Databases

Lecture 7 - Subqueries and Views

Emily Lucia Antosch

HAW Hamburg

07.04.2025

Contents

1. Introduction . . . 2
2. Views . . . 6
3. Subqueries & Views . . . 75
4. License Notice . . . 119

1. Introduction

1.1 Where are we right now?

- Last time, we looked at the
- Today, we'll be discussing
  - how you can work with subqueries and views,
  - how subqueries and views are powerful tools that you can use to design complex databases and
  - how stacking views can enable complex solutions.

1.1 Where are we right now?

1. Introduction
2. Basics
3. SQL
4. Entity-Relationship-Model
5. Relationships
6. Constraints
8. **Subqueries & Views**
9. Transactions
10. Database Applications
11. Integrity, Trigger & Security

1.2 What is the goal of this chapter?

- At the end of this lesson, you should be able to
  - create views in PostgresQL and use them effectively
  - use subqueries in different points in the development of your database to enable your ideas and
  - know best practices and tricks that allow for complex data structures.

2. Views

2.1 Relational Algebra

Overview

- While SQL is the what, Relational Algebra is the how!
- In mathematics an algebra is a values range combined with defined operations
- Relational Algebra: The values range is the content of the database; operations are functions to calculate the query results
  - a set of operations for the relational model
- Relational Calculus: Descriptive approach that is based on mathematical logic

2.1 Relational Algebra

- higher-level declarative language for specifying relational queries, e.g., no order of operations, only what information the result should contain

2.1 Relational Algebra

Overview

- Algebra operations produce new relations
- These can be further manipulated using operations of the same algebra
- Sequence of relational algebra operations: relational algebra expression
- The result of a relational algebra expression is also a relation representing the result of a database query (retrieval request)

2.1 Relational Algebra

Overview

- Algebra operations can be divided into two groups
  - First group consists of operations developed specifically for relational databases
    - i.e., Selection, Projection, and Join
  - Second group includes set operations from mathematical set theory
    - i.e., Union, Intersection, Set Difference, and Cartesian Product

2.1 Relational Algebra

Overview

- Order of explanation
  1. Selection
  2. Projection
  3. Renaming
  4. Union, Intersection, Set Difference
  5. Cartesian Product
  6. Join (Equijoin, Natural Join)

2.1 Relational Algebra

Queries

SELECT – Basic form

```
SELECT  <attribute list>        → Projection
FROM    <table list>
WHERE   <condition>             → Selection
```

- `<attribute list>` is a list of attribute names (columns) whose values are to be retrieved by the query
- `<table list>` is a list of the relation names (e.g., tables) required to process the query

2.1 Relational Algebra

- `<condition>`: optional conditional (Boolean) expression that identifies the tuples to be retrieved by the query

2.1 Relational Algebra

Selection

- **Selection**(σ): mask out rows
  - Specify, which rows should remain (subset of the tuple)
    - Usage of selection: Specify, which tuples are interesting
    - Selection condition is a Boolean expression (condition)
    - The condition may contain complex expressions (combinations)
  - Specify, which relation is meant
    - Notice that R is generally a relational algebra expression whose result is a relation, e.g., a relation
  - Syntax: $\sigma_{\text{selection condition}}(R)$

2.1 Relational Algebra

Example

$$\sigma_{\text{Salary}>30{,}000}(\text{Employee})$$

$$\sigma_{(\text{DNr}=4\ \text{AND}\ \text{Salary}>30{,}000)\text{OR}(\text{DNr}=5\ \text{AND}\ \text{Salary}\ >\ 25{,}000)}(\text{Employee})$$

2.1 Relational Algebra

Selection

Example

2.1 Relational Algebra

Selection

Info

- Selection is unary (apply to a single relation)
- The degree of the relation resulting from a Selection is the same as the degree of R
- The number of tuples in the resulting relation is always less than or equal to the number of tuples in R

2.1 Relational Algebra

Selection

- Selection condition is typically specified in the `WHERE` clause of a SQL query

Example

$$\sigma_{\text{salary}>30{,}000}(\text{Employee})$$

```sql
SELECT * FROM Employee WHERE Salary > 30,000
```

SQL

2.1 Relational Algebra

Projection

- Projection (π): mask out columns
  - Specify, which columns should remain
  - Specify, which relation is meant
  - Syntax: $\pi_{\text{attribute list}}(R)$

Example

$\pi_{\text{SSN,lastName}}(\text{Person})$

2.1 Relational Algebra

Projection

2.1 Relational Algebra

Info

- The degree of the result is equal to the number of attributes in attribute list
- If the attribute list includes only non-key attributes of R, duplicate tuples are likely to occur
  - The Projection removes any duplicate tuples, so, the result of the Projection is a set of distinct tuples, and hence a valid relation
- The number of tuples in a relation resulting from a Projection is always less than or equal to the number of tuples in R

2.1 Relational Algebra

Projection

The Projection attribute list is specified in the SELECT clause of a SQL query.

