Database systems I

Radim Bača

radim.baca@vsb.cz

dbedu.cs.vsb.cz

VSB TECHNICAL UNIVERSITY OF OSTRAVA | FACULTY OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE | DEPARTMENT OF COMPUTER SCIENCE

EVROPSKÁ UNIE
Evropské strukturální a investiční fondy
Operační program Výzkum, vývoj a vzdělávání

MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

- Relational algebra
- SQL
  - Inner Join
  - Self Join
  - Outer Join

Relational algebra

- Relational algebra - set of operators on relations
- Operator - takes one or more relations as its input and produce a new relation

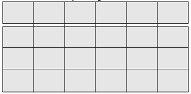
Selection	$\sigma_{condition}$
Projection	π
Cartesian product	$\times$
Join	$\bowtie$
Theta join	$\bowtie_{condition}$
Union	$\cup$
Intersection	$\cap$
Minus	$-$

Example

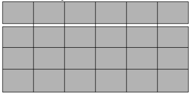
- Queries consist of elementary operations above relations, whose result is again a relation
- Example of a query:

Find name of those employees working at departments having sales at least 10 millions

Employee



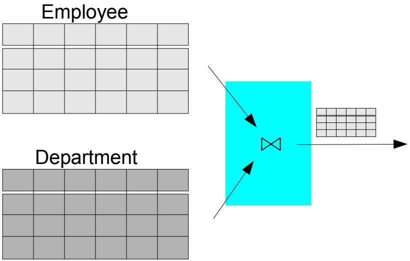
Department



Example

- Queries consist of elementary operations above relations, whose result is again a relation
- Example of a query:

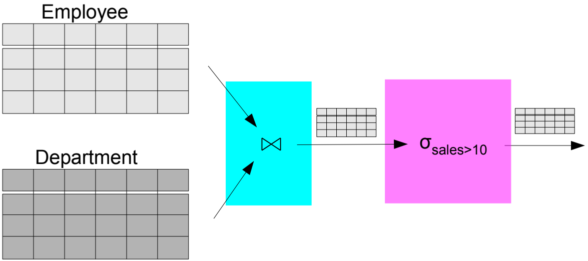
Find name of those employees working at departments having sales at least 10 millions



Example

- Queries consist of elementary operations above relations, whose result is again a relation
- Example of a query:

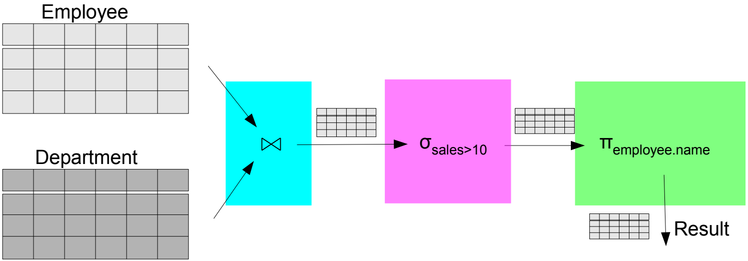
Find name of those employees working at departments having sales at least 10 millions



Example

- Queries consist of elementary operations above relations, whose result is again a relation
- Example of a query:

Find name of those employees working at departments having sales at least 10 millions



Restriction (selection)

- We select some rows from an input relation
- Notation: $\sigma_{condition}(Relation)$ - the condition defines rows that we want to pick
- *Example: Find all employees whose position is 'programmer'.*

Employee

eID	eName	passport no.	position
223	Newman	7905051111	programmer
124	Carter	6901112233	manager
154	Trier	7105029876	programmer

$$\Downarrow \sigma_{position\ =\ 'programmer'}(Employee)$$

eID	eName	passport no.	position
223	Newman	7905051111	programmer
154	Trier	7105029876	programmer

Restriction (selection)

- We select some rows from an input relation
- Notation: $\sigma_{condition}(Relation)$ - the condition defines rows that we want to pick
- *Example: Find all employees whose position is 'programmer'.*

Employee

eID	eName	passport no.	position
223	Newman	7905051111	programmer
124	Carter	6901112233	manager
154	Trier	7105029876	programmer

$\Downarrow \sigma_{position\ =\ 'programmer'}(Employee)$

eID	eName	passport no.	position
223	Newman	7905051111	programmer
154	Trier	7105029876	programmer

Projection

- We select some columns from an input relation
- Notation: $\pi_{\textit{list of attributes}}(\textit{Relation})$
- *Example: Find IDs and names of all employees.*

Employee

eID	eName	passport no.	position
223	Newman	7905051111	programmer
124	Carter	6901112233	manager
154	Trier	7105029876	programmer

