CHAPTER 4

Module III

Relational Algebra

Syllabus

Introduction to Relational Algebra, Relational Algebra expressions for Unary Relational Operations, Set Theory operations, Binary Relational operation, Relational Algebra Queries, Self-learning Topics: Map the ER model designed in module II to relational schema.

4.1 Relational Algebra

Q. Explain any four relational algebra operations with proper examples. **MU - Dec. 14, Dec. 16, 10 Marks**

Q. Discuss fundamental operations in relational algebra. **MU - May 17, 10 Marks**

- Relational algebra becomes popular after the publication of E.F. Codd's relational model of data in 1970.
- It is procedural language useful for representing query execution plan and relatively close to SQL.
- Relational algebra is set of operations which accept one relation and produces new relation as a result.
- This query is applied to tables/relations and output is also a table/relation.
- Fundamental operations of Relational Algebra,
- Unary Relational Operations
  - Project operation (π)
  - Select operation (σ)
  - Rename operation (ρ)
- SET Theory Operations
  - Union operation ($\cup$)
  - Difference operation (-)
  - Intersection operation ($\cap$)
- Binary Operations
  - Join operations ($\bowtie$)
  - Cartesian product operations (X)
  - Division operation (%)

4.2 Selection Operation (σ)

Q. Describe the following relational algebra operation : Select. **MU - Dec. 15, 3 Marks**

Q. Explain different types of operators in relational algebra. **MU - Dec. 17, May 18, Dec.19, 10 Marks**

Q. Explain Illustrate relational algebra with example. **MU - Dec. 18, 10 Marks**

a. Overview

- This operator is used to select some rows from table which satisfy particular selection condition given in selection operation.
- Selection operator selects a set of tuples that satisfy a selection predicate or condition.
- Output of query is exactly same as input schema of table.
- This is unary relational operator having only one input table.

b. Syntax

σ <attribute name><comparison operator><constant value> (Input_Table_Name)

Where,

Attribute_name : Name of column in table

Comparison_operator : =, <, < =, >, > =, < >

c. Example

Eid	Ename	Age	Salary
1	Suhas	24	50000
2	Jayendra	24	15000
3	Sachin	25	52000
4	Mahesh	23	41000
5	Satish	34	25000
6	Suma	54	50000
7	Raj	69	45000
8	Anu	74	50000

Query : Select all employees having age below 30 years.

Solution : $\sigma_{age < 30}$ **(Employee)**

Eid	Ename	Age	Salary
1	Suhas	24	50000
2	Jayendra	24	15000
3	Sachin	25	52000
4	Mahesh	23	41000

d. Combining multiple conditions

We can have more than one predicate by using logical connectives like AND ($\wedge$), OR ($\vee$).

Query : Select all employees having salary above 5000 and age above 65.

Solution : $\sigma_{salary > 5000 \wedge age > 65}$ **(Employee)**

Eid	Ename	Age	Salary
7	Raj	69	45000
8	Anu	74	50000

Query : Select all employees with either salary above 50000 or age above 65.

Solution : $\sigma_{salary > 50000 \vee age > 65}$ **(Employee)**

Eid	Ename	Age	Salary
3	Sachin	25	52000
7	Raj	69	45000
8	Anu	74	50000

4.3 Projection Operation (π)

Q. Explain Project Relational algebra operators with suitable examples. **MU - May 12, Dec 13, 2 Marks**

Q. Describe the following Relational algebra operation : Project **MU - Dec. 15, 3 Marks**

Q. Explain different types of operators in relational algebra. **MU - Dec. 17, May 18, 10 Marks**

Q. Explain Illustrate relational algebra with example. **MU - Dec. 18, 10 Marks**

Q. Discuss the basic operations that can perform using relational algebra. **MU - May 19, 10 Marks**

a. Overview

- This operator is used for selecting some of many columns in table to display in result set.
- Projection operator can select a column or set of columns of table to be display in output of query.
- We can select only few columns or all columns of a table as per requirements.
- This is unary relational operator having only one input table.

b. Syntax

$\pi_{<column\_list>}$ (Input_Table_Name)

c. Example

Query : Find salary and age of all Employees.

Solution : $\pi_{age, salary}$ **(Employee)**

Age	Salary
24	50000
24	15000
25	52000
23	41000
34	25000
54	50000
69	45000
74	50000

Query : Find salary of all employees having age less than 25.

