```
psql <dbname>
```

- Semicolon and postgres prompt:

```
steven=> select 1+1
steven-> ;
```

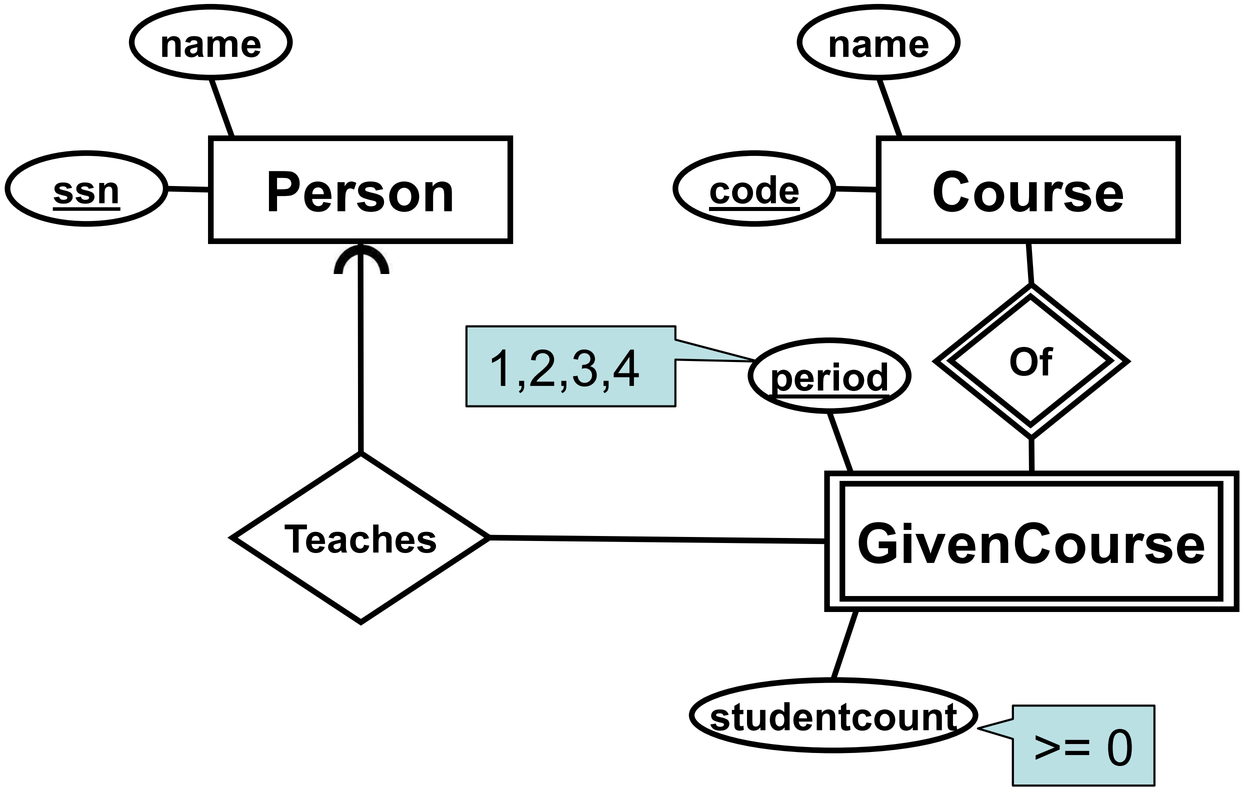
Lines should end with ';', otherwise statements are continued on the next line. Note the prompt change!

Case convention

- SQL is completely case insensitive. Upper-case or Lower-case makes no difference. We will use case in the following way:
  - `UPPERCASE` marks keywords of the SQL language.
  - `lowercase` marks the name of an attribute.
  - `Capitalized` marks the name of a table.

SQL Data Definition Language

Working example




```
Person(ssn, name)
Course(code, name)
GivenCourse(code, period, studentcount, teacher)
       code -> Course.code
       teacher -> Person.ssn
```

Creating and dropping tables

- Relations become tables, attributes become columns.

```
CREATE TABLE Tablename (
  <list of table elements>
);
```

- Get all info about a created table:

```
\d+ Tablename;
```

PostgreSQL specific!

