

# Relational Algebra (Part 2)

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## **Summary of Relational Operators**

Operator	Notation	Meaning
Selection	$\sigma_{arphi}(R)$	choose rows
Projection Ass	ignament Projec	tchaose ddtalpns
Union Intersection Difference	Rtps://tutorcs R1 \cap R2 WeChat: cstu	com set operations orcs
Cartesian product Join Natural-join	$R_1 \times R_2$ $R_1 \bowtie_{\varphi} R_2$ $R_1 \bowtie R_2$	combine tables
Renaming	$ \begin{array}{c} \rho_{R'(A_1,,A_n)}(R) \\ \rho_{R'}(R) \\ \rho_{(A_1,,A_n)}(R) \end{array} $	rename relation and attributes

### **A Complete Set of Relational Operators**

- The following six operators constitute a complete set:

  - projection  $\pi$ ; https://tutorcs.com
  - renaming  $\rho$ ; WeChat: cstutorcs
  - union ∪;
  - difference –;
  - Cartesian product ×.

### **A Complete Set of Relational Operators**

- Six operators (i.e., selection  $\sigma$ , projection  $\pi$ , renaming  $\rho$ , union  $\cup$ , difference and Cartesian product  $\times$ ) constitute a complete set.

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- It means that the other RA operators like intersection and join are not necessary and can hetexpressed by these six operators.
  - join:  $R_1 \bowtie_{\varphi} R_2$  join:  $R_1 \bowtie_{\varphi} R_2$  join:  $R_1 \bowtie_{\varphi} R_2$  join:  $R_1 \bowtie_{\varphi} R_2$  join:  $R_2 \bowtie_{\varphi} R_2$
  - intersection:  $R_1 \cap R_2 = R_1 (R_1 R_2)$
- Hence, intersection and join do not increase the expressive power of RA.
- Nonetheless it is important to include intersection and join because they are convenient to use and commonly applied in database applications.

#### **Relational Algebra Queries**

- The output of each RA operation is a relation, which can be used again as the input for another RA operation.
- RA operations can be nested to arbitrary depth for expressing complex queries, as in antimetic.
  - Parentheses and typecedent corosless define the order of evaluation: from highest to lowest:  $\{\sigma, \pi, \rho\}$ ,  $\{\times, \bowtie\}$ ,  $\{\cap\}$ ,  $\{\cup, -\}$
  - Operators with We Sahret prested to Sare evaluated from left to right.
  - Use brackets if you are not sure.
- A query in RA is a sequence of RA operations and each RA operation takes one or two relations as its input and produces one relation as its output.
- Different from SQL, RA considers relations as sets (not multisets as in SQL). Hence, relations produced by an RA operation have no duplicate tuples.

#### **Hints for Writing RA Queries**

- Firstly, identify which relations need to be involved, while ignoring the rest.
- Then break the answer down by considering intermediate relations, i.e., queries may be expressed as a sequence of assignment statements.

**Example:**  $R := \pi_{HTeam,GTeam}(\sigma_{HScore=1}(\rho_{(HTeam,HScore,GScore,GTeam)}(SOCCER)))$ https://tutorcs.com

- Use good names for intermediate relations;
- Keep track of attributes you have at each step.
- When combining relations, check attribute names and make sure that:
  - attributes that should match are to match.
  - attributes that shouldn't match are not to match.
- When using set operations, make sure that two relations of an operation have the same type (i.e., type compatibility).