2.1 Relational Algebra

Example

$\pi_{\text{LastName}}(\text{Person})$

```sql
SELECT
    LASTNAME
FROM
    PERSON
```

2.1 Relational Algebra

$Person$

<u>SSN</u>	Last Name	First Name	Mobile	…
123456789	Miller	Jane	0044 7701 123456	…
234567891	Miller	Steven	0044 7701 123457	…
345678912	Smith	Maria		…
…	…	…	…	…

$\sigma_{LastName="Miller"}\ (Person)$

<u>SSN</u>	Last Name	First Name	Mobile	…
123456789	Miller	Jane	0044 7701 123456	…
234567891	Miller	Steven	0044 7701 123457	…

2.1 Relational Algebra

Renaming

- Renaming (ρ): Column gets new name
  - Specify, which column
  - Specify, which new name
  - Specify, which relation
  - Set theory: Union ($\cup$), Intersection ($\cap$) and Set Difference ($-$) are only defined for the same relation schema
    - To achieve similar relation schema use projection and renaming
  - Renaming allows the renaming of attributes and relations

2.1 Relational Algebra

Renaming

- Renaming in SQL is done using the keyword `AS`

Example

$\rho_{\text{surname<-LastName}}(\text{Person})$

SQL

```sql
SELECT SSN, LastName AS Surname
FROM PERSON;
```

2.1 Relational Algebra

$Person$

SSN	Last Name	First Name	Mobile	…
123456789	Miller	Jane	0044 7701 123456	…
234567891	Miller	Steven	0044 7701 123457	…
345678912	Smith	Maria		…
…	…	…	…	…

$\pi_{SSN,LastName}(Person)$

SSN	Last Name
123456789	Miller
234567891	Miller
345678912	Smith
…	…

2.2 Union, Intersection and Difference

Union

- Union, intersection, and set difference can only be applied on two relations that are union compatible
  - Union compatible means that the two relations have the same number of attributes and
  - each corresponding pair of attributes has the same domain

2.2 Union, Intersection and Difference

Union

- Union $\cup$
  - Example: Retrieve the Social Security numbers of all employees who
    - either work in department 5
    - or directly supervise an employee who works in department 5

2.2 Union, Intersection and Difference

Example

DEP5_EMPS <-$\sigma_{\text{DNr}=5(\text{Employees})}$ RESULT1 <-$\pi_{\text{SSN}(\text{DEP5\_EMPS})}$ RESULT2 <-$\pi_{\text{Superssn}(\text{DEP5\_EMPS})}$ RESULT <- RESULT1 $\cup$ RESULT2

2.2 Union, Intersection and Difference

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Alicia	J	Zelaya	999887777	1968-01-19	3321 Castle, Spring, TX	F	25000	987654321	4
Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5
Ahmad	V	Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

2.2 Union, Intersection and Difference

Union

- Union $\cup$
  - Example: Retrieve the Social Security numbers of all employees who
    - either work in department 5
    - or directly supervise an employee who works in department 5

2.2 Union, Intersection and Difference

Example

SQL

```sql
(SELECT ssn FROM EMPLOYEE
WHERE DEPARTMENT_NUM = 5)
UNION
(SELECT Superssn FROM EMPLOYEE
WHERE DEPARTMENT_NUM = 5)
```

2.2 Union, Intersection and Difference

Union

Student

FirstName	LastName
Susan	Yao
Ramesh	Shah
Johnny	Kohler
Barbara	Jones
Amy	Ford
Jimmy	Wand
Ernest	Gilbert

Instructor

FirstName	LastName
John	Smith
Ricardo	Brown
Susan	Yao
Francis	Johnson
Ramesh	Shah

Student ∪ Instructor

FirstName	LastName
Susan	Yao
Ramesh	Shah
Johnny	Kohler
Barbara	Jones
Amy	Ford
Jimmy	Wand
Ernest	Gilbert
John	Smith
Ricardo	Brown
Francis	Johnson

Intersection

- Intersection $\cap$
  - The result is a relation that includes all tuples in both R and S
  - Commutative $R \cap S = S \cap R$
  - Duplicate tuples are eliminated

Example

SQL

```sql
SELECT supplier_id FROM SUPPLIERS
INTERSECT
SELECT SUPPLIER_ID FROM ORDERS;
```

Union, Intersection and Difference

2.2 Union, Intersection and Difference

Student

FirstName	LastName
Susan	Yao
Ramesh	Shah
Johnny	Kohler
Barbara	Jones
Amy	Ford
Jimmy	Wand
Ernest	Gilbert

Instructor

FirstName	LastName
John	Smith
Ricardo	Brown
Susan	Yao
Francis	Johnson
Ramesh	Shah

Student ∩ Instructor

FirstName	LastName
Susan	Yao
Ramesh	Shah

2.2 Union, Intersection and Difference

Union, Intersection and Difference

- Set Difference (-)
  - The result $(R - S)$ is a relation that includes all tuples that are in R but not in S
  - Not commutative: $R - S \neq S - R$
  - Duplicate tuples are eliminated

Example

SQL

```sql
STUDENT except INSTRUCTOR;
STUDENT MINUS INSTRUCTOR;
```

2.2 Union, Intersection and Difference

Union, Intersection and Difference

2.2 Union, Intersection and Difference

Student

FirstName	LastName
Susan	Yao
Ramesh	Shah
Johnny	Kohler
Barbara	Jones
Amy	Ford
Jimmy	Wand
Ernest	Gilbert

Instructor

FirstName	LastName
John	Smith
Ricardo	Brown
Susan	Yao
Francis	Johnson
Ramesh	Shah

Student - Instructor

FirstName	LastName
Johnny	Kohler
Barbara	Jones
Amy	Ford
Jimmy	Wand
Ernest	Gilbert

Instructor - Student

FirstName	LastName
John	Smith
Ricardo	Brown
Francis	Johnson

2.2 Union, Intersection and Difference

Union, Intersection and Difference

2.2 Union, Intersection and Difference

Student

FirstName	LastName
Susan	Yao
Ramesh	Shah
Johnny	Kohler
Barbara	Jones
Amy	Ford
Jimmy	Wand
Ernest	Gilbert

Instructor

FirstName	LastName
John	Smith
Ricardo	Brown
Susan	Yao
Francis	Johnson
Ramesh	Shah

Student ∪ Instructor

FirstName	LastName
Susan	Yao
Ramesh	Shah
Johnny	Kohler
Barbara	Jones
Amy	Ford
Jimmy	Wand
Ernest	Gilbert
John	Smith
Ricardo	Brown
Francis	Johnson

