Data Base Systems

VU 184.686, WS 2020

SQL Details

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Acknowledgements

The slides are based on the slides (in German) of Sebastian Skritek.

The Section on Views is based on Chapter 4 of
(Kemper, Eickler: Datenbanksysteme – Eine Einführung)

The remaining topics are based on the respective chapters in the PostgreSQL Online-Documentation:
`https://www.postgresql.org/docs/current/static/`

SQL Details

1. Overview
2. Decomposing Complex Queries and Recursive Queries
3. Views
4. Window Functions
5. Sequences
6. (Other) Data Types and Built-In Functions
7. Learning Objectives

Topics

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Decomposing Complex Queries

problem:

- nested SQL queries sometimes become confusing and unclear
- in many cases very similar sub queries

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Example (nested queries)

find all those students, that have the best average grades

```
SELECT matrNr, avg(grade)
FROM examine
GROUP BY matrNr
HAVING avgGrade >= all (SELECT avg(grade)
                        FROM examine
                        GROUP BY matrNr)
```

Decomposing Complex Queries

Example (SQL WITH statement (slight "overkill"))

find all those students, that have the best average grades

```
WITH avgGrade AS (
  SELECT matrNr, avg(grade) AS dsN
  FROM examine
  GROUP BY matrNr ),
 bestavgGrade AS (
  SELECT matrNr, dsN
  FROM avgGrade
  WHERE dsn = (SELECT max(dsN)
               FROM avgGrade))
SELECT matrNr, dsN
FROM bestavgGrade
```

SQL: `SELECT` in `WITH`

`WITH` queries (also Common Table Expressions (CTE)):

- allow for the definition of temporary "tables"
- only visible and usable in the current query
- useful for structuring the query

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distinction: WITH and WITH RECURSIVE

WITH "syntactic sugar" — no additional expressive power

WITH RECURSIVE allows for "recursive" queries — was not possible before

Recursive Queries

problem: SQL queries we have had so far do not allow for querying transitive properties:

Example

- ancestors or descendants from the parent-child relationship
- all preconditions (and their preconditions, and . . .) of a lecture
- all answers or contributions to a discussion
- reachability in graphs
- . . .

Recursive Queries: General Structure

- query that is able to work on its own output

```
WITH RECURSIVE tabName(attrList) AS (
    non recursive part
  UNION [ ALL ]
    redursive part
    )
SELECT ...
```

- only the recursive part may link to its own output
- both parts contain sub queries (SELECT)
- output has to correspond to *attrList*
- *attrList* contains only names

Recursive Queries: Semantics (Idea)

1. non recursive part constructs a result set T_0
2. recursive part constructs a result set T_{i+1} from input T_i
3. step 2 is repeated until $T_{i+1} = \emptyset$
4. entire result set corresponds to `UNION` resp. `UNION ALL` of $T_0, \ldots, T_n$

remark:

- when using `UNION` (instead of `UNION ALL`): $T_i \cap \bigcup_{j=0}^{i-1} T_j = \emptyset$
- attention: in case the recursive part is generating always (new) tuples: endless loop

Recursive Queries: Semantics

- three tuple sets: result, *working table*, *intermediate table*

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execution:

1. evaluate the non recursive part
   - in case of `UNION`: eliminate duplicates
   - copy remaining tuples both into the result set and in the *working table*

Recursive Queries: Semantics

- three tuple sets: result, *working table*, *intermediate table*

execution:

2. as long as the *working table* is not empty repeat:
   1. evaluate the recursive part:
      - *working table* is used as input for the self reference
      - store the result in the *intermediate table*
   2. in case of `UNION`: remove all duplicates from *intermediate table* and tuples that are already contained in the result set
   3. insert content of *intermediate table* into the result set
   4. replace content of the *working table* with the one of the *intermediate table*, then empty *intermediate table*

Recursive Queries (Example)

Example (all numbers from 1 to 100)

```
WITH RECURSIVE t(n) AS (
    SELECT 1
  UNION ALL
    SELECT n+1 FROM t WHERE n < 100
)
SELECT n FROM t;
```

Recursive Queries (Example)

Example (all preconditions of lecture 5216)

```
WITH RECURSIVE pred(v) AS (
    SELECT predNr
    FROM presuppose
    WHERE succNr = 5216
  UNION
    SELECT presuppose.predNr
    FROM pred, presuppose
    WHERE pred.v=presuppose.succNr
)
SELECT v FROM pred;
```

Recursive Queries (Example)

remark: self reference is not permitted in nested queries

Example (all preconditions of lecture 5216)

```
WITH RECURSIVE pred(v) AS (
    SELECT predNr FROM presuppose
    WHERE succNr = 5216
  UNION
    SELECT predNr
    FROM presuppose
    WHERE succNr in (SELECT v FROM pred)
) SELECT v FROM pred;
```

results in: `ERROR: recursive reference to query "pred"must not appear within a subquery LINE 8: WHERE succNr in (SELECT v FROM pred)`

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3.2 Realization of the Generalization
3.3 Updates on Views

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Views ...

