ĐẠI HỌC

BÁCH KHOA

25 YEARS ANNIVERSARY

SOICT

HA NOI UNIVERSITY OF SCIENCE AND TECHNOLOGY
SCHOOL OF INFORMATION AND COMMUNICATION TECHNOLOGY

Lesson 2
Relational Algebra

Learning points

1. Introduction to relational algebra
2. Set operators
3. Relational operators: Projection, Selection, Rename, Join
4. Common extensions

Learning objectives

- Upon completion of this lesson, students will be able to:
    - Understand relational algebra operators
    - Write relational algebraic expressions

Keywords and descriptions

Keyword	Description
Relational data model	Is data representation format as a table of values, each row in the table represents a collection of related data values
Set	Is collection of Object
Operator	Is a special token that represent computations such as union, minus, selection, join, etc
Expression	Is an expression built up from operators and operands

Database Schema

student(**student_id**, first_name, last_name, dob, gender, address, note, *clazz_id*)

clazz(**clazz_id**, name, *lecturer_id*, *monitor_id*)

subject(**subject_id**, name, credit, percentage_final_exam)

enrollment(***student_id, subject_id, semester***, midterm_score, final_score)

lecturer(**lecturer_id**, first_name, last_name, dob, gender, address, email)

teaching(***subject_id, lecturer_id***)

grade(**code**, from_score, to_score)

Database

student

student_id	first_name	last_name	dob	…	clazz_id
20160001	Ngọc An	Bùi	3/18/1987	…	
20160002	Anh	Hoàng	5/20/1987	…	20162101
20160003	Thu Hồng	Trần	6/6/1987	…	20162101
20160004	Minh Anh	Nguyễn	5/20/1987	…	20162101
20170001	Nhật Ánh	Nguyễn	5/15/1988	…	20172201

clazz

clazz_id	name	lecturer_id	monitor_id
20162101	CNTT1.01-K61	02001	20160003
20162102	CNTT1.02-K61		
20172201	CNTT2.01-K62	02002	20170001
20172202	CNTT2.02-K62		

subject

subject_id	name	credit	percentage_final_exam
IT1110	Tin học đại cương	4	60
IT3080	Mạng máy tính	3	70
IT3090	Cơ sở dữ liệu	3	70
IT4857	Thị giác máy tính	3	60
IT4866	Học máy	2	70

enrollment

student_id	subject_id	semester	midterm_score	final_score
20160001	IT1110	20171	9	8.5
20160001	IT3080	20172	8	
20160001	IT3090	20172	6	9
20160001	IT4857	20172	7.5	9
20160001	IT4866	20172	7	9
20160002	IT3080	20172	9	
20160003	IT1110	20171	7	6
20160004	IT1110	20171	6	5

1. Introduction to relational algebra

- Relational algebra providing a theoretical foundation for relational databases, particularly query languages for relational databases.