$\Downarrow \pi_{\textit{eID, eName}}(\textit{Employee})$

eID	eName
223	Newman
124	Carter
154	Trier

Projection

- We select some columns from an input relation
- Notation: $\pi_{\textit{list of attributes}}(\textit{Relation})$
- *Example: Find IDs and names of all employees.*

Employee

eID	eName	passport no.	position
223	Newman	7905051111	programmer
124	Carter	6901112233	manager
154	Trier	7105029876	programmer

$\Downarrow \pi_{\textit{eID, eName}}(\textit{Employee})$

eID	eName
223	Newman
124	Carter
154	Trier

Duplications

- *Example: Find all positions of employees.*
  - **Relational algebra**: $\pi_{position}(Employee)$ - the resulting relation has two rows $\{$(programmer),(manager)$\}$
  - Duplications are automatically eliminated since we work with sets
  - **SQL**: `SELECT position FROM Employee` - the resulting relation has three rows
  - SQL works with multisets and the elimination of duplications has to be explicitly claimed

Duplications

- *Example: Find all positions of employees.*
  - **Relational algebra**: $\pi_{position}(Employee)$ - the resulting relation has two rows $\{$(programmer),(manager)$\}$
  - Duplications are automatically eliminated since we work with sets
  - **SQL**: `SELECT position FROM Employee` - the resulting relation has three rows
  - SQL works with multisets and the elimination of duplications has to be explicitly claimed

Cartesian Product

- Cartesian product $R \times S$ is a "combination" of two relations R and S
- Each row of the relation R is combined with each row of S
- *Example:*

Employee

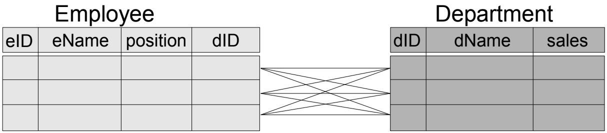
eID	eName	position	dID

Department

dID	dName	sales

Cartesian Product

- Cartesian product $R \times S$ is a "combination" of two relations R and S
- Each row of the relation R is combined with each row of S
- *Example:*



$\Downarrow$ *Employee* $\times$ *Department*

eID	eName	position	dID	dID	dName	sales

Combination of Operations

- *Example: To all employees with the position 'manager' add an information about department at which they work.*

$$\sigma_{position='manager' \wedge Employee.dID=Department.dID}(Employee \times Department)$$

$$\sigma_{Employee.dID=Department.dID}(\sigma_{position='manager'}(Employee) \times Department)$$

Employee

eID	eName	position	dID

Department

dID	dName	sales

Combination of Operations

- *Example: To all employees with the position 'manager' add an information about department at which they work.*

$$\sigma_{position='manager' \wedge Employee.dID=Department.dID}(Employee \times Department)$$

$$\sigma_{Employee.dID=Department.dID}(\sigma_{position='manager'}(Employee) \times Department)$$

Employee

eID	eName	position	dID

Department

dID	dName	sales

Combination of Operations

- *Example: To all employees with the position 'manager' add an information about department at which they work.*

$$\sigma_{position='manager' \wedge Employee.dID=Department.dID}(Employee \times Department)$$

$$\sigma_{Employee.dID=Department.dID}(\sigma_{position='manager'}(Employee) \times Department)$$

Employee

eID	eName	position	dID

Department

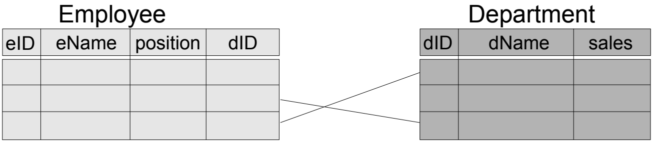
dID	dName	sales

Combination of Operations

- *Example: To all employees with the position 'manager' add an information about department at which they work.*

$$\sigma_{position='manager' \wedge Employee.dID=Department.dID}(Employee \times Department)$$

$$\sigma_{Employee.dID=Department.dID}(\sigma_{position='manager'}(Employee) \times Department)$$



Natural Join

- Natural join $R \bowtie S$ - from the product $R \times S$ we pick only rows with the same values of attributes of the same name in both relations
- Having the natural join introduced, the situation from the last example is simplified
- *Example: To all employees the with position 'manager' add an information about department at which they work.*

Original version:

$\sigma_{position='manager' \wedge Employee.dID=Department.dID}(Employee \times Department)$

Natural join version:

$\sigma_{position='manager'}(Employee \bowtie Department)$

Theta Join (JOIN)