Student - Instructor

FirstName	LastName
Johnny	Kohler
Barbara	Jones
Amy	Ford
Jimmy	Wand
Ernest	Gilbert

Instructor - Student

FirstName	LastName
John	Smith
Ricardo	Brown
Francis	Johnson

Student ∩ Instructor

FirstName	LastName
Susan	Yao
Ramesh	Shah

2.2 Union, Intersection and Difference

Union, Intersection and Difference

- In SQL, there are three operations — `UNION`, `INTERSECT`, and `EXCEPT` — that correspond to the set operations described here
- In addition, there are multiset operations — `UNION ALL`, `INTERSECT ALL`, and `EXCEPT ALL` — that do not eliminate duplicates

2.2 Union, Intersection and Difference

Cartesian Product

- Cartesian Product
  - This is also a binary set operation
  - Relations do not have to be union compatible
  - The result ($A \times B$) is the combination of each tuple of the first relation A with each tuple of the second one B
  - In general, the result of $R(A_1, A_2, ...A_n) \times S(B_1, B_2, ...B_m)$ is a relation Q with degree $n + m$ attributes $Q(A_1, A_2, ...A_n, B_1, B_2, ...B_m)$
  - If R has n_R-tuples, and S has n_S-tuples, then Q will have $n_R \cdot n_S$-tuples

2.2 Union, Intersection and Difference

- In SQL, the Cartesian Product can be realized by using the `CROSS JOIN` option in joined tables.

2.2 Union, Intersection and Difference

Cartesian Product

Person

SSN	Last Name	First Name	Mobile
123456789	Miller	Jane	0044 7701 123456
234567891	Miller	Steven	0044 7701 123457
…	…	…	…

House

Address	Phone
221 Baker Street, 1NW London	0044 20 7946 0000
112 Baker Street, 1NW London	0044 20 7946 1000
…	…

$Person \times House$

SSN	Last Name	First Name	Mobile	Address	Phone
123456789	Miller	Jane	0044 7701 123456	221 Baker Street, 1NW London	0044 20 7946 0000
123456789	Miller	Jane	0044 7701 123456	112 Baker Street, 1NW London	0044 20 7946 1000
234567891	Miller	Steven	0044 7701 123457	221 Baker Street, 1NW London	0044 20 7946 0000
234567891	Miller	Steven	0044 7701 123457	112 Baker Street, 1NW London	0044 20 7946 1000
…	…	…	…	…	…

2.2 Union, Intersection and Difference

Cartesian Product

Example

Retrieve a list of names of each female employee and her dependents $\text{FEMALE\_EMPS} \leftarrow \sigma_{\text{sex=F(EMPLOYEE)}}$

$\text{EMPNAMES} \leftarrow \pi_{\text{FName, LName, SSN(FEMALE\_EMPS)}}$

$\text{EMP\_DEPENDENTS} \leftarrow \text{EMPNAMES} \times \text{DEPENDENT}$

$\text{ACTUAL\_DEPENDENTS} \leftarrow \sigma_{\text{SSN=ESSN(EMP\_DEPENDENTS)}}$

$\text{RESULT} \leftarrow \pi_{\text{Fname, Lname, Dependent\_name(ACTUAL\_DEPENDENTS)}}$

2.2 Union, Intersection and Difference

FEMALE_EMPS

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
Alicia	J	Zelaya	999887777	1968-07-19	3321Castle, Spring, TX	F	25000	987654321	4
Jennifer	S	Wallace	987654321	1941-06-20	291Berry, Bellaire, TX	F	43000	888665555	4
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5

EMPNAMES

Fname	Lname	Ssn
Alicia	Zelaya	999887777
Jennifer	Wallace	987654321
Joyce	English	453453453

2.2 Union, Intersection and Difference

Cartesian Product

2.2 Union, Intersection and Difference

EMP_DEPENDENTS

Fname	Lname	Ssn	Essn	Dependent_name	Sex	Bdate	...
Alicia	Zelaya	999887777	333445555	Alice	F	1986-04-05	...
Alicia	Zelaya	999887777	333445555	Theodore	M	1983-10-25	...
Alicia	Zelaya	999887777	333445555	Joy	F	1958-05-03	...
Alicia	Zelaya	999887777	987654321	Abner	M	1942-02-28	...
Alicia	Zelaya	999887777	123456789	Michael	M	1988-01-04	...
Alicia	Zelaya	999887777	123456789	Alice	F	1988-12-30	...
Alicia	Zelaya	999887777	123456789	Elizabeth	F	1967-05-05	...
Jennifer	Wallace	987654321	333445555	Alice	F	1986-04-05	...
Jennifer	Wallace	987654321	333445555	Theodore	M	1983-10-25	...
Jennifer	Wallace	987654321	333445555	Joy	F	1958-05-03	...
Jennifer	Wallace	987654321	987654321	Abner	M	1942-02-28	...
Jennifer	Wallace	987654321	123456789	Michael	M	1988-01-04	...
Jennifer	Wallace	987654321	123456789	Alice	F	1988-12-30	...
Jennifer	Wallace	987654321	123456789	Elizabeth	F	1967-05-05	...
Joyce	English	453453453	333445555	Alice	F	1986-04-05	...
Joyce	English	453453453	333445555	Theodore	M	1983-10-25	...
Joyce	English	453453453	333445555	Joy	F	1958-05-03	...
Joyce	English	453453453	987654321	Abner	M	1942-02-28	...
Joyce	English	453453453	123456789	Michael	M	1988-01-04	...
Joyce	English	453453453	123456789	Alice	F	1988-12-30	...
Joyce	English	453453453	123456789	Elizabeth	F	1967-05-05	...