- Relational algebra expression is composed of one or several relational algebraic operators:
  - Operator: represent computations
    - Input: one or two relations
    - Output: a relation
  - Unary operator (one input) vs. binary operator (two inputs)
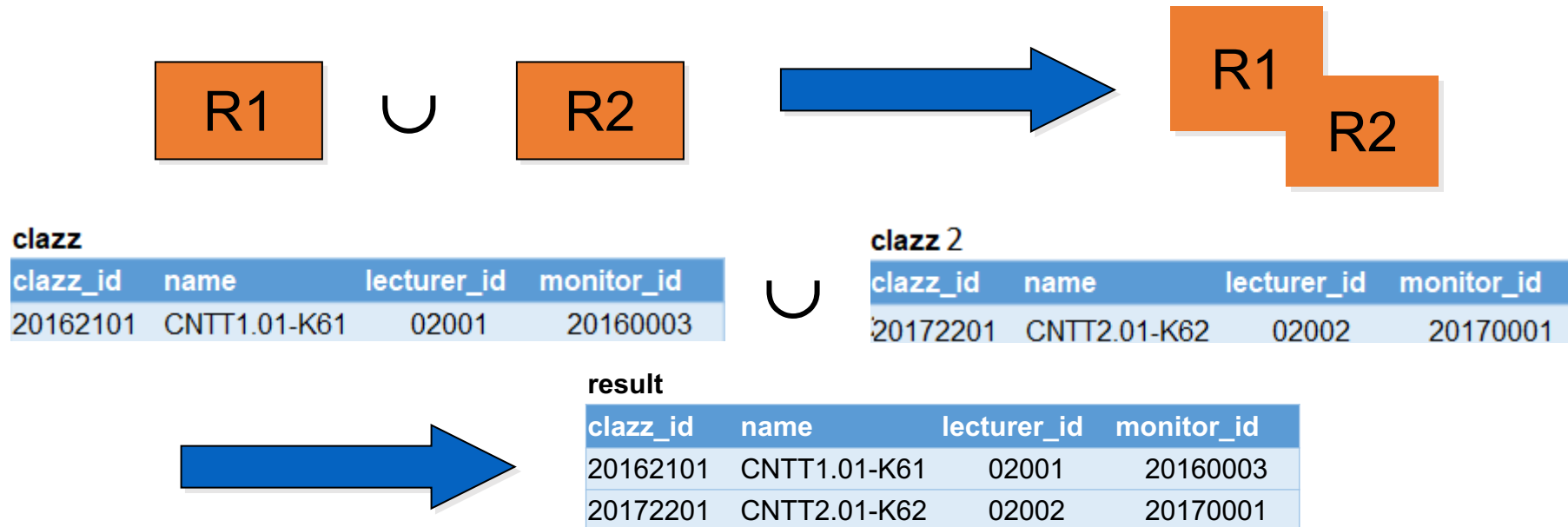
2. Set operators

2.1. Union

2.2. Intersection

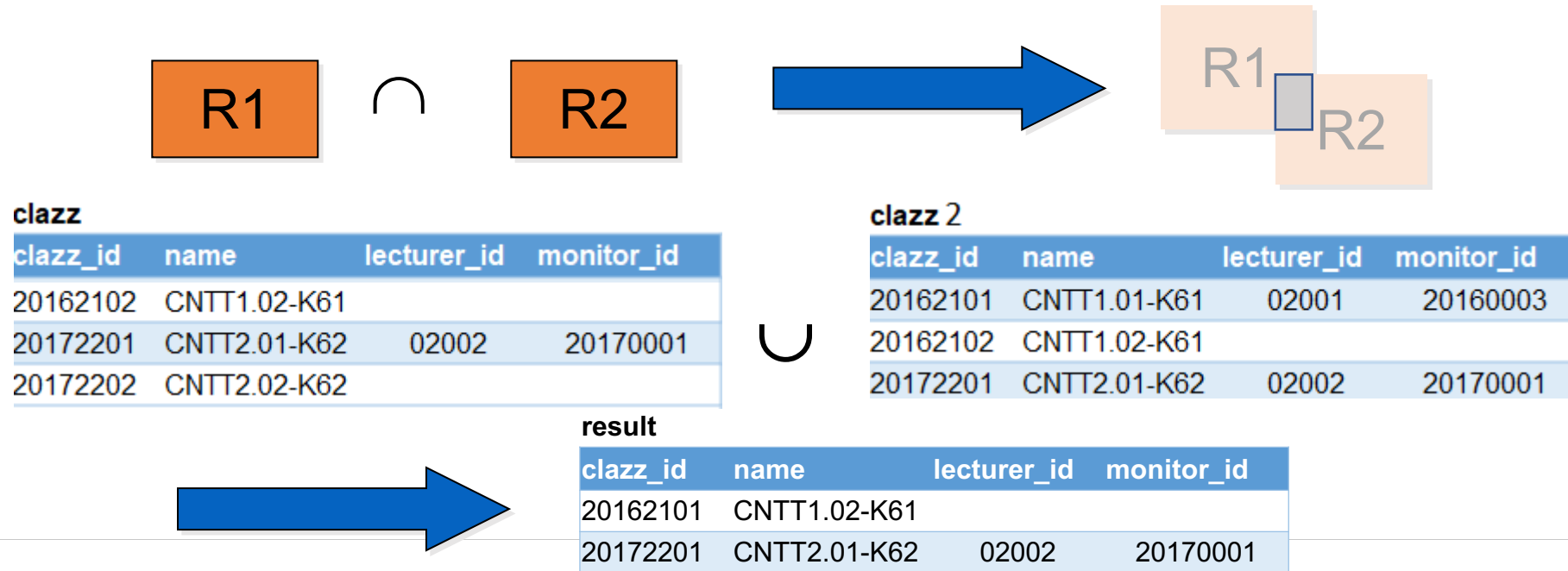2.3. Difference

2.4. Cartesian product

2.1. Union

- Combining the tuples from two *union-compatible relation* inputs (having the same set of attributes).
  - Warning: result does not contain duplicated records.