- Theta join (abbreviated to join) $R \bowtie_{\Theta} S$ - from the product $R \times S$ we pick only rows satisfying the Θ condition
- Once again, by using theta join, we simplify the notation
- *Example: To all employees the with position 'manager' add an information about department at which they work.*

Original version:

$\sigma_{position='manager' \wedge Employee.dID=Department.dID}(Employee \times Department)$

Theta join version:

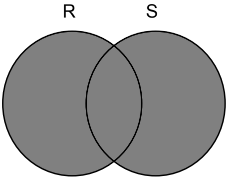
$Employee \bowtie_{position='manager' \wedge Employee.dID=Department.dID} Department$

Join Operation

- Although, when using joins, we do not improve the expressing capabilities of language, joins enable us to simplify notation of queries
- Theta join is implemented in SQL as the JOIN operation and it is a very frequent operation!

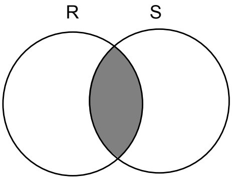
Standard Set Operations

Union



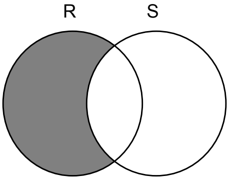
$R \cup S$

Intersection



$R \cap S$

Difference



$R - S$

Intersection

- Intersection can be expressed by other set operations of relational algebra

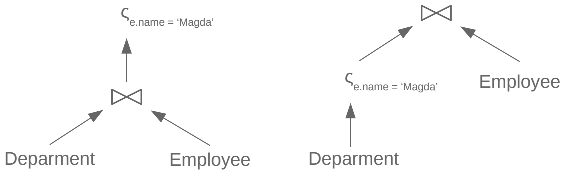
  $R \cap S = R - (R - S)$

  $R \cap S = R \bowtie S$ when schemes of R and S are the same

- So it again mainly simplifies the notation

Final Notes

- Some kind of relational algebra is often used as an internal representation of *query plans*
- Query plan describe how to execute the query
- To better understand a query plan or a relational algebra expression we usually use a tree.
- *Example: Find department names where an employee with name 'Magda' works.*



SQL

- Language for relational database systems
- Declarative
- SQL standards:
  - SQL-92 - Basic SQL constructs
  - SQL-99 - Regex, triggers, OO
  - SQL-2003 - XML, windows, sequences, auto-gen IDs
  - SQL-2008 - Truncate, offset/fetch
  - SQL-2011 - Temporal DB
  - SQL-2016 - JSON

SQL

- Data Definition Language (DDL) - alter database scheme
- Data Manipulation Language (DML) - alter database data & data retrieval
- Data Control Language (DCL) - configuration, access management, ...

SELECT Statement and Relational Algebra

- Basic structure of the SELECT statement:

  SELECT $A_1, \ldots, A_n$
  FROM $R_1, \ldots, R_m$
  WHERE *condition*

SELECT Statement and Relational Algebra

- Basic structure of the SELECT statement:

  SELECT $A_1, \ldots, A_n$ - which columns will be returned
  FROM $R_1, \ldots, R_m$
  WHERE *condition*

SELECT Statement and Relational Algebra

- Basic structure of the SELECT statement:

SELECT $A_1, \ldots, A_n$	- which columns will be returned
FROM $R_1, \ldots, R_m$	- from which tables we will read data
WHERE *condition*	

SELECT Statement and Relational Algebra

- Basic structure of the SELECT statement:

SELECT $A_1, \dots, A_n$	- which columns will be returned
FROM $R_1, \dots, R_m$	- from which tables we will read data
WHERE *condition*	- which condition has to be satisfied by returned rows

SELECT Statement and Relational Algebra

- Basic structure of the SELECT statement:

  SELECT $A_1, \ldots, A_n$
  FROM $R_1, \ldots, R_m$
  WHERE *condition*

  $$\Updownarrow$$

  $$\pi_{A_1,\ldots,A_n}\left(\sigma_{condition}(R_1 \times \cdots \times R_m)\right)$$

- The only difference between these two statements concerns duplications

SELECT Statement and Relational Algebra

- Basic structure of the SELECT statement:

  SELECT $A_1, \ldots, A_n$
  FROM $R_1, \ldots, R_m$
  WHERE *condition*

  $$\Updownarrow$$

  $$\pi_{A_1,\ldots,A_n}\left(\sigma_{condition}(R_1 \times \cdots \times R_m)\right)$$

- The only difference between these two statements concerns duplications

SELECT Statement and Relational Algebra (JOIN)