Solution : $\pi_{age, salary}$ **(Employee)**

Age	Salary
24	50000
24	15000
23	41000

4.4 Rename Operation (ρ)

Q. Explain Rename Relational algebra operators with suitable examples. **MU - May 12, Dec. 13, May 14, 2 Marks**

Q. Explain different types of operators in relational algebra. **MU - Dec. 17, May 18, Dec.19, 10 Marks**

Q. Explain Illustrate relational algebra with example. **MU - Dec. 18, 10 Marks**

Q. Discuss the basic operations that can perform using relational algebra. **MU - May 19, 10 Marks**

a. Overview

- We can give alternative name to any column (attribute) or any table of query expressions using operator called as RENAME operator.
- This operator is specially introduced to select specific column from joined table (set of two or more tables) containing multiple columns of same column name.
- Rename operator, denoted by the lowercase Greek letter rho (ρ).

b. Syntax

$\rho_{<New\_Name>}$ (Input_Table_Name)

c. Example

Query : Find salary and age of all Employees.

Solution : $\pi_{e.age, e.salary}(\rho_e(Employee))$

e.Age	e.Salary
24	50000
24	15000
25	52000
23	41000
34	25000
54	50000
69	45000
74	50000

4.5 SET Operation

Q. Explain different types of operators in relational algebra. **MU - Dec. 17, May 18, Dec.19,10 Marks**

Q. Explain Illustrate relational algebra with example. **MU - Dec. 18, 10 Marks**

Q. Discuss the basic operations that can perform using relational algebra. **MU - May 19, 10 Marks**

Q. Explain various SET operators in relational algebra.

1. Introduction

- SQL SET operators allow combining results from two or more SELECT statements or combines result set of multiple queries.
- The results of two queries can be combined using the set operations union, intersection and difference.

```
Query_1 UNION     [ALL] Query_2
Query_1 INTERSECT [ALL] Query_2
Query_1 EXCEPT    [ALL] Query_2
```

2. SET Compatibility

- In order to apply SET operations the source tables must possess following Requirements,
- SELECT statement of both queries must retrieve the same number of columns.
- SELECT columns of both queries must be of same Data types.

4.5.1 Union Operator

Q. Explain Set Union Relational algebra operators with suitable examples. **MU - May 14, 2 Marks**

a. Overview

- This operator finds out all combined rows in table 1 and table 2.
- Union effectively appends the result of first query to the result of second query.
- It does not eliminate all duplicate rows and they are printed in result expression.

b. Syntax

(Query Expression 1) ∪ (Query Expression 2)

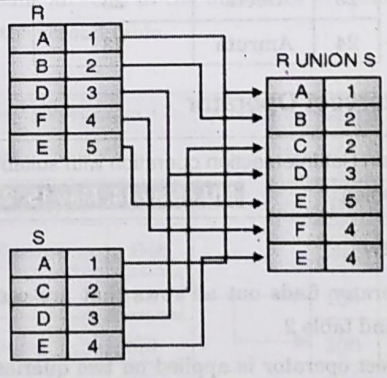


Fig. 4.5.1: SET Operation

c. Example

1. IT Employee table

Table Name : IT_Employee		
Eid	**Ename**	**Age**
11	Suhas	24
12	Jayendra	24
13	Sachin	25
14	Mahesh	23

2. Computer department Employee table

Table Name : COMP_Employee		
Eid	**Ename**	**Age**
21	Varsha	24
22	Bhavna	24
23	Geeta	25
24	Amrita	23

Query : Find all Employees in computer and IT departments.

Solution : (IT_Employee) ∪ (COMP_Employee)

Eid	Ename	Age
11	Suhas	24
12	Jayendra	24
13	Sachin	25
14	Mahesh	23
21	Varsha	24
22	Bhavna	24
23	Geeta	25
24	Amruta	23

4.5.2 Intersect Operator

Q. Explain Set Intersection operation with suitable examples. **MU - May 14, May 15, 2 Marks**

a. Overview

- This operator finds out all rows that are common in table 1 and table 2.
- If Intersect operator is applied on two queries then it will return all rows that are common in the result of Query 1 and Query 2.

b. Syntax

(Query Expression 1) ∩ (Query Expression 2)

R	
A	1
B	2
D	3
F	4
E	5

S	
A	1
C	2
D	3
E	4

R INTERSECTION S	
A	1
D	3

c. Example

1. All employees in IT department.

Table Name : IT_Employee		
Eid	**Ename**	**Age**
11	Suhas	24
12	Jayendra	24
13	Sachin	25
14	Mahesh	23

2. All employees in Vidya Engineering College.

Table Name : Vidya_Employee		
Eid	**Ename**	**Age**
11	Suhas	24
12	Jayendra	24
23	Geeta	25
24	Amruta	23
35	Sangita	21

Query : Find all Employees in IT department of Vidya Engineering College.