- Remove a created table:

```
DROP TABLE Tablename;
```

Table declaration elements

- The basic elements are pairs consisting of a column name and a type.
- Most common SQL types:
  - INT or INTEGER (synonyms)
  - REAL or FLOAT (synonyms)
  - CHAR(*n*) = fixed-size string of size *n*.
  - VARCHAR(n) = variable-size string of up to size *n*.
  - TEXT = string of unrestricted length

Example

Example:

```
CREATE TABLE Courses (
  code CHAR(6),
  name TEXT NOT NULL
);
```

NULL is allowed by default!

Created the table courses:

code	name

Declaring keys

- An attribute or a list of attributes can be declared PRIMARY KEY or UNIQUE
  - PRIMARY KEY: (At most) One per table, never NULL. Efficient lookups in all DBMS.
  - UNIQUE: Any number per table, can be NULL. Could give efficient lookups (may vary in different DBMS).
- Both declarations state that all other attributes of the table are functionally determined by the given attribute(s).

Example

```
CREATE TABLE Courses(
  code CHAR(6),
  name TEXT NOT NULL,
  PRIMARY KEY (code)
);
```

Foreign keys

- Referential constraints are handled with references, called *foreign keys*.
  - FOREIGN KEY *attribute*
    REFERENCES *table(attribute)*.

```
FOREIGN KEY course
  REFERENCES Courses(code)
```

Foreign keys

- **General:**

```
FOREIGN KEY course REFERENCES Courses(code)
```

- **If course is Primary Key in Courses:**

```
FOREIGN KEY course
    REFERENCES Courses
```

- **Give a name to the foreign key:**

```
CONSTRAINT ExistsCourse
FOREIGN KEY course
REFERENCES Courses
```

Example

```
CREATE TABLE GivenCourses (
    course          CHAR(6),
    period          INT,
    numStudents     INT,
    teacher         INT REFERENCES People(ssn) NOT
    NULL,
    PRIMARY KEY (course, period),
    FOREIGN KEY (course) REFERENCES Courses(code)
);
```

Example

```
CREATE TABLE GivenCourses (
    course CHAR(6) REFERENCES Courses,
    period              INT,
    numStudents         INT,
    teacher             INT REFERENCES People(ssn) NOT
    NULL,
    PRIMARY KEY (course, period)
);
```

Value constraints

- Use CHECK to insert simple value constraints.
  - CHECK (*some test on attributes*)

```
CHECK (period IN (1,2,3,4))
```

Example

```
CREATE TABLE GivenCourses (
    course CHAR(6) REFERENCES Courses,
    period          INT CHECK (period IN (1,2,3,4)),
    numStudents     INT,
    teacher         INT REFERENCES People(ssn) NOT
    NULL,
    PRIMARY KEY (course, period)
);
```

Example

```
CREATE TABLE GivenCourses (
    course CHAR(6) REFERENCES Courses,
    period          INT,
    numStudents     INT,
    teacher         INT REFERENCES People(ssn) NOT
    NULL,
    PRIMARY KEY (course, period),
    CONSTRAINT ValidPeriod CHECK (period in (1,2,3,4))
);
```

SQL Data Manipulation Language: Modifications

Inserting data

```
INSERT INTO tablename
  VALUES (values for attributes);
```

```
INSERT INTO Courses
  VALUES ('TDA357', 'Databases');
```

code	*name*
TDA357	Databases

Example

- **Legal:**
  - `INSERT INTO GivenCourses VALUES ('TDA357',2,199,1);`
- **Not Legal:**
  - `INSERT INTO GivenCourses VALUES ('TDA357',7,199,1);`
- **ERROR: new row for relation "givencourses" violates check constraint "givencourses_period_check"DETAIL: Failing row contains (TDA357, 7, 199, 1).**

Deletions

```
DELETE FROM tablename
  WHERE test over rows;
```

```
DELETE FROM Courses
  WHERE code = 'TDA357';
```

Updates

```
UPDATE  tablename
SET     attribute = ...
WHERE   test over rows
```

```
UPDATE  GivenCourses
SET     teacher = 'Graham Kemp'
WHERE   course = 'TDA357'
  AND   period = 2;
```

Queries:
SQL and Relational Algebra

Querying

- To *query* the database means asking it for information.
  - ”List all courses that have lectures in room VR”
- Unlike a modification, a query leaves the database unchanged.

SQL

- SQL = Structured Query Language
  - The querying parts are really the core of SQL. The DDL and DML parts are secondary.
- Very-high-level language.
  - Specify *what* information you want, not *how* to get that information (like you would in e.g. Java).
- Based on Relational Algebra

”Algebra”

- An *algebra* is a mathematical system consisting of:
  - Operands: variables or values to operate on.
  - Operators: symbols denoting functions that operate on variables and values.