clazz

clazz_id	name	lecturer_id	monitor_id
20162101	CNTT1.01-K61	02001	20160003

∪

clazz 2

clazz_id	name	lecturer_id	monitor_id
20172201	CNTT2.01-K62	02002	20170001

result

clazz_id	name	lecturer_id	monitor_id
20162101	CNTT1.01-K61	02001	20160003
20172201	CNTT2.01-K62	02002	20170001

2.2. Intersection

- Keeping only common tuples from 2 input union-compatible relations.

clazz

clazz_id	name	lecturer_id	monitor_id
20162102	CNTT1.02-K61		
20172201	CNTT2.01-K62	02002	20170001
20172202	CNTT2.02-K62		

clazz 2

clazz_id	name	lecturer_id	monitor_id
20162101	CNTT1.01-K61	02001	20160003
20162102	CNTT1.02-K61		
20172201	CNTT2.01-K62	02002	20170001

result

clazz_id	name	lecturer_id	monitor_id
20162101	CNTT1.02-K61		
20172201	CNTT2.01-K62	02002	20170001

2.3. Difference

- Containing tuples occurred in the first relation but not in the second.
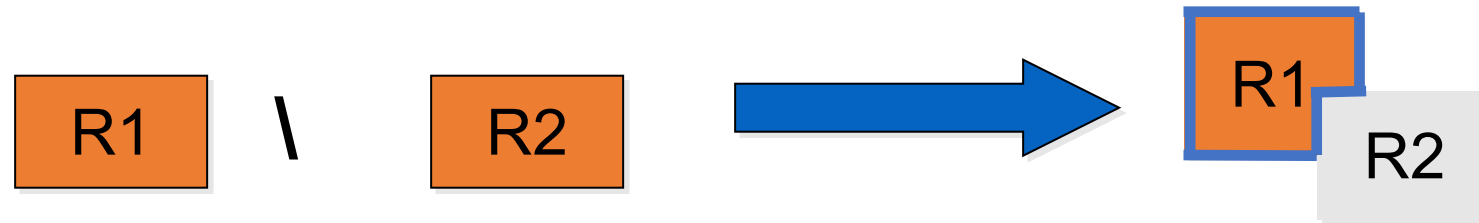
R1 \ R2 → R1 R2

clazz

clazz_id	name	lecturer_id	monitor_id
20162101	CNTT1.01-K61	02001	20160003
20162102	CNTT1.02-K61		
20172201	CNTT2.01-K62	02002	20170001
20172202	CNTT2.02-K62		

\

clazz 2

clazz_id	name	lecturer_id	monitor_id
20172202	CNTT2.02-K62		
20162102	CNTT1.02-K61		

result

clazz_id	name	lecturer_id	monitor_id
20162101	CNTT1.01-K61	02001	20160003
20172201	CNTT2.01-K62	02002	20170001

