

---

Introduction to Databases, Fall 2005  
IT University of Copenhagen

**Lecture 2: Relations and SQL**

September 5, 2005

Lecturer: Rasmus Pagh

---

# — Today's lecture —

---

- What, exactly, is the relational data model?
- What are the basic ways of writing expressions in SQL?
- How do you query data stored in multiple relations?
- How do you create relations, and modify their data?

# — What you should remember from last week —

In this lecture I will assume that you remember:

- The intuitive concept of a relation as a two-dimensional table.
- How a subset of a relation  $R$  can be obtained using “SELECT ... FROM  $R$  WHERE ...”.

## — What is the relational data model? —

A **data model** is a *precise, conceptual* way of describing the data stored in a database.

The **relational data model** is a data model where all data takes the form of so-called relations.

**Note:** The term **data model** is also used when speaking about a concrete, conceptual description of a database.

## — What is a tuple? —

---

A relation consists of so-called tuples.

A **tuple** is an ordered list of values.

Tuples are usually written in parentheses, with commas separating the values (or **components**), e.g.

(Star Wars, 1977, 124, color)

which contains the four values Star Wars, 1977, 124, and color.

### **Note:**

Order is significant, e.g., the tuple (Star Wars, 124, 1977, color) is different from the tuple above.

## — What is a relation? —

---

Mathematically, a relation is a **set of tuples**.

A relation is always defined on certain sets (or **domains**):

“the sets from which the values in the tuples come”.

**Example:** The tuple (Star Wars, 1977, 124, color) could be part of a relation defined on the sets:

- All text strings,
- the integers,
- the integers, and
- {'color', 'black and white'}.

# Attributes

---

In order to be able to refer to the different components in a tuple, we will assign them names (called **attributes**).

## Example:

For the tuple (Star Wars, 1977, 124, color) we might choose the attributes *title*, *year*, *length*, and *filmType*.

The attribute *length* would then refer to the third value of the tuple, 124.

## — How do we write relations? —

Relations are usually written as two-dimensional tables, with the attributes as a first, special row, and the tuples in the remaining rows.

### Example:

<i>title</i>	<i>year</i>	<i>length</i>	<i>filmType</i>
Star Wars	1977	124	color
Mighty Ducks	1991	104	color
Wayne's World	1992	95	color

## — Equivalent ways of writing relations —

The order of the rows does not matter (just the **set** of rows).

We may freely reorder the columns, including the attributes.

**Example:** Two ways of writing the same relation:

<i>title</i>	<i>year</i>	<i>length</i>	<i>filmType</i>
Star Wars	1977	124	color
Mighty Ducks	1991	104	color
Wayne's World	1992	95	color

<i>title</i>	<i>filmType</i>	<i>length</i>	<i>year</i>
Wayne's World	color	95	1992
Star Wars	color	12	1977
Mighty Ducks	color	104	1991

# Data types in SQL

---

In SQL, any attribute must have a data type. The data types available depend on the particular DBMS. However, you can come a long way using the following widely available data types:

- VARCHAR(x) for text strings of at most x characters.
- INT for integers.
- FLOAT for real numbers.
- DATE for Gregorian dates.

Some newer DBMSs allow XML as a data type. XML may be a good choice for less structured or ad-hoc data in a relation.

# Schemas

---

In the relational data model, a relation is described using a **schema** which consists of:

- The name of the relation, and
- a tuple with its attributes (+ sometimes also the attribute data types).

**Example:** The relation we saw before could have the schema:

```
Movies(title, year, length, filmType)
```

A schema that lists the data types could look like this:

```
Movies(title VARCHAR(20), year INT, length INT, filmType VARCHAR(13))
```

This is the kind of schema used when creating new relations in SQL.

# — Relations, schemas and relation instances —

We use the word “relation” in two different meanings:

- The data model, i.e., what is described by a schema.
- The concrete set of data tuples.

When we want to be specific about the difference, we may refer to the former as the schema, and the latter as the **relation instance**.

## — Problem session (5 minutes) —

---

Explain to each other the following terms (in the context of this lecture):

- data model
- relational data model
- tuple
- component in a tuple
- data type of a component
- attribute
- relation
- schema
- relation instance

Identify any unclarities about the terms to be discussed in class.

---

**Next: Basic expressions in SQL**

---



# Selection

---

The choice of certain tuples in the WHERE part of SELECT-FROM-WHERE is referred to as **selection**.