- Basic structure of the SELECT statement:

SELECT $A_1, \ldots, A_n$
FROM R_1
JOIN R_2 ON *join_condition* - Theta join between tables
WHERE *condition*

$\Updownarrow$

$\pi_{A_1,\ldots,A_n}(\sigma_{condition}(R_1 \bowtie_{join\_condition} R_2))$

SELECT Statement and Relational Algebra (JOIN)

- Basic structure of the SELECT statement:

SELECT $A_1, \ldots, A_n$
FROM R_1
JOIN R_2 ON *join_condition* - Theta join between tables
WHERE *condition*

$$\Updownarrow$$

$$\pi_{A_1,\ldots,A_n}\left(\sigma_{condition}\left(R_1 \bowtie_{join\_condition} R_2\right)\right)$$

Sakila Database

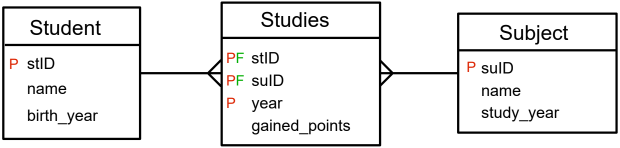
- Sakila database `https://github.com/ivanceras/sakila`
- Open-source, well-designed, support for more database systems
- One database for lectures and exercises

Database model

- Student(stID, name, birth_year)

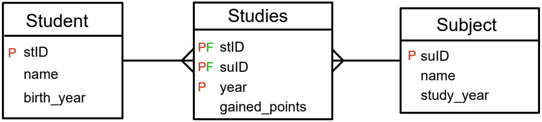
  Subject(suID, name, study_year)

  Studies(stID, suID, year, gained_points)



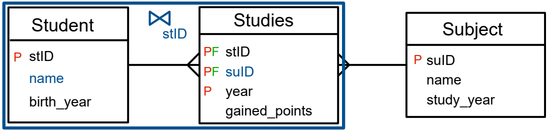
- The database stores students, subjects, and the information when a student studied given subject and how many points he/she gained

Example: Join of two tables



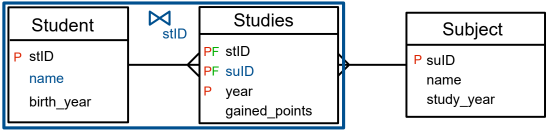
- *To every name of student find also suID of a subject, which he/she studies or studied.*

Example: Join of two tables



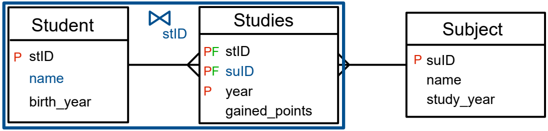
- *To every name of student find also suID of a subject, which he/she studies or studied.*

Example: Join of two tables



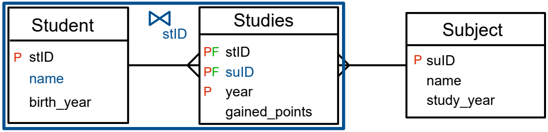
- *To every name of student find also suID of a subject, which he/she studies or studied.*
  - ```
    SELECT name, suID
    FROM Student
    JOIN Studies ON Student.stID = Studies.stID
    ```
  - $\pi_{name,suID}\left(Student \bowtie Studies\right)$
  - From the duplications perspective, the results of both queries do not have to be the same!
    ```

Example: Join of two tables



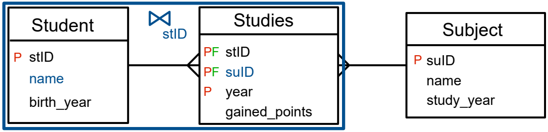
- *To every name of student find also suID of a subject, which he/she studies or studied.*
  - ```
    SELECT name, suID
    FROM Student
    JOIN Studies ON Student.stID = Studies.stID
    ```
  - $\pi_{name,suID}\ (Student \bowtie Studies)$
  - From the duplications perspective, the results of both queries do not have to be the same!
    ```