Relational Algebra

- An algebra whose operands are relations (or variables representing relations).
- Operators representing the most common operations on relations.
  - Selecting rows
  - Projecting columns
  - Composing (joining) relations

Selection

- Selection = Given a relation (table), choose what tuples (rows) to include in the result.

$$\sigma_C(T)$$

```
SELECT * FROM T WHERE C;
```

  - Select the rows from relation T that satisfy condition C.
  - σ = sigma = greek letter **s** = **s**election

Example:

GivenCourses =

course	per	teacher
TDA357	3	Niklas Broberg
TDA357	2	Graham Kemp
TIN090	1	Devdatt Dubhashi

```
SELECT *
FROM   GivenCourses
WHERE  course = 'TDA357';
```

Result =

What?

Example:

GivenCourses =

course	per	teacher
TDA357	3	Niklas Broberg
TDA357	2	Graham Kemp
TIN090	1	Devdatt Dubhashi

```
SELECT *
FROM   GivenCourses
WHERE  course = 'TDA357';
```

Result =

course	per	teacher
TDA357	3	Niklas Broberg
TDA357	2	Graham Kemp

Projection

- Given a relation (table), choose what attributes (columns) to include in the result.

$\pi_X(\sigma_C(T))$ **`SELECT X FROM T WHERE C;`**

  - Select the rows from table T that satisfy condition C, and project columns X of the result.
  - π = pi = greek letter **p** = **p**rojection

Example:

GivenCourses =

course	*per*	*teacher*
TDA357	3	Niklas Broberg
TDA357	2	Graham Kemp
TIN090	1	Devdatt Dubhashi

```
SELECT course, teacher
FROM   GivenCourses
WHERE  course = 'TDA357';
```

Result =

What?

Example:

GivenCourses =

course	per	teacher
TDA357	3	Niklas Broberg
TDA357	2	Graham Kemp
TIN090	1	Devdatt Dubhashi

```
SELECT course, teacher
FROM   GivenCourses
WHERE  course = 'TDA357';
```

Result =

course	teacher
TDA357	Niklas Broberg
TDA357	Graham Kemp

The confusing SELECT

Example:

GivenCourses =

course	*per*	*teacher*
TDA357	3	Niklas Broberg
TDA357	2	Graham Kemp
TIN090	1	Devdatt Dubhashi

```
SELECT course, teacher
FROM   GivenCourses;
```

Result =

What?

The confusing **`SELECT`**

Example:

GivenCourses =

course	*per*	*teacher*
TDA357	3	Niklas Broberg
TDA357	2	Graham Kemp
TIN090	1	Devdatt Dubhashi

```
SELECT course, teacher
FROM   GivenCourses;
```

Result =

course	*teacher*
TDA357	Niklas Broberg
TDA357	Graham Kemp
TIN090	Devdatt Dubhashi

Quiz: **`SELECT`** is a projection??

Mystery revealed!

```
SELECT course, teacher
  FROM GivenCourses;
```

$$\pi_{code,teacher}(\sigma(\text{GivenCourses})) \\ = \pi_{code,teacher}(\text{GivenCourses})$$

- In general, the SELECT clause could be seen as corresponding to projection, and the WHERE clause to selection (don't confuse the naming though).

Quiz!

- What does the following expression compute?

Courses

code	*name*
TDA357	Databases
TIN090	Algorithms

GivenCourses

course	*per*	*teacher*
TDA357	3	Niklas Broberg
TDA357	2	Graham Kemp
TIN090	1	Devdatt Dubhashi

```
SELECT *
FROM   Courses, GivenCourses
WHERE  teacher = 'Niklas Broberg';
```

FROM Courses, GivenCourses

code	*name*	*course*	*per*	*teacher*
TDA357	Databases	TDA357	3	Niklas Broberg
TDA357	Databases	TDA357	2	Graham Kemp
TDA357	Databases	TIN090	1	Devdatt Dubhashi
TIN090	Algorithms	TDA357	3	Niklas Broberg
TIN090	Algorithms	TDA357	2	Graham Kemp
TIN090	Algorithms	TIN090	1	Devdatt Dubhashi

WHERE teacher = 'Niklas Broberg'

code	*name*	*course*	*per*	*teacher*
TDA357	**Databases**	**TDA357**	**3**	**Niklas Broberg**
TDA357	Databases	TDA357	2	Graham Kemp
TDA357	Databases	TIN090	1	Devdatt Dubhashi
TIN090	**Algorithms**	**TDA357**	**3**	**Niklas Broberg**
TIN090	Algorithms	TDA357	2	Graham Kemp
TIN090	Algorithms	TIN090	1	Devdatt Dubhashi