2.2 Union, Intersection and Difference

Cartesian Product

Example

$$\text{FEMALE\_EMPS} \leftarrow \sigma_{\text{sex=F(EMPLOYEE)}} \ \text{EMPNAMES} \leftarrow \pi_{\text{FName, LName, SSN(FEMALE\_EMPS)}} \ \text{EMP\_DEPENDENTS} \leftarrow \text{EMPNAMES} \times \text{DEPENDENT} \ \text{ACTUAL\_DEPENDENTS} \leftarrow \sigma_{\text{SSN=ESSN(EMP\_DEPENDENTS)}} \ \text{RESULT} \leftarrow \pi_{\text{Fname, Lname, Dependent\_name(ACTUAL\_DEPENDENTS)}}$$

2.2 Union, Intersection and Difference

ACTUAL_DEPENDENTS

Fname	Lname	Ssn	Essn	Dependent_name	Sex	Bdate	...
Jennifer	Wallace	987654321	987654321	Abner	M	1942-02-28	...

RESULT

Fname	Lname	Dependent_name
Jennifer	Wallace	Abner

2.2 Union, Intersection and Difference

Join

- Join ($\bowtie$):
  - Combine related tuples from two relations into single “longer” tuples
  - **Very important concept!**
  - Specify, which tables should be combined
  - The same attribute name merges
  - Without same attributes: the join is the cartesian product
  - There are different types of joins, which are presented later in more detail

2.2 Union, Intersection and Difference

- Comparison to Cartesian Product: The result has one tuple for each combination of tuples of the two relations whenever the combination satisfies the join condition

2.2 Union, Intersection and Difference

Join

Example

Retrieve all attributes of the managers of each department.

$$\mathrm{DEPT\_MGR} \leftarrow \mathrm{DEPARTMENT} \bowtie_{\mathrm{Mgr\_SSN} \,=\, \mathrm{SSN}} (\mathrm{EMPLOYEE})$$

DEPT_MGR

Dname	Dnumber	Mgr_ssn	...	Fname	Minit	Lname	Ssn	...
Research	5	333445555	...	Franklin	T	Wong	333445555	...
Administration	4	987654321	...	Jennifer	S	Wallace	987654321	...
Headquarters	1	888665555	...	James	E	Borg	888665555	...

2.2 Union, Intersection and Difference

Join

Example

With Cartesian Product: $\text{EMP\_DEPENDENTS} \leftarrow \text{EMPNAMES} \times \text{DEPENDENT}$ $\text{ACTUAL\_DEPENDENT} \leftarrow \sigma_{\text{SSN}=\text{ESSN}(\text{EMP\_DEPENDENTS})}$

- With Equijoin:

$\text{ACTUAL\_DEPENDENTS} \leftarrow \text{EMPNAMES} \bowtie_{\text{SSN}=\text{ESSN}(\text{DEPENDENT})}$