Example: Join of Two Tables with Condition



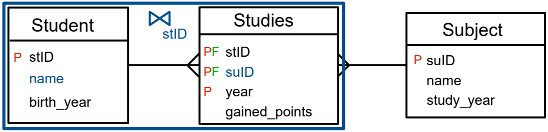
- *Find suIDs of all subjects, which students called Petr studied in 2010.*
  - ```
    SELECT name, suID
    FROM Student
    JOIN Studies ON Student.stID = Studies.stID
    WHERE year = 2010 and name = 'Petr'
    ```
  - $\pi_{suID}\left(\sigma_{year=2010 \wedge name='Petr'}(Student \bowtie Studies)\right)$
    ```

Example: Join of Two Tables with Condition



- *Find suIDs of all subjects, which students called Petr studied in 2010.*
  - ```
    SELECT name, suID
    FROM Student
    JOIN Studies ON Student.stID = Studies.stID
    WHERE year = 2010 and name = 'Petr'
    ```
  - $\pi_{suID}\left(\sigma_{year=2010\ \wedge\ name='Petr'}\left(Student \bowtie Studies\right)\right)$
    ```

Example: Join of Two Tables with Condition



- *Find suIDs of all subjects, which students called Petr studied in 2010.*
  - ```
    SELECT name, suID
    FROM Student
    JOIN Studies ON Student.stID = Studies.stID
    WHERE year = 2010 and name = 'Petr'
    ```
  - $\pi_{suID}\left(\sigma_{year=2010\ \wedge\ name='Petr'}\left(Student \bowtie Studies\right)\right)$
    ```

Example: Join of Two Tables with Condition

SELECT distinct pID

FROM Student

JOIN Study On Student.sID = Study.sID

WHERE year = 2011 and name = 'Petr'

Student

sID	name	birth_date
1	Petr	1990
2	Pavel	1991
3	Ivana	1990

Study

sID	pID	year	points
1	35	2010	23
1	35	2011	55
1	21	2010	89
2	46	2010	59

π_{pID}

$\sigma_{year=2011 \wedge name='Petr'}$

$Student \bowtie Study$

Example: Join of Two Tables with Condition

SELECT distinct pID

FROM Student

JOIN Study On Student.sID = Study.sID

WHERE year = 2011 and name = ’Petr’

π_{pID}

$\sigma_{year=2011 \wedge name='Petr'}$

$Student \bowtie Study$

Student

sID	name	birth_date
1	Petr	1990
2	Pavel	1991
3	Ivana	1990

Study

sID	pID	year	points
1	35	2010	23
1	35	2011	55
1	21	2010	89
2	46	2010	59

Student_Study

sID	name	birth_date	sID	pID	year	points
1	Petr	1990	1	35	2010	23
1	Petr	1990	1	35	2011	55
1	Petr	1990	1	21	2010	89
2	Pavel	1991	2	46	2010	59

Example: Join of Two Tables with Condition

SELECT distinct pID

FROM Student, Study

JOIN Study On Student.sID = Study.sID

WHERE year = 2011 and name = 'Petr'

π_{pID}

$\sigma_{year=2011 \,\wedge\, name='Petr'}$

$Student \bowtie Study$

Student

sID	name	birth_date
1	Petr	1990
2	Pavel	1991
3	Ivana	1990

Study

sID	pID	year	points
1	35	2010	23
1	35	2011	55
1	21	2010	89
2	46	2010	59

Student_Study

sID	name	birth_date	sID	pID	year	points
1	Petr	1990	1	35	2010	23
1	Petr	1990	1	35	2011	55
1	Petr	1990	1	21	2010	89
2	Pavel	1991	2	46	2010	59

Example: Join of Two Tables with Condition

SELECT distinct pID

FROM Student, Study

JOIN Study On Student.sID = Study.sID

WHERE year = 2011 and name = ’Petr’

π_{pID}

$\sigma_{year=2011\ \wedge\ name='Petr'}$

$Student \bowtie Study$

Student

sID	name	birth_date
1	Petr	1990
2	Pavel	1991
3	Ivana	1990

Study

sID	pID	year	points
1	35	2010	23
1	35	2011	55
1	21	2010	89
2	46	2010	59

Student Study **Duplication!**

sID	name	birth_date	sID	pID	year	points
1	Petr	1990	1	35	2010	23
1	Petr	1990	1	35	2011	55
1	Petr	1990	1	21	2010	89
2	Pavel	1991	2	46	2010	59

Example: Join of Two Tables with Condition

SELECT distinct pID

FROM Student, Study

JOIN Study On Student.sID = Study.sID

WHERE year = 2011 and name = 'Petr'

π_{pID}

$\sigma_{year=2011 \ \wedge \ name='Petr'}$

$Student \bowtie Study$

Student_Study

sID	name	birth_date	sID	pID	year	points
1	Petr	1990	1	35	2010	23
1	Petr	1990	1	35	2011	55
1	Petr	1990	1	21	2010	89
2	Pavel	1991	2	46	2010	59

Student_Study

sID	name	birth_date	sID	pID	year	points
1	Petr	1990	1	35	2011	55

Example: Join of Two Tables with Condition

SELECT distinct pID

FROM Student, Study

JOIN Study On Student.sID = Study.sID

WHERE year = 2011 and name = 'Petr'

π_{pID}

$\sigma_{year=2011 \ \wedge \ name='Petr'}$

$Student \bowtie Study$

Student_Study

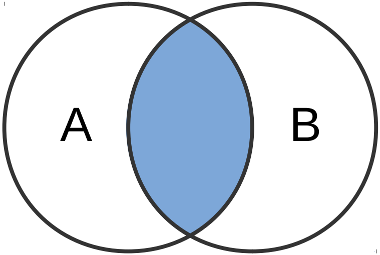
sID	name	birth_date	sID	pID	year	points
1	Petr	1990	1	35	2011	55

Student_Study

pID
35

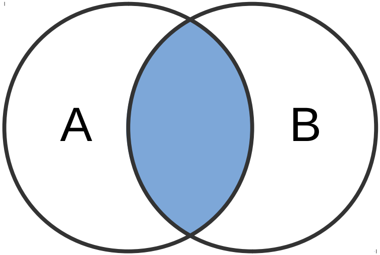
Inner Join Observation