Answer:

```
SELECT *
FROM   Courses, GivenCourses
WHERE  teacher = 'Niklas Broberg';
```

code	*name*	*course*	*per*	*teacher*
TDA357	Databases	TDA357	3	Niklas Broberg
TIN090	Algorithms	TDA357	3	Niklas Broberg

The result is all rows from **`Courses`** combined in all possible ways with all rows from **`GivenCourses`**, and then keep only those where the **`teacher`** attribute is Niklas Broberg.

Cartesian Products

- The *cartesian product* of relations R_1 and R_2 is all possible combinations of rows from R_1 and R_2.
  - Written $R_1 \times R_2$
  - Also called *cross-product*, or just *product*

```
SELECT *
FROM   Courses, GivenCourses
WHERE  teacher = 'Niklas Broberg';
```

$$\sigma_{\text{teacher = 'Niklas Broberg'}}(\text{Courses} \times \text{GivenCourses})$$

Quiz!

List all courses, with names, that Niklas Broberg is responsible for.

```
Courses(code,name)
GivenCourses(course,per,teacher)
   course -> Courses.code
```

```
SELECT *
FROM   Courses, GivenCourses
WHERE  teacher = 'Niklas Broberg'
  AND  code = course;
```

code	*name*	*course*	*per*	*teacher*
TDA357	Databases	TDA357	3	Niklas Broberg

`code = course`

code	*name*	*course*	*per*	*teacher*
TDA357	**Databases**	**TDA357**	**3**	**Niklas Broberg**
TDA357	Databases	TDA357	2	Graham Kemp
TDA357	Databases	TIN090	1	Devdatt Dubhashi
TIN090	**Algorithms**	**TDA357**	**3**	**Niklas Broberg**
TIN090	Algorithms	TDA357	2	Graham Kemp
TIN090	Algorithms	TIN090	1	Devdatt Dubhashi

Not equal

Joining relations

- Very often we want to join two relations on the value of some attributes.
  - Typically we join according to some reference, as in:

```
SELECT *
FROM   Courses, GivenCourses
WHERE  code = course;
```

- Special operator $\bowtie_C$ for joining relations.

$$R_1 \bowtie_C R_2 = \sigma_C(R_1 \times R_2)$$

```
SELECT *
FROM   R1 JOIN R2 ON C;
```

Example

Courses

code	*name*
TDA357	Databases
TIN090	Algorithms

GivenCourses

course	*per*	*teacher*
TDA357	3	Niklas Broberg
TDA357	2	Graham Kemp
TIN090	1	Devdatt Dubhashi

```
SELECT *
FROM   Courses JOIN GivenCourses
  ON   code = course;
```

code	*name*	*course*	*per*	*teacher*
TDA357	Databases	TDA357	3	Niklas Broberg
TDA357	Databases	TDA357	2	Graham Kemp
TIN090	Algorithms	TIN090	1	Devdatt Dubhashi

Natural join

- ”Magic” version of join.
  - Join two relations on the condition that all attributes in the two that share the same name should be equal.
  - Remove all duplicate columns
  - Written $R_1 \bowtie R_2$ (like join with no condition)

Example

Courses

code	*name*
TDA357	Databases
TIN090	Algorithms

GivenCourses

code	*per*	*teacher*
TDA357	3	Niklas Broberg
TDA357	2	Graham Kemp
TIN090	1	Devdatt Dubhashi

```
SELECT *
FROM   Courses NATURAL JOIN GivenCourses;
```

code	*name*	*per*	*teacher*
TDA357	Databases	3	Niklas Broberg
TDA357	Databases	2	Graham Kemp
TIN090	Algorithms	1	Devdatt Dubhashi

Sets or Bags?

- Relational algebra formally applies to sets of tuples.
- SQL, the most important query language for relational databases is actually a bag language.
  - SQL will eliminate duplicates, but usually only if you ask it to do so explicitly.
- Some operations, like projection, are much more efficient on bags than sets.

Sets or Bags?

R(A,B)

A	B
1	2
5	6
1	3

SQL

```
SELECT A
FROM R
```

A
1
5
1

Bag

Relational Algebra

$\pi_A(R)$

A
1
5

Set
(no repeating values)

Next time, Lecture 6

More Relational Algebra, SQL, Views