SQL offers a variety of ways of forming conditional expressions

- Comparison operators (used between e.g. a pair of integers or strings):  
=, <, <=, >, >=, <>.
- Boolean operators (used to combine conditional expressions):  
AND, OR, NOT.
- The LIKE operator used to find strings that match a given pattern.
- Parentheses can be used to indicate the order of evaluation. If no parentheses are present, a standard order is used.

## — Truth values

---

Often we want to represent truth values (or **boolean values**) in relations.

**Example:** The `inColor` attribute of the `Movie` relation should contain the value “true” if a movie is in color, and “false” otherwise.

Many RDBMSs use integers to represent truth values (i.e., there is no special data type for that). Typically:

- 0 is used to represent the value “false”, and
- 1 is used to represent the value “true”.

## — Problem session (5 minutes) —

How many tuples will be returned by each of the following selection queries:

1. `SELECT * FROM R WHERE a=1 OR b=1 OR (d='August');`
2. `SELECT * FROM R WHERE (a=1 AND NOT b=1) OR (NOT a=1 AND b=1);`
3. `SELECT * FROM R WHERE c>22 AND d<'November';`
4. `SELECT * FROM R WHERE d LIKE '%ber';`

	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>
<i>R</i>	0	0	11	August
	0	1	22	September
	1	0	33	October
	1	1	44	November
	0	0	55	December

---

**Next: Querying data stored in multiple relations**

---

## — Join in SQL —

---

Combination of several relations is known as a **join**.

We first consider the case of *two* relations (call them R1 and R2).

SQL's SELECT-FROM-WHERE can be used to perform what is known as a **theta-join**: *Combine of all pairs of tuples that satisfy some condition.*

```
SELECT *  
FROM R1, R2  
WHERE <condition>
```

Often the condition will be the AND of one or more equalities that make sure that we join the pairs of tuples that “belong together”.

## — How tuples are combined in the join —

When a tuple  $(x_1, x_2, \dots)$  from R1 and a tuple  $(y_1, y_2, \dots)$  from R2 are combined by the join query, it results in the **concatenation** of the two tuples:

$$(x_1, x_2, \dots, y_1, y_2, \dots)$$

That is, one tuple is put after the other.

Unless the attributes are renamed, we keep the attributes of R1 and R2 in the resulting relation.

## — Problem session (5 minutes) —

How many tuples will be returned by each of the following join queries:

1. SELECT \*  
FROM R1, R2  
WHERE a=d AND b=e;

2. SELECT \*  
FROM R1, R2  
WHERE a=d;

	<i>a</i>	<i>b</i>	<i>c</i>
<i>R1</i>	7	9	13
	21	37	69
	21	9	0
	7	9	14

	<i>d</i>	<i>e</i>	<i>f</i>
<i>R2</i>	7	9	12
	21	31	41
	21	37	0
	21	37	5
	7	9	15

## — When attributes have the same name —

Suppose we had attributes a and b in both R1 and R2.

	<i>a</i>	<i>b</i>	<i>c</i>		<i>a</i>	<i>b</i>	<i>d</i>
<i>R1</i>	7	9	13	<i>R2</i>	7	9	12
	21	37	69		21	31	41
	21	9	0		21	37	0
	7	9	14		21	37	5
					7	9	15

We would then have to put the relation name in front of these attribute names in order to distinguish them. For example:

```
SELECT *  
FROM R1, R2  
WHERE R1.a=R2.a AND R1.b=R2.b;
```

If we want to join tuples with the same values in attributes of the same name, we can choose to instead use SQL's NATURAL JOIN.

## — Joining more than two relations —

SQL may be used to join any number of relations:

```
SELECT *  
FROM R1, R2, ..., Rk  
WHERE <condition>
```

How this is evaluated (the **semantics** of the query):

For every list of tuples  $t_1, t_2, \dots, t_k$  from  $R_1, R_2, \dots, R_k$ , respectively, include the concatenation of  $t_1, t_2, \dots, t_k$  in the result if  $\langle \text{condition} \rangle$  is true.