```
SELECT *
FROM A
JOIN B ON A.k = B.k
```



Inner Join Observation

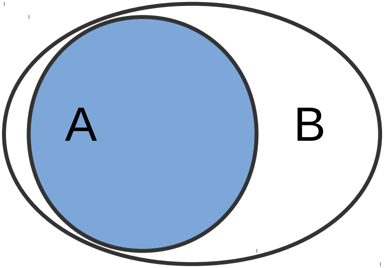
```
SELECT *
FROM A
JOIN B ON A.k = B.k
```



What if `A.k` is foreign key and `B.k` is a primary key?

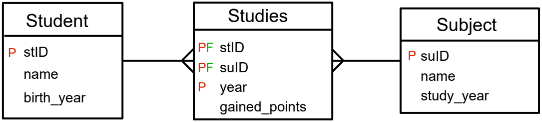
Inner Join Observation

```
SELECT *
FROM A
JOIN B ON A.k = B.k
```



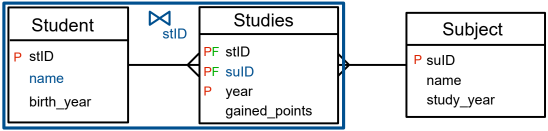
Note that set `B` is usually smaller (i.e. the visualization is not very accurate)

Example: Join of Three Tables



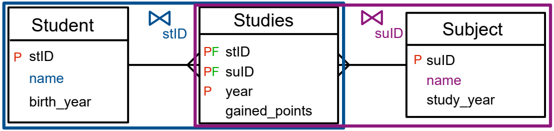
- *To each name of subject find name of student who studies or studied this subject.*

Example: Join of Three Tables



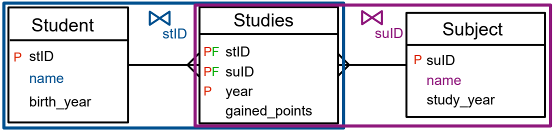
- *To each name of subject find name of student who studies or studied this subject.*
  - ```
    SELECT distinct Studies.suID, Student.name
    FROM Student
    JOIN Studies ON Student.stID = Studies.stID
    ```
    ```

Example: Join of Three Tables



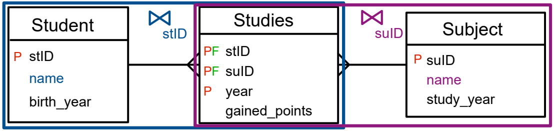
- *To each name of subject find name of student who studies or studied this subject.*
  - ```
    SELECT distinct Subject.name, Student.name
    FROM Student
    JOIN Studies ON Student.stID = Studies.stID
    JOIN Subject ON Studies.suID = Subject.suID
    ```
    ```

Example: Join of Three Tables



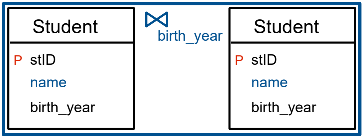
- *To each name of subject find name of student who studies or studied this subject.*
  - ```
    SELECT distinct Subject.name, Student.name
    FROM Student
    JOIN Studies ON Student.stID = Studies.stID
    JOIN Subject ON Studies.suID = Subject.suID
    ```
  - $\pi_{Subject.name, Student.name}(Student \bowtie Studies \bowtie Subject)$
    ```