- ... are stored queries, that are available as virtual tables
- ... originally used only for the reading access, but with certain constraints also for updates
- ... are constructed dynamically at each access.
- ... are not part of the physical schema

Views ...

use:

- concept for the adaptation to several users
- simplification of queries
- realization of the generalization

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- realization of the generalization

DBMS proprietary:
- materialized views (ORACLE):
  pre-compiled non virtual query
- indexed views (SQL Server):
  additionally stored index

used to speed-up frequently executed queries

Adjustment to Several Usergroups

Example

due to data security in general only the exam list but not the grade are readable:

```
create view examineView as
select matrNr, lecNr, persNr
from examine;
```

Simplification of Queries

Example

avoiding constant use of join

$$student \bowtie attend \bowtie lecture \bowtie professor$$

```
create view
  StudProf(Sname, semester, title, Pname) as
select s.name, s.semester, v.title, p.name
from student s, attend h,
     lecture v, professor p
where s.matrNr=h.matrNr and
      h.lecNr=v.lecNr and
      v.heldBy = p.persNr;
```

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create view
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select s.name, s.semester, v.title, p.name
from student s, attend h,
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where s.matrNr=h.matrNr and
      h.lecNr=v.lecNr and
      v.heldBy = p.persNr;
```

find name and semester of all students of Sokrates

```
select distinct name, semester from StudProf
where Pname='Sokrates';
```

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Realization of Generalization

realization of inclusion and inheritance via views:

- tuple of sub type should belong automatically to the super type
- attributes of the super type: should be inherited automatically

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- tuple of sub type should belong automatically to the super type
- attributes of the super type: should be inherited automatically

$$\Rightarrow$$

define either sub type or super type as view
decision based on access frequency

Realization of Generalization

Example (sub types as view)

relations for storing the information
(super type + additional information for sub types):

```
create table employee(
                persNr integer not null,
                name varchar(30) not null);
create table profData (
                persNr integer not null,
                rank character(2),
                room integer);
create table assiData (
                persNr integer not null,
                field varchar(30),
                boss integer);
```

Realization of Generalization

Example (sub types as view)

views with entire information about the sub types:

```
create view professor as select *
from employee natural join profData;

create view assistant as select *
from employee natural join  assiData;
```

Realization of Generalization

Example (sub types as view)

views with entire information about the sub types:

```
create view professor as select *
from employee natural join profData;

create view assistant as select *
from employee natural join  assiData;
```

only the relation `employee` as well as views `professor` and `assistant` visible

Realization of Generalization

Example (super types as view)

```
create table professor(
                persNr integer not null,
                name varchar(30) not null,
                rank character (2),
                room integer);
create table assistant(
                persNr integer not null,
                name varchar(30) not null,
                field varchar(30),
                boss integer);
create table otherEmpl(
                persNr integer not null,
                name varchar(30) not null);
```

Realization of Generalization

Example (super types as view)

```
create view employee as
(select persNr, name from professor) union
(select persNr, name from assistant) union
(select * from otherEmpl);
```

idea: only relations `professor` and `assistant` and the view `employee` visible

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Updates on Views

problematic: `insert`, `update`, `delete` on a view

Example (views incapable of update)

```
create view
  howDifficultAsExaminer(persNr, average) as
select persNr, avg(grade)
from examine
group by persNr;
```

Updates on Views

problematic: `insert`, `update`, `delete` on a view

Example (views incapable of update)

```
create view
  howDifficultAsExaminer(persNr, average) as
select persNr, avg(grade)
from examine
group by persNr;
```

```
create view lecturesView as
select title, SWS, name
from lectures, professor
where heldBy = persNr;
```

Updates on Views

restriction of views capable of update in SQL to (SQL-92):

- only one basic relation
- key has to exist
- no aggregate functions, grouping and duplicate elimination

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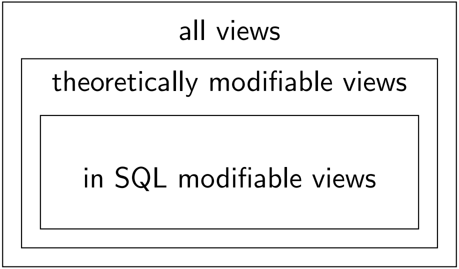
extension with SQL-99 (idea: consider key):

- a field of a view can be updated when
  - it can be assigned uniquely to a basic relation and
  - the corresponding key is part of the view
- distinction between views capable of update and views that allows for inserting new tuples

Updates on Views



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From an Exercise...

Example