2.4. Cartesian Product

- The concatenation of every tuple of one relation with every tuple of the other relation.
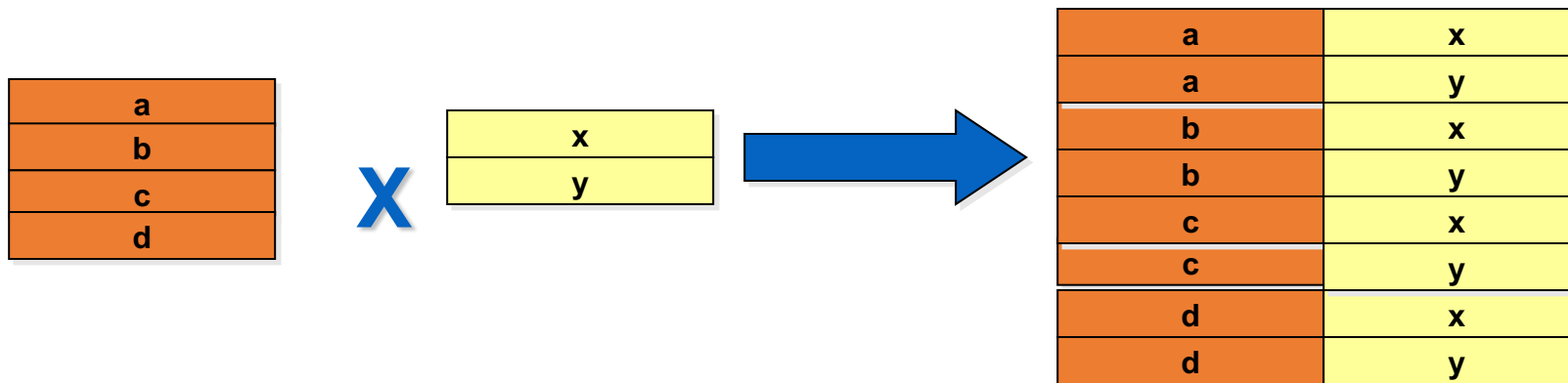
3. Relational algebra operators

3.1. Selection

3.2. Projection

3.3. Rename

3.4. Join

3.5. Division

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3.1. Selection

- Choose from R each tuple where the condition holds.

$$\sigma_{<condition>}(R)$$

R1
R2
R3
R4

→

R2
R3

clazz

clazz_id	name	lecturer_id	monitor_id
20162101	CNTT1.01-K61	02001	20160003
20162102	CNTT1.02-K61		
20172201	CNTT2.01-K62	02002	20170001
20172202	CNTT2.02-K62		

$$\sigma_{lecturer\_id \,!=\, null}(clazz)$$

result

clazz_id	name	lecturer_id	monitor_id
20162101	CNTT1.01-K61	02001	20160003
20172201	CNTT2.01-K62	02002	20170001

3.2. Projection

- Choose some attributes.
  - Warning: Result does not contain duplicated records.

$$\prod\nolimits_{A1, A2,\ldots}(R)$$

C1 C2 C3 C4 C5 → C2 C5

$$\prod\nolimits_{\text{clazz\_id, name}}(\text{clazz})$$

clazz

clazz_id	name	lecturer_id	monitor_id
20162101	CNTT1.01-K61	02001	20160003
20162102	CNTT1.02-K62		
20172201	CNTT2.01-K62	02002	20170001
20172202	CNTT2.01-K61		