• Given the following relation schema:

STUDENT={StudentID, Name, DoB}

• Query 1: Find paris the students wish to have the part of the paris of the paris

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STUDENT			
StudentID Name DoB			
457	Lisa	18-Oct-1993	
458	Mike	16-May-1990	
459	Peter	18-Oct-1993	

• Given the following relation schema:

```
STUDENT={StudentID, Name, DoB}
```

• Query 1: Find parison students wie have with a me with the day. Show their names.

```
https://tutorcs.com
```

```
\pi_{R_1.Name,R_2.Name}(\sigma_{R_1.StudentID} < R_2.StudentID(\sigma_{R_1.DoB} = R_2.DoB(\rho_{R_1}(STUDE)))
```

```
SELECT R_1.name, R_2.name

FROM Student AS R_1, Student AS R_2

WHERE R_1.DoB = R_2.DoB AND R_1.StudentID < R_2.StudentID;
```

- Why do we need  $\sigma_{R_1.StudentID < R_2.StudentID}$  in the above query?
- Why do we need to use renaming in the above query?

• Given the following relation schema:

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Query 1: Find pairs of students who have the same birthday. Show their names.
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#### Two different solutions: cstutorcs

- (1).  $\pi_{R_1.Name,R_2.Name}(\sigma_{R_1.StudentID < R_2.StudentID}(\sigma_{R_1.DoB=R_2.DoB}(\rho_{R_1}(STUDENT) \times \rho_{R_2}(STUDENT)))$
- (2).  $\pi_{Name,Name'}(\sigma_{StudentID < StudentID'}(STUDENT))$ STUDENT  $\bowtie \rho_{S(StudentID',Name',DoB)}(STUDENT))$

 Query 1: Find pairs of students who have the same birthday. Show their names.

```
(1). \pi_{R_1.Name,R_2.Name} Project Exame P_{R_2.DoB} P_{R_2.DoB} P_{R_1.Name,R_2.DoB} (STUDENT) P_{R_2} (STUDENT)))

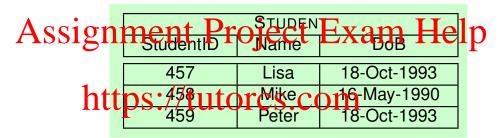
(2). \pi_{Name,Name'} (StudentID P_{R_2.DoB} (STUDENT) P_{R_2.DoB} (STUDENT) P_{R_2.DoB} (STUDENT) P_{R_2.DoB} (STUDENT) P_{R_2.DoB} (STUDENT) P_{R_2.DoB} (STUDENT) P_{R_2.DoB} (STUDENT)) P_{R_2.DoB} (STUDENT)
```

If evaluating our queries over the following relation, what will be the result?

STUDENT			
StudentID Name DoB			
457	Lisa	18-Oct-1993	
458	Mike	16-May-1990	
459	Peter	18-Oct-1993	

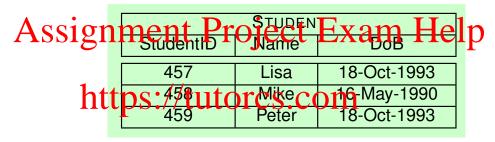


• Query 1 (solution 1):  $\pi_{R_1.Name,R_2.Name}(\sigma_{R_1.StudentID} < R_2.StudentID}(\sigma_{R_1.DoB=R_2.DoB}(\rho_{R_1}(STUDENT)))$ .



WAS (STUDENT) START (STUDENT)					
R <sub>1</sub> .StudentID	$R_1$ .Name	R <sub>1</sub> .DoB	R <sub>2</sub> .StudentID	$R_2$ .Name	R <sub>2</sub> .DoB
457	Lisa	18-Oct-1993	457	Lisa	18-Oct-1993
457	Lisa	18-Oct-1993	458	Mike	16-May-1990
457	Lisa	18-Oct-1993	458	Peter	18-Oct-1993
458	Mike	16-May-1990	457	Lisa	18-Oct-1993
458	Mike	16-May-1990	458	Mike	16-May-1990
458	Mike	16-May-1990	458	Peter	18-Oct-1993
458	Peter	18-Oct-1993	457	Lisa	18-Oct-1993
458	Peter	18-Oct-1993	458	Mike	16-May-1990
458	Peter	18-Oct-1993	458	Peter	18-Oct-1993

• Query 1 (solution 1):  $\pi_{R_1.Name,R_2.Name}(\sigma_{R_1.StudentID} < R_2.StudentID(\sigma_{R_1.DoB} = R_2.DoB(\rho_{R_1}(STUDENT)))$ .