```
SELECT floorNr, type
FROM   hive
WHERE (SELECT COUNT(*) OVER ()
      FROM workerBee NATURAL JOIN pollinate
      WHERE worksinType = type AND ...
      GROUP BY fieldID, town LIMIT 1)
        < 10 AND
      ...;
```

Window Functions: OVER ()

- allows for the calculation of (for instance aggregate-) functions over defined window
- grouping of rows not necessary

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```
function_name ( args )
  [ FILTER ( WHERE filter_clause ) ]
  OVER ( window_definition )
```

- in SELECT or ORDER BY

here only basics, there are also other functionalities

Aggregate Functions without Grouping

Example

find for all students the number of attended lectures

```
SELECT DISTINCT matrnr,
  count(*) OVER (PARTITION BY matrnr)
  as number
FROM attend
ORDER BY number DESC;
```

Avoiding Nested SELECT

Example

find for all students all attended lectures and the number of attended lectures

```
SELECT matrnr, lecNr,
  count(*) OVER (PARTITION BY matrnr)
  as number
FROM attend
ORDER BY number DESC;
```

Evaluation Order of Window Functions

- evaluation logically after `WHERE, GROUP BY, HAVING`
- corresponding removed rows are not considered

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Example

find for all students the number of attended lectures with lecNr bigger than 5001

```
SELECT DISTINCT matrnr,
  count(*) OVER (PARTITION BY matrnr)
  as number
FROM attend
WHERE lecNr > 5001
ORDER BY number DESC;
```

Special Window Functions

- in addition to “normal” functions as window functions there are also extra functions
- have to be used via `OVER`
- allow for the computation of values within a partition
- for instance `row_number()`, `rank()`, ...

Example: rank()

- assigns a “ranking” to each entry

Example

find for each semester those students that attend the most lectures

```
SELECT * FROM (
SELECT matrnr, count(*) as numberVO, sem,
  rank() OVER
   (PARTITION BY sem ORDER BY count(*) DESC)
   as pos
FROM attend NATURAL JOIN student
GROUP BY matrnr, sem
ORDER BY numberVo DESC) as subq WHERE pos=1;
```

Window Frame

- in addition to the entire partition there is a window frame for each row
- subset of partition, depending on sorting:
  - without `ORDER BY`: entire partition
  - with `ORDER BY`: all rows from the beginning until current row, additionally all rows with same `ORDER BY` value

Example

```
SELECT matrnr, lecNr, sws,
  sum(sws) OVER (PARTITION BY matrnr
    ORDER BY lecNr)
FROM attend NATURAL JOIN lectures
ORDER BY matrnr;
```

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Idea

problem:

- in some cases unique (integer) values are needed, whose specific value is not relevant
- example: invoice numbers, visitor numbers, numbering of entries, . . .

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solution (in SQL): `SEQUENCE`

- constructs numerical sequence based on given properties (domain, step size, ascending/descending)
- no value is assigned twice
- in some circumstances numbers cannot be assigned, or cannot be assigned in chronological order
- modifications are kept also with `ROLLBACK`

Constructing and Using Sequences

```
CREATE SEQUENCE name
[INCREMENT [ BY ] increment]
[MINVALUE minvalue | NO MINVALUE]
[MAXVALUE maxvalue | NO MAXVALUE]
[START [WITH] start] [CACHE cache]
[[NO] CYCLE]
```

Constructing and Using Sequences

```
CREATE SEQUENCE name
[INCREMENT [ BY ] increment]
[MINVALUE minvalue | NO MINVALUE]
[MAXVALUE maxvalue | NO MAXVALUE]
[START [WITH] start] [CACHE cache]
[[NO] CYCLE]
```

Zugriff:

`nextval`(*sname*) increases the sequence and returns current value

`currval`(*sname*) returns the last value which was read with `nextval` in the session

`setval`(*sname*, *val*) sets the counter to the given value

SEQUENCE (Example)

Example

```
CREATE SEQUENCE persnr_seq
 START WITH 2200 INCREMENT BY 5
 MINVALUE 2200 MAXVALUE 15000
 NO CYCLE;

INSERT INTO professor VALUES(
 nextval('persnr_seq'), 'Nietzsche','C3',205);
INSERT INTO professor VALUES(
 nextval('persnr_seq'), 'Sun Tzu','C3',206);
SELECT curval('persnr_seq');
```

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(Postgre)SQL Data Types

- numeric data types: `integer`, `int`, `numeric(p,s)`, ...
- strings: `char(n)`, `varchar(n)`, text, ...
- date and time data types: `date`, `timestamp`, ...
- enumerating types: `ENUM`
- geometric data types: `point`, `line`, `circle`, ...
- XML and JSON data types
- arrays
- ...