Example: Join of Three Tables + Renaming a Relation



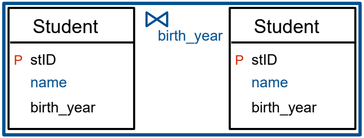
- *To each name of subject find name of student who studies or studied this subject.*
  - ```
    SELECT distinct su.name, st.name
    FROM Student st
    JOIN Studies se ON st.stID = se.stID
    JOIN Subject su ON se.suID = su.suID
    ```
  - $\pi_{Subject.name, Student.name}\ (Student \bowtie Studies \bowtie Subject)$
  - For the sake of clarity, we can rename the relations
    ```

Example: Self Join



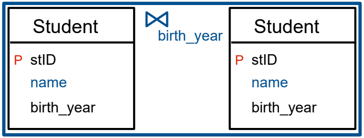
- *Find all pairs of students having the same birth year.*
  - ```
    SELECT s1.name, s2.name
    FROM Student s1
    JOIN Student s2
            ON s1.birth_year = s2.birth_year
    ```
    ```

Example: Self Join



- *Find all pairs of students having the same birth year.*
  - ```
    SELECT s1.name, s2.name
    FROM Student s1
    JOIN Student s2
            ON s1.birth_year = s2.birth_year
    ```
  - Not quite correct solution!
    ```

Example: Self Join



- *Find all pairs of students having the same birth year.*
  - ```
    SELECT s1.name, s2.name
    FROM Student s1
    JOIN Student s2
            ON s1.birth_year = s2.birth_year
            AND s1.stID > s2.stID
    ```
    ```

Inner Join Rules

Student

sID	name	birth_date
1	Petr	1990
2	Pavel	1991
3	Ivana	1990

Study

sID	pID	year	points
1	35	2010	23
1	35	2011	55
1	21	2010	89
2	46	2010	59

- **Multiplication** - Every student is repeated as many times as is the number of his studies
- **Elimination** - A student is eliminated if he did not study anything

Inner Join Rules

Student

sID	name	birth_date
1	Petr	1990
2	Pavel	1991
3	Ivana	1990

Study

sID	pID	year	points
1	35	2010	23
1	35	2011	55
1	21	2010	89
2	46	2010	59
null	null	null	null

- **Multiplication** - Every student is repeated as many times as is the number of his studies
- **Elimination** - A student is eliminated if he did not study anything

However, sometimes we do not want to eliminate!

Outer Join

Student

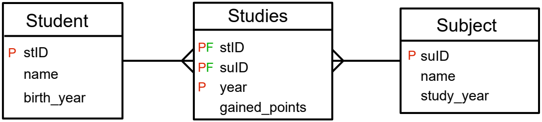
sID	name	birth_date
1	Petr	1990
2	Pavel	1991
3	Ivana	1990

Study

sID	pID	year	points
1	35	2010	23
1	35	2011	55
1	21	2010	89
2	46	2010	59
null	null	null	null

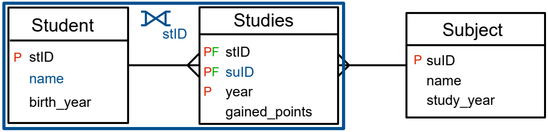
- This is called outer join
- We have more types of outer joins:
    - Left/Right outer join
    - Full outer join

Example: Left Outer Join



- *List names of students and suIDs of subjects studied by them; if a student does not study any subject, write NULL to his/her name.*

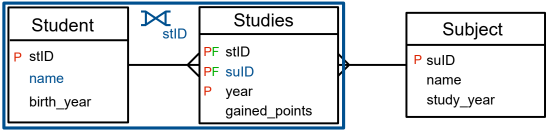
Example: Left Outer Join



- *List names of students and suIDs of subjects studied by them; if a student does not study any subject, write NULL to his/her name.*

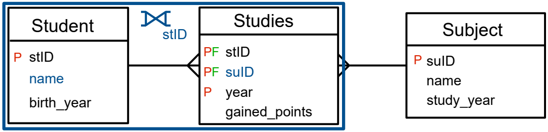
  - ```
    SELECT name, suID
    FROM Student
    LEFT JOIN Studies ON
         Student.stID = Studies.stID
    ```
    ```

Example: Left Outer Join with Condition



- *List student names and suIDs of subjects studied by them in 2011; if a student does not study a subject, write NULL to his name.*

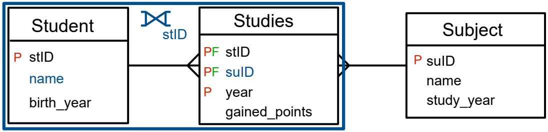
Example: Left Outer Join with Condition



- *List student names and suIDs of subjects studied by them in 2011; if a student does not study a subject, write NULL to his name.*