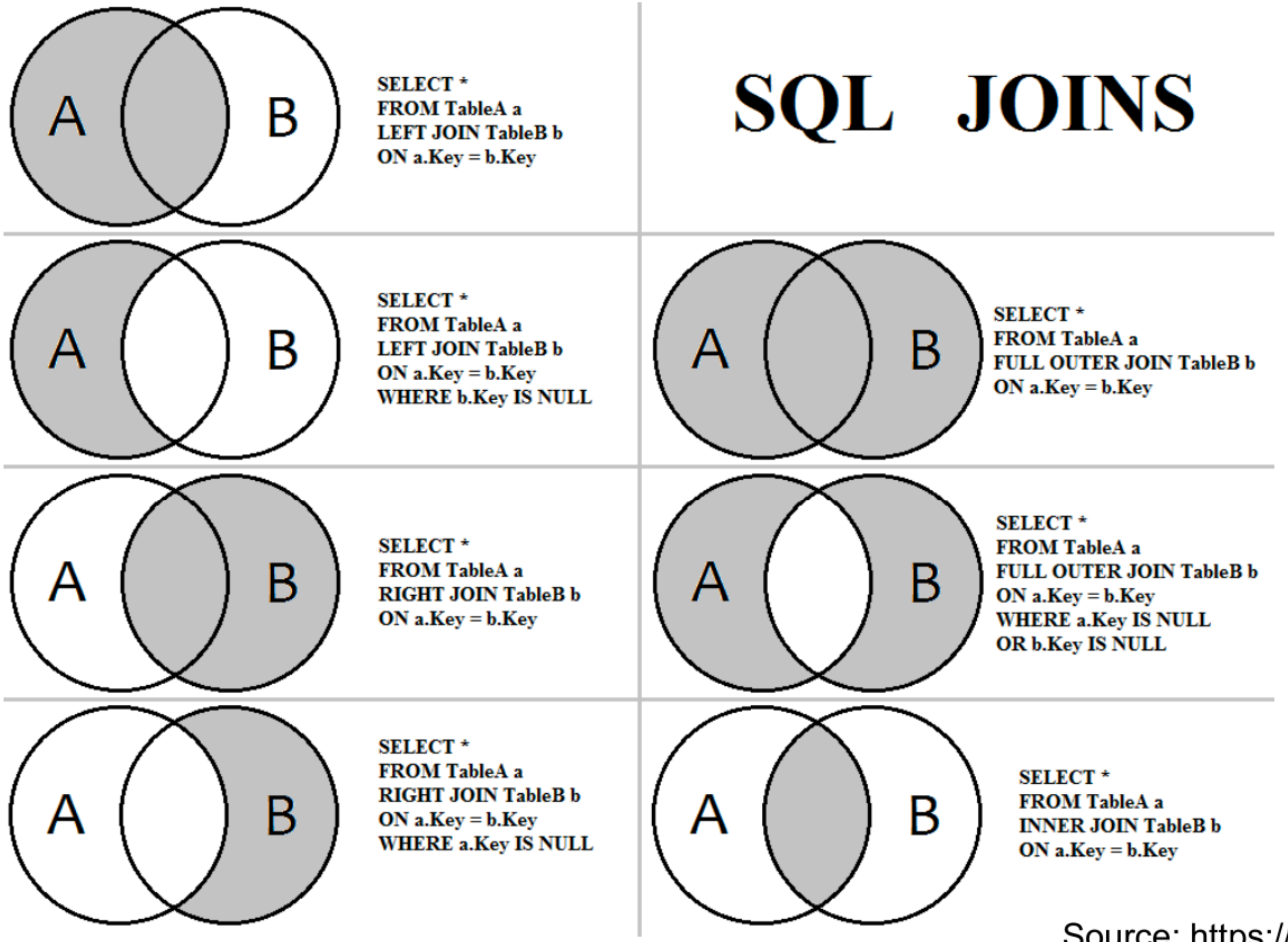
Join

- Variations of JOIN:
  - Equijoin
    - Used comparison operator is = only
    - Two attributes requires the values to be identical in every tuple in the result
  - Natural Join
    - Two join attributes (or each pair of join attributes) have the same name in both relations.
    - If this is not the case, a renaming operation is applied first

2.2 Union, Intersection and Difference

Join

2.2 Union, Intersection and Difference



Source: https://huklee.github.io/2017/01/28/021.SQL-all-kinds-of-join-queries/

2.2 Union, Intersection and Difference

Size of Result

- How many tuples are in my result set (cardinality)?
  - Interesting question for end user ("I'll just print it!")
  - Interesting question for programmer ("Program is running forever?!")
  - Interesting question for DBMS creator ("I'll start with operation 1 and do operation 2 afterwards")
- The answer to this question depends on involved operations…

2.2 Union, Intersection and Difference

Size of Result

- The answer to this question depends on involved operations:
- Projection
  - Upper bounds: number of tuples in the projected relation
  - Lower bounds: 1 (for not empty original relation)
  - Rule: If the projected attribute contains a key candidate, then the cardinality of the result is equal to the amount of tuples
  - This rule also applies if the attributes of the current database state are coincidentally a key candidate

2.2 Union, Intersection and Difference

Size of Result

- The answer to this question depends on involved operations:
- Selection
  - The cardinality of the selection depends on the selection conditions
  - Upper bounds: amount of tuples
  - Lower bounds: 0
  - Selection is used to restrict the number of tuples, thus, the upper bounds is rarely present in practice

2.2 Union, Intersection and Difference

Size of Result

- The answer to this question depends on involved operations:
- Cartesian Product
  - Cardinality is the product of the cardinalities of participating relations
  - Thus, the cartesian product is always an ”expensive” operation
- Join
  - Upper bounds: Product of cardinalities of participating relations
  - Lower bounds: 0
  - Thus, the join operation may be an ”expensive” operation

2.2 Union, Intersection and Difference

Operations

- Minimal set of operations
  - It‘s sufficient if a language provides the operations $\rho, \sigma, \pi, \cup, -, \times$
    - The language is then “relational complete”, meaning “everything” is requestable
    - The operations are also independent, therefore none of it are dispensable
  - Other operations are representable by these operations:
    - Example: $R \cap S \Leftrightarrow (R \cup S) - ((R - S) \cup (S - R))$

2.2 Union, Intersection and Difference

- Important for the implementation of a DBMS and for the optimization of queries

2.2 Union, Intersection and Difference

Operations

- Selection (σ (sigma))
- Projection (π (pi))
- Renaming (ρ (rho))
- Union ($\cap$)
- Set Difference (or Except, Minus, $-$)
- Cartesian Product ($\times$)
- All other operations can be built from these!

2.2 Union, Intersection and Difference

Operations

Operation	Purpose	Notation
Selection	Selects all tuples that satisfy the selection condition from a relation R	$\sigma_{<selection\ condition>}(R)$
Projection	Produces a new relation with only some of the attributes of R, and removes duplicate tuples	$\pi_{<attribute\ list>}(R)$
Renaming	Column in the result relation gets new name	$\rho_{new\ name \leftarrow attribute\ name}(R)$
Join	Produces all combinations of tuples from R_1 and R_2 that satisfy the join condition	$R_1 \bowtie_{<join\ condition>} R_2$
Equijoin	Produces all the combinations of tuples from R_1 and R_2 that satisfy a join condition with only equality comparisons	$R_1 *_{<join\ condition>} R_2$

2.2 Union, Intersection and Difference

Operations

Operation	Purpose	Notation
Union	Produces a relation that includes all the tuples in R_1 or R_2 or both R_1 and R_2; R_1 and R_2 must be union compatible	$R_1 \cup R_2$
Intersection	Produces a relation that includes all the tuples in both R_1 and R_2; R_1 and R_2 must be union compatible	$R_1 \cap R_2$
Set Difference	Produces a relation that includes all the tuples in R_1 that are not in R_2; R_1 and R_2 must be union compatible	$R_1 - R_2$
Cartesian Product	Produces a relation that has the attributes of R_1 and R_2 and includes as tuples all possible combinations of tuples from R_1 and R_2	$R_1 \times R_2$

2.2 Union, Intersection and Difference

Relational Calculus

- The relational algebra constructs the query result by applying operations and an order (project on X, select the Y and combine that with R_2,. . .)
- In contrast, the relational calculus are using a descriptive approach
- Calculus are logic-based approaches like the predicate logic
- Therefore, sets are characterized that correspond with the query result
- Calculus has variables, constants, comparison operations, logical operations and quantifier