## — Joining several relations – explanation 2 —

The semantics of

```
SELECT *  
FROM R1, R2, ..., Rk  
WHERE <condition>
```

is specified by the following pseudocode:

```
for n1=1 to size(R1) do  
  for n2=1 to size(R2) do  
    ...  
    for nk=1 to size(Rk) do  
      if <condition on R1[n1], R2[n2], ..., Rk[nk]>  
        output R1[n1]+R2[n2]+...+Rk[nk]
```

## — Joining a relation with itself! —

Sometimes you need to join a relation with itself:

“Find all pairs of tuples in R such that. . .”

This can be done using so-called **tuple variables** which can be thought of as representing *different copies* of the relation.

Joining R with itself using tuple variables r1 and r2 in the condition:

```
SELECT *  
FROM R r1, R r2  
WHERE <condition using r1 and r2>
```

### **Semantics:**

Same as when joining relations r1 and r2 that are both identical to R.

## — Problem session (5 minutes) —

How many tuples will be returned by the join query:

```
SELECT *  
FROM R r1, R r2, R r3  
WHERE r1.a=r2.a AND r2.a=r3.a;
```

	<i>a</i>	<i>b</i>	<i>d</i>
<i>R</i>	7	9	12
	21	31	41
	21	37	0
	21	37	5
	7	9	15

---

**Next: Creating a relation; Modifying its data**

---

## — Inserting tuples —

---

Inserting a tuple with value  $x_1$  for attribute  $a_1$ , value  $x_2$  for attribute  $a_2$ , etc:

```
INSERT INTO StarsIn(a1,a2,a3,...)
VALUES (x1,x2,x3,...);
```

If the **standard order** of the attributes is  $a_1, a_2, a_3, \dots$  this can also be written:

```
INSERT INTO StarsIn
VALUES (x1,x2,x3,...);
```

## — Deleting tuples —

---

Deletion is similar to selection, except that the tuples selected are permanently removed from the relation (and not returned as a result):

```
DELETE FROM R  
WHERE <condition>;
```

## — Modifying tuples —

---

Modification is similar to selection, except that the tuples selected are modified according to the SET clause (and not returned as a result).

Changing attribute a of all tuples in R that satisfy <condition>:

```
UPDATE R
SET a = <expression>
WHERE <condition>;
```

## — Creating a new relation —

---

In SQL creating a relation called `NewRel` with attributes `a1`, `a2`, `a3`, ... can be done as follows:

```
CREATE TABLE NewRel
(a1 <data type of a1>, a2 <data type of a2>, ...);
```

The data types must be chosen from SQL's data types, e.g., `INT`, `FLOAT`, and `VARCHAR`.

A relation `UselessRel` can be permanently deleted using

```
DROP TABLE UselessRel;
```

---

**Next: Some final points**

---

## — Results are relations —

---

As you have seen, the result of a query on one or more relations is itself a relation.

Later in the course, we will see that this is quite handy, using the so-called **subquery** capability of SQL.

## — Relations in DBMSs —

---

There are differences between the mathematical formulation of a relation (as a set of tuples) and the representation in an RDBMS (which can be thought of as similar to the way we write relations as a table).

- Different terminology: Rows/records vs tuples, tables vs relations, attributes vs fields, ...
- An RDBMS stores each tuple in a specific “standard” order, and stores the tuples as a list, rather than a set.
- An RDBMS may store the same tuple several times (i.e., we have a **bag** of tuples rather than a set).

It is important to understand both worlds (and their differences) – more on this in the rest of the course.

## — Outstanding point: NULL and UNKNOWN —

NULL is a special value that may be used for any data type when no other value is applicable.

### **Evaluating expressions involving NULL:**

- Arithmetic expressions involving NULL evaluate to NULL.
- Boolean expressions evaluate to NULL only when the correct value cannot be deduced.

**Important point:** Evaluation is done in a local, “step by step” way.

Some RDBMSs support a null value for booleans called UNKNOWN.

## — Most important points in this lecture —

As a minimum, you should after this week:

- Understand what a relation is (mathematically and in an RDBMS).
- Know the basic ways of forming SQL expressions: Projection and renaming, selection using e.g. AND, OR, LIKE, <, <=, ...
- Understand how to query (in SQL) information stored in multiple relations, including:
  - Dealing with identical attribute names.
  - Using tuple variables.
- Know how to modify, insert, and delete tuples in SQL.
- Know how to create a new relation in SQL.

## Next time

---

Next week we will begin our study of database design:

- Conceptual modeling of a database using “E/R modeling”.
- Conversion of an E/R model to a relational data model.