Solution : (IT_Employee) ∪ (Vidya_Employee)

Eid	Ename	Age
11	Suhas	24
12	Jayendra	24

4.5.3 Difference Operator

Q. Explain Set Difference Relational algebra operators with suitable examples. **MU - May 12, 2 Marks**

a. Overview

- This operator finds out all rows that are present in table 1 and not in table 2.
- If Intersect operator is applied on two queries then it will return all rows that are present in the result of Query 1 and not in Query 2.

b. Syntax

(Query Expression 1) - (Query Expression 2)

R	
A	1
B	2
D	3
F	4
E	5

R DIFFERENCE S	
B	2
F	4
E	5

S	
A	1
C	2
D	3
E	4

S DIFFERENCE R	
C	2
E	4

c. Example

1. All faculties in IT department of Vidya Engineering College.

Table Name : Vidya_Employee		
Eid	**Ename**	**Age**
11	Suhas	24
12	Jayendra	24
13	Sachin	25
14	Mahesh	23

2. All faculties in IT department of all colleges.

Table Name : IT_Employee		
Eid	**Ename**	**Age**
11	Suhas	24
12	Jayendra	24
13	Sachin	25

Table Name : IT_Employee		
Eid	**Ename**	**Age**
14	Mahesh	23
23	Geeta	25
24	Amruta	23
35	Sangita	21

Query : Find all Employees in IT department but not in Vidya Engineering College.

Solution : (IT_Employee) - (Vidya_Employee)

Eid	Ename	Age
23	Geeta	25
24	Amruta	23
35	Sangita	21

4.6 Cross Product / Cartesian product

Q. Explain different types of operators in relational algebra. **MU - Dec. 17, Dec.19, 10 Marks**

Q. Explain Illustrate relational algebra with example. **MU - Dec. 18, 10 Marks**

a. Overview

- A cross join performs relational product or Cartesian product of two tables specified in query.
- In this case every row in first table will be joined with every row in second table. So finally number of rows in result table will be equals to product of number of rows in table 1 and number of rows in table 2.
- That means all rows in the first table are joined to all rows in the second table.

b. Syntax

(Query Expression 1) × (Query Expression 2)

c. Example

Employee		
Eid	**Ename**	**Did**
1	Mahesh	100
2	Suhas	200
3	Jayendra	100

Department	
Did	**Dname**
100	HR
200	TIS

Query : Find combination all Employees and departments.

Solution : (Employee) X (Department)

Eid	Ename	Did	Did	Dname
1	Mahesh	100	100	HR
1	Mahesh	100	200	TIS
2	Suhas	200	100	HR
2	Suhas	200	200	TIS
3	Jayendra	100	100	HR
3	Jayendra	100	200	TIS

Cartesian product

- In DBMS, CROSS join occur due to WHERE condition is missing in query or some invalid operations in where clause leads to undesired results or CROSS Join.
- A Cartesian product is formed when :
  - A join condition is omitted.
  - A join condition is invalid.
- To avoid a Cartesian product, always include a valid join condition in a WHERE clause.

4.7 Join Operation ($\bowtie_\theta$)

Q. Explain different types of operators in relational algebra. **MU - Dec. 17, 10 Marks**

Q. Explain joins and types of joins with suitable example. **MU - Dec. 19, 10 Marks**

Q. Express Join in terms of basic relational algebra operations.

a. Overview

- Join operator helps us to retrieve data from multiple tables or relations.
- Most common type of join is **Natural join** ($\bowtie$) in which column having same name in two table will be taken for joining tables.

b. Syntax

(< table_name>) $\bowtie_{<join\_condition>}$ (table_name)

c. There are various types of joins possible in relational algebra.

1. **Type 1 :** Natural joins
2. **Type 2 :** Inner joins
3. **Type 3 :** Outer joins

Type 1 : Natural join ($\bowtie$)

Q. Explain Natural Join Relational algebra operators with suitable examples. **MU - May 12, Dec. 13, May 14, May 15, 2 Marks**

- Natural join can join tables based on the common columns in the tables being joined.
- A natural join returns all rows by matching values in common columns having same name and data type of columns and that column should be present in both tables.
- Prerequisites for Natural Join

  Both table must have at list one common column with same column name and same data type.