2.2 Union, Intersection and Difference

Relational Calculus

- Two types of relational calculus
  - Tuple relational calculus: variables declare tuples (are bounded to them)
  - Domain relational calculus: variables declare domain elements (thus, values range of attributes)
- Expressions in the calculus are called formula
- A result tuple is more or less an assignment of constants to variables, so that the formula is evaluated as TRUE

2.2 Union, Intersection and Difference

Relational Calculus

2.2 Union, Intersection and Difference

Example

- In mathematics:
  - $\{x^2 \mid x \in N \wedge x^3 < 1000 \wedge x^3 > 0\}$
  - This defines the set of all square numbers that cube number is between 0 and 1000.
- Relational calculus:
  - $A = \{x \mid \text{Person}(x, y) \wedge y = \text{'Jones'}\} = \{2\}$
  - By usage of complex expressions (formula), the calculus has the same expressiveness as the relational algebra

2.2 Union, Intersection and Difference

Relational Calculus

- Query languages for relational database schemas are mathematical substantiated
- The mathematical basis are the relational algebra and the relational calculus
- The relational algebra defines few operations, with that every request is expressible: Projection, Selection, Join, Renaming, Union, Set difference
- The relational calculus characterizes sets, which corresponds with the query result

2.2 Union, Intersection and Difference

- The relational calculus is descriptive, because it doesn’t have to define an order of operations that construct the result
- Relational algebra and relational calculus have the same expressiveness

3. Subqueries & Views

3.1 Subqueries

Nested Queries

- SELECT returns relation: a (multi-)set
- Result of SELECT can be included in query
  - `WHERE` clause
  - also, for `UPDATE`, `DELETE`
  - `HAVING` clause
  - `FROM` clause
  - SELECT clause (in column list)
- So, we have two (or more) `SELECT`s:
  - Outer `SELECT`
  - Nested (or inner) `SELECT`: subquery

3.1 Subqueries

Nested Queries

```sql
INSERT INTO UNDERPAID (lname, fname) SELECT lname, fname FROM Employee WHERE salary < 1000;
```

SQL

- WHERE clause belongs to SELECT

3.1 Subqueries

`WHERE` x in

- In general, the nested query will return a table (relation), which is a set or multiset of tuples
- Check if value is a member of set

```
WHERE a IN (1,4,9)
```

- Set can be result of query

```
WHERE a IN (SELECT x FROM y)
```

3.1 Subqueries

WHERE x in

SQL

```sql
SELECT DISTINCT Essn FROM WORKS_ON WHERE (Pno) IN (SELECT Pno FROM WORKS_ON WHERE Essn='123456789');
```

3.1 Subqueries

WHERE x in

```sql
SELECT title FROM books WHERE isbn IN (SELECT isbn FROM recommended_books)
```

SQL

- The subqueries are independent of each other, because they do not access the same tables

3.1 Subqueries

WHERE x in

```sql
SELECT lastname FROM person WHERE 1.0 IN (SELECT grade  FROM exam WHERE person.no = exam.no)
```

SQL

- In this example both queries depend on each other, because the second query references a part of the first relation (“person”).

3.1 Subqueries

WHERE x in

SQL

```sql
SELECT E.Fname, E.Lname FROM EMPLOYEE AS E WHERE E.Ssn IN ( SELECT Essn FROM DEPENDENT AS D WHERE E.Sex = D.Sex );
```

3.1 Subqueries

WHERE x in

- The operator IN can also be used for explicit enumerations

```sql
WHERE value IN ( value1 , value2 , value3 , … );
WHERE colour IN ( 'red' , 'blue’ );

SELECT DISTINCT Essn FROM WORKS_ON WHERE  Pno IN (1, 2, 3);
```

3.1 Subqueries

WHERE x in

- Example from last chapter (about set operations):

```sql
(SELECT DISTINCT Pnumber
FROM PROJECT, DEPARTMENT, EMPLOYEE
WHERE Dnum=Dno AND Mgr_ssn=Ssn AND Lname="Wong")
UNION
(SELECT DISTINCT Pnumber
FROM  PROJECT, WORKS_ON, EMPLOYEE
WHERE Pnumber= Pno AND Essn= Ssn AND Lname="Wong");
```

3.1 Subqueries

WHERE x in

- Example from last chapter (alternative statement using subqueries):

```sql
SELECT DISTINCT Pnumber
FROM PROJECT
WHERE Pnumber IN
(SELECT Pnumber FROM PROJECT, DEPARTMENT, EMPLOYEE WHERE Dnum=Dnumber AND Mgr_ssn=Ssn AND Lname="Wong")
OR Pnumber IN
(SELECT Pno FROM WORKS_ON, EMPLOYEE WHERE Essn=Ssn AND Lname="Wong" );
```

3.1 Subqueries

WHERE x in

- Special case: Nested query returns only one value
  - In such cases, it is permissible to use = instead of `IN` for the comparison operator
- Example: `SELECT *  FROM y  WHERE x = ( SELECT MAX(x) FROM y );`

3.1 Subqueries

WHERE x in

- In general, a query written with nested `SELECT-FROM-WHERE` blocks and using the = or `IN` comparison operators can always be expressed as a single block query.
- Example from before:

```sql
SELECT E.Fname, E.Lname
FROM EMPLOYEE AS E
WHERE E.Ssn IN
(SELECT Essn FROM DEPENDENT AS D WHERE E.Sex=D.Sex);
```

3.1 Subqueries

WHERE x in

- Example from last slide (Alternative statement without a subquery)

```sql
SELECT E.Fname, E.Lname FROM EMPLOYEE AS E, DEPENDENT AS D WHERE E.Ssn=D.Essn AND E.Sex=D.Sex;
```

SQL

3.1 Subqueries

Other Comparison Operators

- `=ANY` (`=SOME`)
  - operator returns `TRUE` if the value v is equal to some value in the set V
  - is equivalent to `IN`
  - Other operations can be combined with ANY, e.g., `>`, `>=`, `<`, `<=`, and `<>`
- Example: Persons who have borrowed a book: `SELECT name FROM Person WHERE PNr = ANY (SELECT PNr FROM book );`

3.1 Subqueries

Other Comparison Operators

- `ALL`
  - Comparison operations can be combined with ALL, e.g., >, >=, <, <=, and <>
  - Example: Employees earning more money as the employees of department 5

```sql
SELECT Lname, Fname FROM EMPLOYEE WHERE Salary >
ALL (SELECT Salary FROM EMPLOYEE WHERE Dno=5) ;
```

3.1 Subqueries

Other Comparison Operators

- Often several queries give the same result
  - but might have difference in the performance!