	$R' = \sigma_{R_1} N_0 R_2 R_2 has (p_R C (STUPEO I) C S \rho_{R_2} (STUDENT))$					
R <sub>1</sub> .StudentID	$R_1$ .Name	R <sub>1</sub> .DoB	$R_2$ .StudentID	R <sub>2</sub> .Name	R <sub>2</sub> .DoB	
457	Lisa	18-Oct-1993	457	Lisa	18-Oct-1993	
457	Lisa	18-Oct-1993	459	Peter	18-Oct-1993	
458	Mike	16-May-1990	458	Mike	16-May-1990	
459	Peter	18-Oct-1993	457	Lisa	18-Oct-1993	
459	Peter	18-Oct-1993	459	Peter	18-Oct-1993	

$\pi$ R $_1$ .Name,R $_2$ .Name $(\sigma$ R $_1$ .StudentID $<$ R $_2$ .StudentID $(R'))$				
R <sub>1</sub> .Name				
Lisa	Peter			



• Query 1 (solution 2):  $\pi_{Name,Name'}(\sigma_{StudentID < StudentID'}(STUDENT))$ .



R <b>V¥ 6</b>	RVY Student & Estudent Comme', DoB) (STUDENT)				
StudentID	Name	DoB	StudentID'	Name'	
457	Lisa	18-Oct-1993	459	Peter	
459	Peter	18-Oct-1993	457	Lisa	
459	Peter	18-Oct-1993	459	Peter	
457	Lisa	18-Oct-1993	457	Lisa	
458	Mike	16-May-1990	458	Mike	

$\pi_{Name,Name'}(\sigma_{StudentID} < StudentID'(R'))$		
Name	Name'	
Lisa	Peter	

• Given the following relation schemas:

STUDENT={StudentID, Name, DoB}
ENROL={StudentID, CourseNo, Semester, EnrolDate}

• Query 2: Which stigents have he in the control of the control of

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Stude	StudentID Name DoB Wellhat: cstutorcs 456 Tom 02-Jan-1991				
45	6	Iom	02-Jan-1991		
45	57	Lisa	18-Oct-1993		
45	8	Mike	16-May-1990		

Enrol					
StudentID	CourseNo	EnrolDate			
456	COMP2400	2010 S2	02-Jul-2010		
458	COMP2400	2010 S2	23-Jun-2010		
458	COMP2600	2010 S2	05-Aug-2010		



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STUDENT={StudentID, Name, DoB}
ENROL={StudentID, CourseNo, Semester, EnrolDate}

• Query 2: Which stigents have her included him the plant of the stigents have the long of the stigents and names.

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#### **Hints:**

- (1) All the students
- (2) Students who have enrolled in at least one course

Answer: Students in the result (1) but not in the result (2).

• Given the following relation schemas:

STUDENT={StudentID, Name, DoB}
ENROL={StudentID, CourseNo, Semester, EnrolDate}

- Query 2: Which stigents have her enforcement the lip pourse? Show their IDs and names.
  - (1) All the students <a href="https://tutorcs.com">https://tutorcs.com</a>

(2) Students who have enrolled in at least one course

$$R_2 := \pi_{StudentID}(\mathsf{ENROL})$$

Answer: Students in the result (1) but not in the result (2)

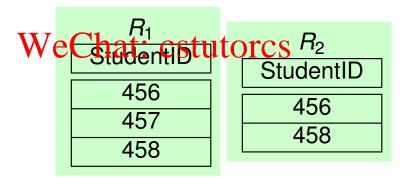
$$\pi_{StudentID,Name}((R_1-R_2)\bowtie \mathsf{STUDENT})$$