Steps of Working

- The two table are joined using Cross join
- DBMS will look for a common column with same name and data type
- Tuples having exactly same values in common columns are kept in result.

Example

Employee		
Eid	**Ename**	**Did**
1	Amit	10
2	Nitin	30
3	Yogesh	50

Department	
Did	**Dname**
10	IT
30	HR
40	TIS

Query : Find all Employees and their respective departments.

Solution : (Employee) $\bowtie$ (Department)

Eid	Ename	Did	Did	Dname
1	Amit	10	10	IT
2	Nitin	30	30	HR
Employee Data			Department Data	

- In above example the employee data having same did as department data are kept in result set.

- All non-matching tuples of cross join are ignored.

Type 2 : Inner joins / Theta Join ($\bowtie_\theta$)

Q. Explain Inner Join Relational algebra operators with suitable examples.

- Theta join will combines tuples from multiple relations if they satisfy the specified join condition.
- This join condition is also called as Theta and denoted by the symbol θ.
- The tables are joined according to join conditions.
- The only rows with matching values are combined using inner join.
- Inner join will ignore all tuple does not find matching tuple in other table.

Example

Query : Find all Employees and their respective departments.

Solution : Employee $\bowtie_{\text{employee.did= Department.did}}$ Department

Eid	Ename	Did	Did	Dname
1	Amit	10	10	IT
2	Nitin	30	30	HR
Employee Data			Department Data	

- In above example the employee data having did exactly same as department data are kept in result set.
- All non-matching tuples of cross join are ignored.

Type 3 : Outer joins

Q. Explain Outer Join Relational algebra operators with suitable examples. **MU - Dec. 13, 2 Marks**

- In an inner join or in case of a simple join, the resultant table contains only the combinations of rows that satisfy the join conditions.
- Rows that do not satisfy the join conditions are discarded. Outer join, joins two table although there is no match between two joining tables.
- Outer joins are useful when you are trying to determine which values in related tables cause referential integrity problem.
- Such problems are created when foreign key values do not match the primary key values in related table.

1. Left outer join

- Table on left side of operator may contain null values.
- Left outer join takes all tuples in the left relation that did not match with any tuple in the right relation.

Example

Query : Find all Employees and their respective department data.

Solution : Employee $\bowtie=_{\text{employee.did= Department.did}}$ Department

Eid	Ename	Did	Did	Dname
1	Amit	10	10	IT
2	Nitin	30	30	HR
3	Yogesh	50	Null	Null
Employee Data			Department Data	

- In above example the employee data having did exactly same as department data are kept in result set.
- All left side non-matching tuples of cross join are also considered.

2. Right outer join

- Table on right side of operator may contain null values.
- Right outer join takes all tuples in the right relation that did not match with any tuple in the left relation.

Example

Query : Find all departments with employee data.

Solution : Employee $=\bowtie_{\text{employee.did= Department.did}}$ Department

Eid	Ename	Did	Did	Dname
1	Amit	10	10	IT
2	Nitin	30	30	HR
Null	Null	Null	40	TIS
Employee Data			Department Data	

- In above example the employee data having did exactly same as department data are kept in result set.

- All right side non-matching tuples of cross join are also considered.

3. Full outer join

- Any table on both sides of operator may contain null values.

Example

Query : Find all Employees and departments.

Solution : Employee $=\bowtie_{\text{employee.did}=\text{Department.did}}$ Department

Eid	Ename	Did	Did	Dname
1	Amit	10	10	IT
2	Nitin	30	30	HR
3	Yogesh	50	Null	Null
Null	Null	Null	40	TIS
Employee Data			Department Data	

- In above example the employee data having did exactly same as department data are kept in result set.
- All right side non-matching tuples of cross join are also considered.