SQL

```sql

SELECT * FROM book WHERE price <= ALL (SELECT price FROM book);
SELECT * FROM book WHERE price = (SELECT MIN(price) FROM book);
SELECT * FROM book WHERE price >= ALL (SELECT price FROM book);
```

3.1 Subqueries

```
SELECT * FROM book WHERE price = (SELECT MAX(price) FROM book);
SELECT * FROM book WHERE price > ANY (SELECT price FROM book);
SELECT * FROM book WHERE price > (SELECT MIN(price) FROM book);
```

3.1 Subqueries

Other Comparison Operators

- Often several queries give the same result
  - but might have difference in the performance!
  - Strategy depends on DBMS, probably equivalent if no index on price, otherwise, the second version will be (much) faster

3.1 Subqueries

Correlated Nested Queries

- Uncorrelated
  - Outer and nested query are independent
  - Nested query must be computed only once
- Correlated
  - Nested query depends on columns of outer query
  - Result of a correlated nested query is different for each tuple of the relation(s) outer query
  - A nested query is evaluated once for each tuple (or combination of tuples) in the outer query

3.1 Subqueries

Question

But what about performance?

3.1 Subqueries

Correlated Nested Queries

Example

Who has borrowed books for 9.99$?

```sql
SELECT name  FROM pers  WHERE 9.99 IN (SELECT price FROM book  WHERE pers.PNr = book.PNr ) ; SELECT name  FROM pers, book WHERE pers.PNr = book.PNr AND  book.price = 9.99;
```

3.1 Subqueries

Correlated Nested Queries

Example

From Before: Who is lead by a female superior?

```sql
SELECT E.Fname, E.Lname FROM EMPLOYEE AS E WHERE
E.Ssn IN ( SELECT Essn FROM DEPENDENT AS D WHERE
D.Sex='F');
```

3.1 Subqueries

Correlated Nested Queries

- In general, we can have several levels of nested queries
  - possible ambiguity among attribute names if attributes of the same name exist:
  - one in a relation in the FROM clause of the outer query, and
  - another in a relation in the FROM clause of the nested query
- The rule is that a reference to an unqualified attribute refers to the relation declared in the **innermost nested query**.

3.1 Subqueries

Ambiguity of Attributes

- Example: Retrieve the name of each employee who has a female dependent:

```sql
SELECT E.Fname, E.Lname FROM EMPLOYEE AS E WHERE
E.Ssn IN ( SELECT Essn FROM DEPENDENT AS D WHERE
D.Sex='F');
```

3.1 Subqueries

Ambiguity of Attributes

! Memorize

It is generally advisable to create tuple variables (aliases) for all the tables referenced in an SQL query to avoid potential errors and ambiguities!!!

3.1 Subqueries

EXISTS

- The operator `EXISTS (NOT EXISTS)` provides the possibility to check if the result of another query is empty (`FALSE`) or not (`TRUE`)

```sql
SELECT isbn FROM book WHERE EXISTS (SELECT * FROM borrowed WHERE book.libraryno = borrowed.libraryno)
```

SQL

- This example provides as result a set of all borrowed books
- Typically, the usage is so that the DBMS may decide, which column should be examined:

```sql
... EXISTS (SELECT *...
```

SQL

EXISTS

Alternative SQL-statement from before:

```sql
SELECT E.Fname, E.Lname FROM EMPLOYEE AS E WHERE
EXISTS (SELECT * FROM DEPENDENT AS D WHERE E.Ssn =
D.Essn AND E.Sex = D.Sex);
```

SQL

3.1 Subqueries

EXISTS

- `EXISTS` and `NOT EXISTS` are typically used in conjunction with a correlated nested query

Example

Retrieve the names of employees who have no dependents

```sql
SELECT Fname, Lname FROM EMPLOYEE WHERE NOT EXISTS ( SELECT * FROM DEPENDENT WHERE Ssn=Essn );
```

SQL

3.1 Subqueries

EXISTS

Example

List the names of managers who have at least one dependent

```sql
SELECT Fname, Lname FROM EMPLOYEE WHERE EXISTS ( SELECT * FROM DEPENDENT WHERE Ssn=Essn ) AND EXISTS ( SELECT * FROM DEPARTMENT WHERE Ssn=Mgr_ssn );
```

SQL

3.1 Subqueries

In FROM

- SELECT returns a new relation so that, we can select values from it
- Necessary: give a name to the relation

Example

Set an alias for a SELECT statement in the FROM statement

```sql
SELECT tab_a.x , newtab_b.y FROM tab_a , (SELECT v1, v2 FROM tab_b) AS newtab_b;
```