result

clazz_id	name
20162101	CNTT1.01-K61
20162102	CNTT1.02-K62
20172201	CNTT2.01-K62
20172202	CNTT2.01-K61
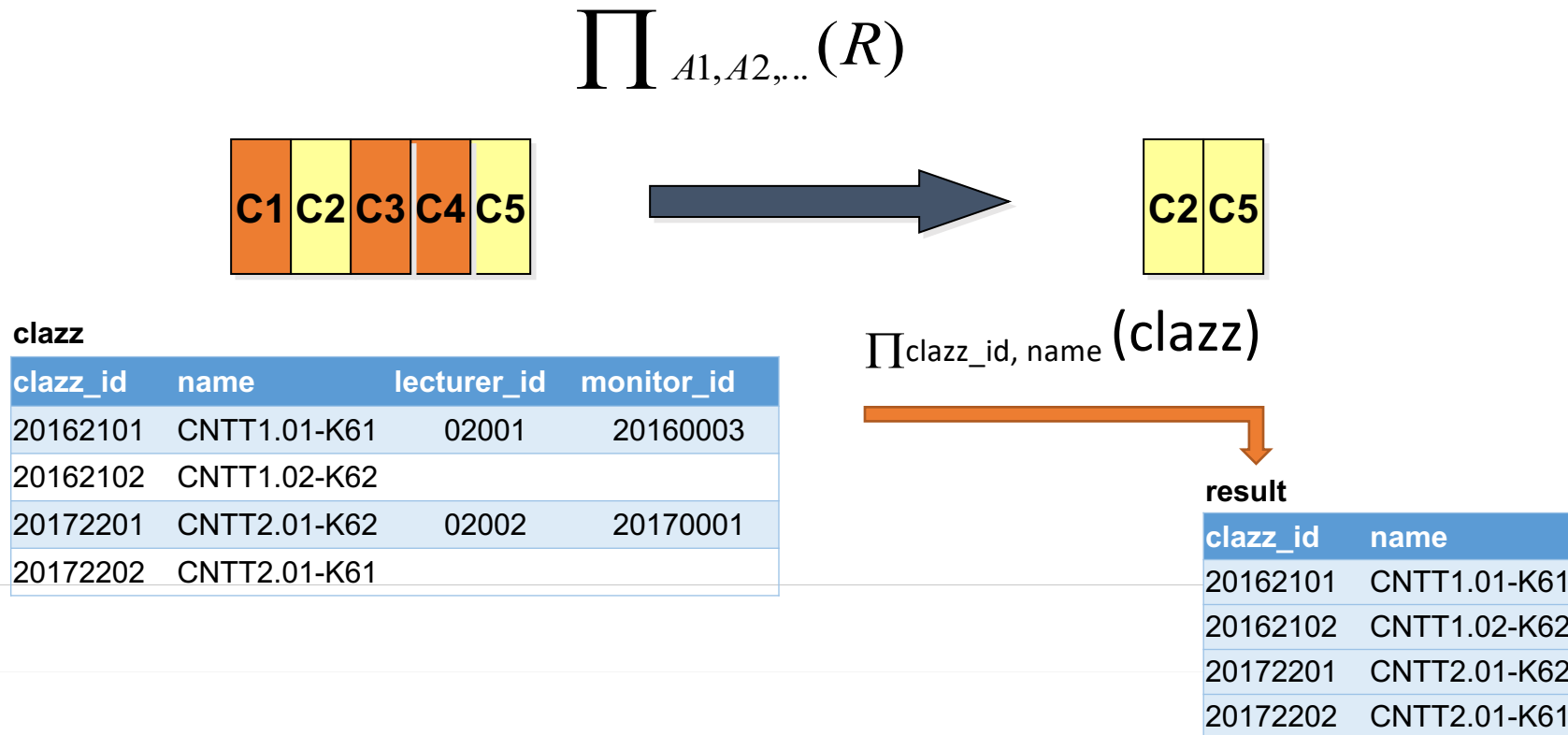
3.3. Rename

- Result is identical to R except that the b attribute in all tuples is renamed to an a attribute.

$$\rho_{a|b}(R)$$

clazz

clazz_id	name	lecturer_id	monitor_id
20162101	CNTT1.01-K61	02001	20160003
20162102	CNTT1.02-K61		
20172201	CNTT2.01-K62	02002	20170001
20172202	CNTT2.02-K62		

$$\rho_{\text{name of class} \mid \text{name}}(\text{clazz})$$

clazz

clazz_id	Name of class	lecturer_id	monitor_id
20162101	CNTT1.01-K61	02001	20160003
20162102	CNTT1.02-K61		
20172201	CNTT2.01-K62	02002	20170001
20172202	CNTT2.02-K62		

3.4. Join

- Combine attributes from 2 tables.

$$R_1 \bowtie_{<join\_condition>} R_2$$

a	r
b	r
c	v

$\bowtie$

r	x
s	y
t	z

→

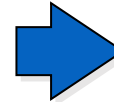| a	r	r	x
b	r	r	x

3.4. Join

$$\Pi_{\text{student\_id, first\_name, last\_name, clazz\_id}}(\text{Student}) \bowtie \Pi_{\text{clazz\_id, name}}(\text{clazz})$$

student

student_id	first_name	last_name	…	clazz_id
20160001	Ngọc An	Bùi		
20160002	Anh	Hoàng		20162101
20160003	Thu Hồng	Trần		20162101
20160004	Minh Anh	Nguyễn		20162101
20170001	Nhật Ánh	Nguyễn		20172201

clazz

clazz_id	name	lecturer_id	monitor_id
20162101	CNTT1.01-K61	02001	20160003
20162102	CNTT1.02-K61		
20172201	CNTT2.01-K62	02002	20170001
20172202	CNTT2.02-K62		

result

student_id	first_name	last_name	clazz_id	name
20160002	Anh	Hoàng	20162101	CNTT1.01-K61
20160003	Thu Hồng	Trần	20162101	CNTT1.01-K61
20160004	Minh Anh	Nguyễn	20162101	CNTT1.01-K61
20170001	Nhật Ánh	Nguyễn	20172201	CNTT2.01-K62