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- arrays
- ...

Example (`ENUM` data type)

```
CREATE TYPE rank AS ENUM ('C2', 'C3', 'C4');
```

Functions

we have already learned about some built-in functions

- aggregate functions
  (compute a value over several rows)
- occasionally also single row functions

other single row functions:

- character functions
- numeric functions
- converting functions
- date functions

Character Functions

- concatenation: of strings, for instance: `SELECT 'Postgre' || 'SQL'`
- `lower()` and `upper()`:
  converting to lower- and upper-case characters
- `length()`:
  returns the length of a strings.
- `substring(string from for)`:
  `substring('Thomas' from 2 for 3)` – returns 'hom'
- `replace (string from to)`:
  `replace('abcdefcdg', 'cd', 'XX')` – returns 'abXXefXXg'

Numeric Functions

- „everything that can be done with a calculator“, for instance
  - `sqrt`(x), `power`(x,y)
  - `exp`(x), `ln`(x), `log`(b, x)
  - `cos`(x), `sin`(x), `tan`(x), `atan`(x), etc.
  - `abs`(x), `sign`(x)
- `round()`:
  rounding (optional: to a certain number of decimal places)
  - `round(105.75)` – returns 106
  - `round(105.75, 1)` – returns 105.8
  - `round(105.75, -1)` – returns 110

Converting Functions

- purpose:
  transforming values between different data types
- for instance: `to_char()`, `to_number()`
  - `to_char(17)` – returns '17'
  - `to_char(12345.678, '99,999.99')` – returns '12,345.68'
  - `to_number('17')` – returns 17
  - `to_number('-12,345.67', '99,999.99')` – returns -12345.67
  - `to_number('123.45', '99.99')` – returns error!
  - `to_number('123.49', '999.9')` – returns 123.4
- many other functions

Data Type DATE

- used for storing dates (day, month, year)
- no time (SQL standard)
- CURRENT_DATE returns current date
  (according to SQL standard: begin of a transaction)
- to_char and to_date offer several formatting possibilities

to_char() Function

cast of DATE to a string

Example (to_char())

```
SELECT to_char(birthDate) FROM professor;
SELECT to_char(sent) FROM order;
```

to_char() Function

cast of DATE to a string

Example (to_char())

```
SELECT to_char(birthDate) FROM professor;
SELECT to_char(sent) FROM order;
```

Example (formatting via to_char())

```
to_char(birthDate, 'MONTH DD, YYYY')
to_char(birthDate, 'DD-MON-YYYY')
to_char(birthDate, 'Day, DD.MM.YY')
to_char(CURRENT_DATE, 'DD-MON-YYYY')
```

TO_DATE() Function

cast of a string to DATE.

Example (to_char())

```
UPDATE clients SET
  born = TO_DATE('12-JUN-1976')
  WHERE clientNr = 1001;
```

TO_DATE() Function

cast of a string to DATE.

Example (to_char())

```
UPDATE clients SET
  born = TO_DATE('12-JUN-1976')
  WHERE clientNr = 1001;
```

Example (formatting via to_char())

```
TO_DATE('12-JUN-1976')
TO_DATE('12.06.1976', 'DD.MM.YYYY')
TO_DATE('October 3, 1974', 'Month DD, YYYY')
```

AGE() Function

difference between two dates given as years/months/days

Example

```
SELECT AGE(CURRENT_DATE,
    TO_DATE('01 Sep 2012', 'DD Mon YYYY'));
-> "5 years 2 mons 14 days"
   (entered 15.11.2017)

SELECT AGE(
    TO_DATE('01 Nov 2012', 'DD Mon YYYY'),
    TO_DATE('05 Dec 2013', 'DD Mon YYYY'));
-> "-1 years -1 mons -4 days"
```

Data Type TIME and TIMESTAMP

TIME for storing the time

TIMESTAMP for storing date and time

CURRENT_TIME resp. CURRENT_TIMESTAMP returns current time resp. time and date (according to SQL standard: begin of transaction)

TO_CHAR resp. TO_TIMESTAMP functions offer several formatting possibilities

EXTRACT() Function

enables reading parts (day, month, ...) of a date

Example

```
SELECT EXTRACT (YEAR FROM Datum) AS year,
  EXTRACT (MONTH FROM Datum) AS month,
  EXTRACT (DAY FROM Datum) AS day
  FROM orders WHERE clientNr = 1003;
```

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Learning Objectives

- How can a (longer) SQL query be structured?
- How do recursive SQL `SELECT` statements work? (understanding and composing)
- What are views?
- What are views used for?
- How are they constructed?
- How do `UPDATE`s behave on views?
- What is a `SEQUENCE`, and how do we construct and use it?