SQL

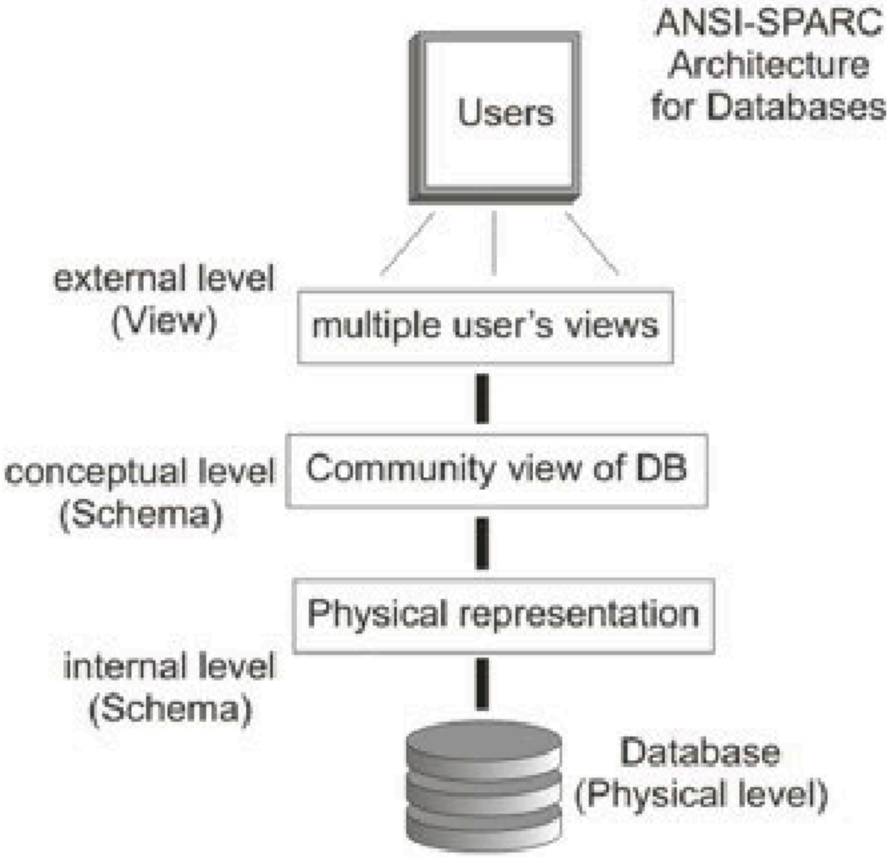
3.1 Subqueries

ANSI-SPARC Model

External Schema

Conceptual Schema

Internal Schema



3.2 Views

Basics

- User or application specific views on data
- Only relevant portions of the data
- A view in SQL terminology is a single table that is derived from other tables
  - Other tables can be base tables or previously defined views
- A view is considered to be a virtual table
  - In contrast to base tables
  - Limits the possible update operations
  - No limitations on querying a view

3.2 Views

Use Cases

- Hide some information
  - Example: Salary not viewable for colleagues
  - Can see only employees of same department?
- Convert data for different users
  - Price in $, EUR, etc.
- Backward Compatibility
  - Example: Add some columns, but old applications do `SELECT *`
- Simplification: Hide away complex queries
  - Example: Data Dictionary Views (all tables)

3.2 Views

Syntax

```sql
CREATE [OR REPLACE] VIEW <vname> AS <query> ;
```

SQL

- `<query>` is an arbitrary `SELECT` statement

3.2 Views

Syntax

- Example for a sample view:

```sql
CREATE VIEW vPerson AS
SELECT Name , Id , BirthDate FROM person ;
```

- Can rename columns in view:

```sql
CREATE VIEW vPerson ( lname , pnr , bd ) AS
SELECT Name , Id , BirthDate FROM person
```

3.2 Views

Syntax

```sql
CREATE VIEW v_WORKS_ON1 AS
SELECT Fname, Lname, Pname, Hours
FROM EMPLOYEE, PROJECT, WORKS_ON
WHERE Ssn=Essn AND Pno=Pnumber;
```

3.2 Views

Syntax

```sql
CREATE VIEW v_DEPT_INFO
(Dept_name, No_of_emps, Total_sal) AS
SELECT Dname, COUNT(*), SUM(Salary)
FROM
DEPARTMENT, EMPLOYEE
WHERE
Dnumber=Dno
GROUP BY Dname;
```

3.2 Views

Queries

- A view is supposed to be always up-to-date
  - If we modify the tuples in the base tables on which the view is defined, the view must automatically reflect these changes
  - View realized at the time when we specify a query on the view

SQL
```sql
SELECT Fname, Lname
FROM
v_WORKS_ON1
WHERE
Pname="ProductX";
```

3.2 Views

DROP

- Views can be dropped

```sql
DROP VIEW v_WORKS_ON1;
```

SQL

3.2 Views

Implementation

- Two strategies:
  1. Query Modification
     - Transforming the view query into a query on the underlying base tables

```sql
SELECT Fname, Lname
FROM EMPLOYEE, PROJECT, WORKS_ON
WHERE Ssn=Essn
AND Pno=Pnumber
AND Pname= "ProductX";
```

3.2 Views

Implementation

- Two strategies:
  2. View Materialization
     - Physically creating a temporary view
     - Incremental update of materialized view
     - If the view is not queried for a certain period of time, the system may then automatically remove the physical table and recompute it from scratch on new queries

3.2 Views

Materialized Views

```sql
CREATE MATERIALIZED VIEW <name> AS SELECT …
```

- Traditional views
- `SELECT` is performed when needed
- Performance penalty

- Materialized view
  - Store select statement and selected data
  - Problems
    - Store data twice
    - When to update selected data?
  - Rules for updating: event vs. time triggered

3.2 Views

- Selected data can be updated
  - manually
  - on a regular basis (every night)
  - event triggered (update to base table)

4. License Notice

4.1 Attribution

The basis of this course stems from: Professor Dr. Ulrike Herster

The following license applies to all unmodified and modified material used throughout this course.

4.1 Attribution

License