3.5. Division

- Divides a dividend relation R_1 or degree m+n by a divisor relation R_2 of degree n, and produces a quotient relation of degree m.

a	x
a	y
a	z
b	x
c	y

:

x
z

→

a

An example

- List student_id who enroll in all subjects.

enrollment

student_id	subject_id	semester	midterm_score	final_score
20160001	IT1110	20171	9	8.5
20160001	IT3080	20172	8	
20160001	IT3090	20172	6	9
20160001	IT4857	20172	7.5	9
20160001	IT4866	20172	7	9
20160002	IT3080	20172	9	
20160003	IT1110	20171	7	6
20160004	IT1110	20171	6	5

subject

subject_id	name	credit	percentage_final_exam
IT1110	Tin học đại cương	4	60
IT3080	Mạng máy tính	3	70
IT3090	Cơ sở dữ liệu	3	70
IT4857	Thị giác máy tính	3	60
IT4866	Học máy	2	70

An example

- List student_id who enroll in all subjects.

enrollment

student_id	subject_id	semester	midterm_score	final_score
20160001	IT1110	20171	9	8.5
20160001	IT3080	20172	8	
20160001	IT3090	20172	6	9
20160001	IT4857	20172	7.5	9
20160001	IT4866	20172	7	9
20160002	IT3080	20172	9	
20160003	IT1110	20171	7	6
20160004	IT1110	20171	6	5

subject

subject_id	name	credit	percentage_final_exam
IT1110	Tin học đại cương	4	60
IT3080	Mạng máy tính	3	70
IT3090	Cơ sở dữ liệu	3	70
IT4857	Thị giác máy tính	3	60
IT4866	Học máy	2	70

$\prod_{student\_id, subject\_id}$ (enrollement)

$\prod_{subject\_id}$ (subject)

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An example

- List student_id who enroll in all subjects.

enrollment

student_id	subject_id
20160001	IT1110
20160001	IT3080
20160001	IT3090
20160001	IT4857
20160001	IT4866
20160002	IT3080
20160003	IT1110
20160004	IT1110

subject

subject_id
IT1110
IT3080
IT3090
IT4857
IT4866

Result

student_id
20160001
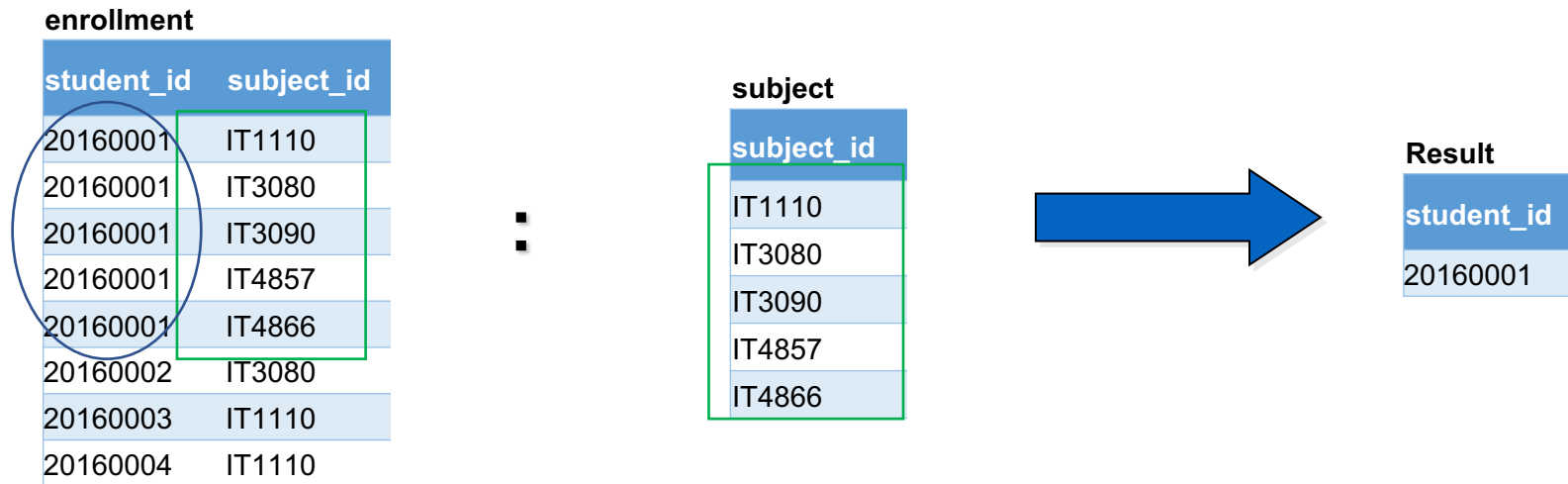
$(\prod_{\text{student\_id, subject\_id}} (\text{enrollement})) \div (\prod_{\text{subject\_id}} (\text{subject}))$