  - ```
    SELECT name, suID
    FROM Student
    LEFT JOIN Studies ON
            Student.stID = Studies.stID
    WHERE year = 2011
    ```
  - Is this correct?
    ```

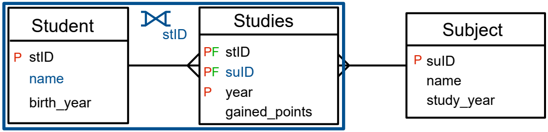
Example: Left Outer Join with Condition



- *List student names and suIDs of subjects studied by them in 2011; if a student does not study a subject, write NULL to his name.*

  - ```
    SELECT name, suID
    FROM Student
    LEFT JOIN Studies ON
          Student.stID = Studies.stID
    WHERE year = 2011
    ```
  - Is this correct?
    ```

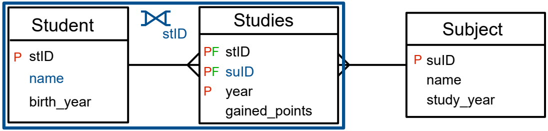
Example: LEFT OUTER JOIN with Condition



- *List student names and suIDs of subjects studied by them in 2011; if a student does not study a subject, write NULL to his name.*

  - ```
    SELECT name, suID
    FROM Student
    LEFT JOIN Studies ON
          Student.stID = Studies.stID
    WHERE year = 2011
    ```
  - No, it is not. The WHERE condition removes all students which does not study anything in 2011!
    ```

Example: LEFT OUTER JOIN with Condition



- *List student names and suIDs of subjects studied by them in 2011; if a student does not study a subject, write NULL to his name.*

  - ```
    SELECT name, suID
    FROM Student
    LEFT JOIN Studies ON
         Student.stID = Studies.stID
        AND year = 2011
    ```
    ```

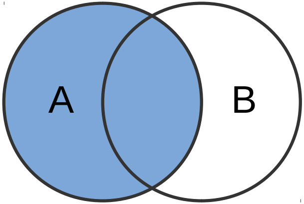
SQL Clausule Priority

1. `FROM`
2. `JOIN`
3. `WHERE`
4. `SELECT`
5. `...`

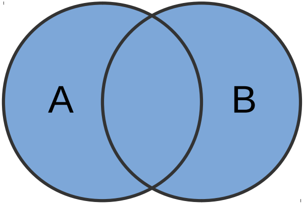
- Semantic order
- Not a query processing order!

Outer Join Visualization

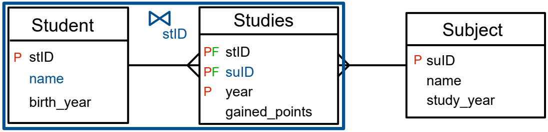
```
SELECT *
FROM A
LEFT JOIN B
         ON A.k = B.k
```




```
SELECT *
FROM A
FULL JOIN B
         ON A.k = B.k
```

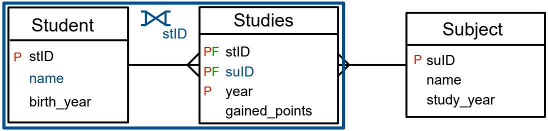


Example: Difference



- *List names of students who did not studied anything*

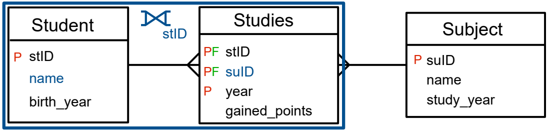
Example: Difference



- *List names of students and suIDs of subjects studied by them; if a student does not study any subject, write NULL to his/her name.*

  - ```
    SELECT name
    FROM Student
    LEFT JOIN Studies ON
           Student.stID = Studies.stID
    WHERE Studies.stID IS NULL
    ```
  - We will show other ways how to implement the difference later
    ```

Example: Difference



- *List names of students and suIDs of subjects studied by them; if a student does not study any subject, write NULL to his/her name.*

  - ```
    SELECT name
    FROM Student
    LEFT JOIN Studies ON
          Student.stID = Studies.stID
    WHERE Studies.stID IS NULL
    ```
  - We will show other ways how to implement the difference later
    ```

References

- Stránky UDBS na `http://dbedu.cs.vsb.cz`
- Relax. Relační algebra online na `https://dbis-uibk.github.io/relax/calc/local/uibk/local/0`
- Andrew Pavlo, CMU Database systems `https://www.youtube.com/watch?v=KG-mqHoXOXY`