- Query 2: Which students have never enrolled in any course? Show their IDs and names.
- If evaluating our query over the following relations, what will be the result?
  - $R_1 := \pi_{St} A_{SS}$  Significant Project Exam Help
  - $R_2 := \pi_{StudentID}(ENROL)$
  - π<sub>StudentID, Name</sub>((**fittps://tutores.in**)

STUDENT			
Studentil	Name	DoB	
456	Tom	02-Jan-1991	
457	Lisa	18-Oct-1993	
458	Mike	16-May-1990	

Enrol					
StudentID	CourseNo	Semester	EnrolDate		
456	COMP2400	2010 S2	02-Jul-2010		
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  - $R_1 := \pi_{St} A_{SS} i$  STIMPEINT Project Exam Help
  - $R_2 := \pi_{StudentID}(ENROL)$
  - $\pi_{StudentID,Name}((Rttps?))$ tratores.



$\pi$ StudentID,Na	$\pi_{StudentID,Name}((R_1-R_2)\bowtie STUDENT)$	
StudentID	Name	
457	Lisa	



• Given the following relation schemas:

STUDENT={StudentID, Name, DoB}
ENROL={StudentID, CourseNo, Semester, EnrolDate}

• Query 3: Which stigents have bring out of the country of the cou

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	StudentID	Name	DoB
	456	Tom	02-Jan-1991
İ	457	Lisa	18-Oct-1993
	458	Mike	16-May-1990

ENROL			
StudentID	CourseNo	Semester	EnrolDate
456	COMP2400	2010 S2	02-Jul-2010
457	COMP2400	2010 S2	08-Jul-2010
458	COMP2400	2010 S2	23-Jun-2010
458	COMP2600	2010 S2	05-Aug-2010



Given the following relation schemas:

STUDENT={StudentID, Name, DoB}
ENROL={StudentID, CourseNo, Semester, EnrolDate}

• Query 3: Which still have only enfolled in the course COMP2400? Show their IDs and names.

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- (1) Students who have enrolled in the course COMP2400.
- (2) Students who have enrolled in a course but not COMP2400.

Answer: Students in the result (1) but not in the result (2).

• Given the following relation schemas:

```
STUDENT={StudentID, Name, DoB}
ENROL={StudentID, CourseNo, Semester, EnrolDate}
```

- Query 3: Which stigents have only entrolled in the course COMP2400? Show their IDs and names.
  - (1) Students who have enrolled in the course COMP2400.

(2) Students who have enrolled in a course but not COMP2400.

$$R_2 := \pi_{StudentID}(\sigma_{CourseNo \neq `COMP2400'}(ENROL))$$

Answer: Students in the result (1) but not in the result (2).

$$\pi_{StudentID,Name}((R_1 - R_2) \bowtie STUDENT) =$$

$$\pi_{StudentID,Name}((\pi_{StudentID}(\sigma_{CourseNo=`COMP2400`}(ENROL)) - \pi_{StudentID}(\sigma_{CourseNo\neq`COMP2400`}(ENROL))) \bowtie STUDENT)$$

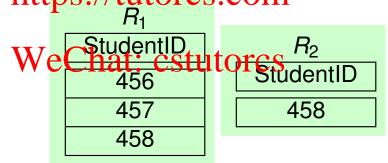
- Query 3: Which students have only enrolled in the course COMP2400? Show their IDs and names.
- If evaluating our query over the following relations, what will be the result?

  - $R_1 := \pi_{StudentID}(\sigma_{CourseNo='COMP2400'}(ENROL))$   $R_2 := \pi_{StudentID}(\sigma_{CourseNo='COMP2400'}(ENROL))$
  - $\pi_{StudentID,Name}((R_1 R_2) \bowtie STUDENT)$

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StudentID	Name	l DoB l
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VV С45gat.	CSTOPHOT	<b>6</b> 2-Jan-1991
457	Lisa	18-Oct-1993
757		
458	Mike	16-May-1990
		,