4. Common extension

4.1. Natural join

4.2. Outer join

4.3. Aggregation

4.1. Natural join

- Special join operation with equal join condition on their common attributes, noted *

student

student_id	first_name	last_name	dob	…	clazz_id
20160001	Ngọc An	Bùi	3/18/1987	…	
20160002	Anh	Hoàng	5/20/1987	…	20162101
20160003	Thu Hồng	Trần	6/6/1987	…	20162101
20160004	Minh Anh	Nguyễn	5/20/1987	…	20162101
20170001	Nhật Ánh	Nguyễn	5/15/1988	…	20172201

clazz

clazz_id	name	lecturer_id	monitor_id
20162101	CNTT1.01-K61	02001	20160003
20162102	CNTT1.02-K61		
20172201	CNTT2.01-K62	02002	20170001
20172202	CNTT2.02-K62		

results

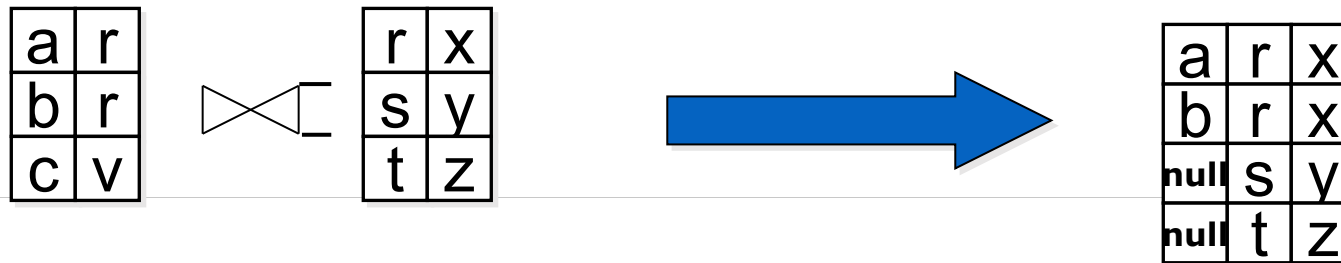| student_id	first_name	last_name	dob	…	clazz_id	Name	lecturer_id	Monitor_id
20160002	Anh	Hoàng	5/20/1987	…	20162101	CNTT1.01-K61	02001	20160003
20160003	Thu Hồng	Trần	6/6/1987	…	20162101	CNTT1.01-K61	02001	20160003
20160004	Minh Anh	Nguyễn	5/20/1987	…	20162101	CNTT1.01-K61	02001	20160003
20170001	Nhật Ánh	Nguyễn	5/15/1988	…	20172201	CNTT2.01-K62	02002	20170001
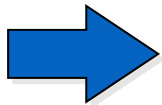
4.2. Outer join