ENROL			
StudentID	CourseNo	Semester	EnrolDate
456	COMP2400	2010 S2	02-Jul-2010
457	COMP2400	2010 S2	08-Jul-2010
458	COMP2400	2010 S2	23-Jun-2010
458	COMP2600	2010 S2	05-Aug-2010

- Query 3: Which students have only enrolled in the course COMP2400?
   Show their IDs and names.
- If evaluating our query over the following relations, what will be the result?
  - $R_1 := \pi_{StudentID}(\sigma_{CourseNo='COMP2400'}(ENROL))$
  - $R_2 := \pi_{studential} Project(Exam) Help$
  - $\pi_{StudentID,Name}((R_1 R_2) \bowtie STUDENT)$ • https://tutorcs.com



$\pi_{StudentID,Name}((R_1-R_2)owtiengs$ STUDENT)	
StudentID	Name
456	Tom
457	Lisa



### More Hints for Writing RA Queries

Pay attention to keywords like not, never, only, always, exactly, etc. which often indicates the use of **difference** in the corresponding RA queries.

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To show "never":

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   Find all the (combinations of) tuples that are involved.
- Use difference We shat that the set that have occurred.
- To show "only" and "always":
  - Find all the (combinations of) tuples that are involved.
  - Use difference to subtract those that didn't always occur.

### **Equivalence of RA and SQL Queries (1)**

Each RA query can be easily re-written in SQL, or vice versa.

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• Selection:  $\sigma_{\varphi}(R)$  corresponds to

```
SELECT DISTINCTON: FROM OF COMERCING;
```

Projection: πΑΥΥΕΘΕΡΕΡΕΡΕΙΟ

```
SELECT DISTINCT A_1, \ldots, A_n FROM R;
```

• Renaming:  $\rho_{S(B_1,...,B_n)}(R)$  (with attributes  $A_1,...,A_n$  in R) corresponds to

```
SELECT A_1 AS B_1, \ldots, A_n AS B_n FROM R AS S;
```

#### **Equivalence of RA and SQL Queries (2)**

• Union:  $R_1 \cup R_2$  corresponds to

```
SELECT * FROM R_1 UNION SELECT * FROM R_2

Intersection: R_1 \cap R_2 corresponds to

SELECT * FROM R_1 \cap R_2 (with attributes R_1 \cap R_2)

Difference: R_1 - R_2 (with attributes R_1 \cap R_2) corresponds to

SELECT * FROM R_1 \cap R_2 (with attributes R_1 \cap R_2)

SELECT * FROM R_1 \cap R_2

SELECT DISTINCT * FROM R_1 \cap R_2

WHERE R_1 \cap R_2 \cap R_2

WHERE R_1 \cap R_2 \cap R_3 \cap R_3 \cap R_4

WHERE R_1 \cap R_2 \cap R_3 \cap R_4 \cap R_4 \cap R_4
```

SQL eliminates duplicate tuples in the resulting relations of set operations UNION, INTERSECT and EXCEPT.

#### **Equivalence of RA and SQL Queries (3)**

- Cartesian Product:  $R_1 \times R_2$  corresponds to SELECT AFRIGINATION Project Exam Help
- Join:  $R_1 \bowtie_{\varphi} R_2$  topose \$\text{tortastos.com}

```
SELECT DISTINCT * FROM R_1 INNER JOIN R_2 ON \varphi; (\varphi \text{ may contain } =, <, \leq, >, \geq, \neq)
```

• Natural-Join:  $R_1 \bowtie R_2$  corresponds to

```
SELECT DISTINCT * FROM R_1 NATURAL JOIN R_2;
```

Outer joins are not considered in the traditional relational algebra, as well as aggregation.

### **Summary**

RA is a procedural query language defined in the relational model.

An RA query it suggestant procedure fox against leding the result (i.e., implement the query).

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RA is not used as a query language by users.

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- RA is used for the internal representation and processing of SQL queries in relational DBMSs, which is a basis of query optimisation techniques.
- Thus, to understand how SQL queries are processed and how they can be optimised, we first need to understand relational algebra.