- Left Outer join
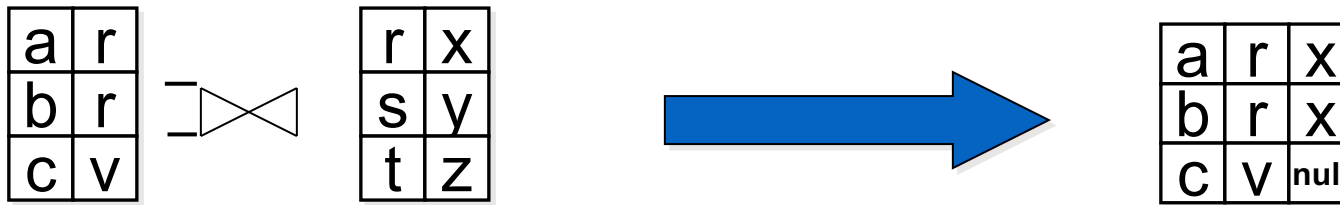
- Right Outer join

4.2. Outer join

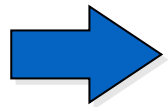- **Example of left-outer join:** List all students and class information if any

student

student_id	first_name	last_name	dob	…	clazz_id
20160001	Ngọc An	Bùi	3/18/1987	…	
20160002	Anh	Hoàng	5/20/1987	…	20162101
20160003	Thu Hồng	Trần	6/6/1987	…	20162101
20160004	Minh Anh	Nguyễn	5/20/1987	…	20162101
20170001	Nhật Ánh	Nguyễn	5/15/1988	…	20172201

clazz

clazz_id	name	lecturer_id	monitor_id
20162101	CNTT1.01-K61	02001	20160003
20162102	CNTT1.02-K61		
20172201	CNTT2.01-K62	02002	20170001
20172202	CNTT2.02-K62		

results

student_id	first_name	last_name	dob	…	clazz_id	Name	lecturer_id	Monitor_id
20160001	Ngọc An	Bùi	3/18/1987					
20160002	Anh	Hoàng	5/20/1987	…	20162101	CNTT1.01-K61	02001	20160003
20160003	Thu Hồng	Trần	6/6/1987	…	20162101	CNTT1.01-K61	02001	20160003
20160004	Minh Anh	Nguyễn	5/20/1987	…	20162101	CNTT1.01-K61	02001	20160003
20170001	Nhật Ánh	Nguyễn	5/15/1988	…	20172201	CNTT2.01-K62	02002	20170001

4.3. Aggregation

- Aggregation

$$G_1, G_2, \ldots G_n \; \mathcal{G} \; F_1(A_1), F_2(A_2), \ldots F_n(A_n) \; (\mathcal{R})$$

- $G_1, G_2, \ldots G_n$ is a list of attributes on which to group $F_1(A_1)$, $F_2(A_2), \ldots F_n(A_n)$ is a list of aggregation function on attribute $A_1, A_2, \ldots A_n$
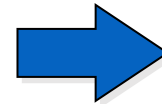
4.3. Aggregation

- Example of Aggregation

$$G_{student\_id} \; Gcount(subject\_id) \; (enrollment)$$

enrollment

student_id	subject_id	semester	midterm_score	final_score
20160001	IT1110	20171	9	8.5
20160001	IT3080	20172	8	
20160001	IT3090	20172	6	9
20160001	IT4857	20172	7.5	9
20160001	IT4866	20172	7	9
20160002	IT3080	20172	9	
20160003	IT1110	20171	7	6
20160004	IT1110	20171	6	5

results

student_id	count(subject_id)
20160001	5
20160002	1
20160003	1
20160004	1

4.3. Aggregation

- Example of Aggregation

$$G \text{ count(student\_id) (student)}$$

student

student_id	first_name	last_name	dob	…	clazz_id
20160001	Ngọc An	Bùi	3/18/1987	…	
20160002	Anh	Hoàng	5/20/1987	…	20162101
20160003	Thu Hồng	Trần	6/6/1987	…	20162101
20160004	Minh Anh	Nguyễn	5/20/1987	…	20162101
20170001	Nhật Ánh	Nguyễn	5/15/1988	…	20172201
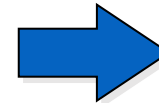
value not a relation

5

Summary

- Introduction to relational algrebra
    - Procedural langue
- Set operators
    - Union, intersection, difference
- Relational operators
    - Projection, Selection, Rename, Join
- Common extensions
    - Natural join, Outer join, Aggregation

Thank you for your attentions!

VIỆN CÔNG NGHỆ THÔNG TIN VÀ TRUYỀN THÔNG
SCHOOL OF INFORMATION AND COMMUNICATION TECHNOLOGY

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