4.8 Relational Division Operator - Map the ER model to Relational Schema (Self Learning Topic)

Q. Explain Division Relational algebra operators with suitable examples. **MU - May 12, Dec. 13, May 15, 2 Marks**

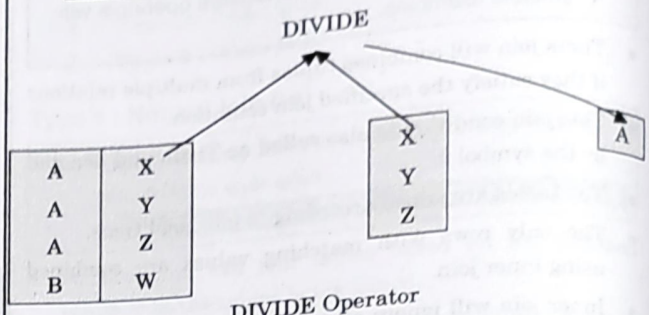
Q. Explain different types of operators in relational algebra. **MU - Dec. 17, 10 Marks**

a. Overview

- The divide operator operates on two tables that must have common columns between them.
- The relational divide operator (so called to distinguish it from mathematical division) returns the records in one record set that have values that match all the corresponding values in the second record set.
- The output of divide operation is one column in which values of common column in both tables match.

b. Syntax

(Query Expression 1) ÷ (Query Expression 2)



DIVIDE Operator

c. Example

Student Table			
Stud_ID	**Sname**	**Course_ID**	**Gender**
1	Mahesh	100	M
2	Manish	100	M
3	Amruta	100	F
3	Amruta	200	F
6	Neesha	100	F
3	Amruta	300	F
6	Neesha	300	F
6	Neesha	200	F

Course Table contains all courses that trainer 401 is taking.

Course_ID	Trainer_ID
100	401
200	401
300	401

Find female students take ALL the courses that 401 are taking.

Student ÷ Course

OR

$\pi_{\text{s.Stud\_ID, s.Sname, s.Gender, s.Course\_ID}}(\rho_s(\text{Student}) \div \rho_c(\text{Course}))$

s.Stud_ID	s.Sname	s.Gender	s.Course_ID
3	Amruta	F	200
6	Neesha	F	100

4.9 Operator Precedence

The normal way to group operators is according to its precedence of operation.

Precedence	Operators
1.	Unary operators σ, π and ρ have highest precedence.
2.	Next highest are the "multiplicative" like operators ⋈ and X.
3.	Lowest are the "additive" operators ∪(Union), ∩(Intersection) and – (minus) operators.

But there is no universal agreement, so we always put parentheses around the argument of a unary operator and it is a good idea to group all binary operators with parentheses enclosing their arguments.

4.10 Relational Algebra Queries - Solved Examples

Example 4.10.1 : Consider the following relations for database that keeps track of student enrollment in courses and books issued for each course.

STUDENT (Ssn, Name, Subject, DOB)

COURSE (Course_id, Name, Dept)

ENROLL (Ssn, Course_id, Semester, Grade)

Book_issued (Course_id, Semester, ISBN)

TEXT (ISBN, Title, Publisher, Author)

Write any 5 Queries in relational algebra.

Solution :

1. **Write a query to select all courses available in institute.**

$$\prod_{\text{course\_id, CName, Dept}} (\text{COURSE})$$

2. **Find all student details registered for course id 10.**

$$\prod_{\text{Ssn, Name}} (\sigma_{\text{course\_id} = 10}(\text{ENROLL} \bowtie \text{STUDENT}))$$

3. **Find various book titles and authors for semester higher than 3.**

$$\prod_{\text{ISBN, Title, Author}} (\sigma_{\text{semester} > 3}(\text{Book\_Issed} \bowtie \text{TEXT}))$$

4. **Find all students belongs to IT Depatment (without join)**

a. To find course_id of 'IT' Department

$$T_1 \leftarrow \prod_{\text{course\_id,}} (\sigma_{\text{Dept} = \text{'IT'}} (\text{COURSE}))$$

b. To find all students enrolled for above course id.

$$T_2 \leftarrow \prod_{\text{ssn ,}} (\text{ENROLL} \bowtie T_1)$$

c. To find student details having above Ssn.

$$\text{Ans} \leftarrow \prod_{\text{Ssn, Name, DOB}} (\text{STUDENT} \bowtie T_2)$$

Example 4.10.2 : Consider the relations given below :

Dealer (Dealer-no, DealerName, address)

Part (Part-no, Part-name, color)

Assigned-to (Dealer-no, Part-no, cost)

Give an expression in relational algebra the following queries :

1. Find the name of all dealers who supply 'Red' Parts.
2. Find the name of the dealers who supply both Yellow and Green Parts.
3. Find the name of the dealers who supply all the Parts.
4. List all dealer names.

Solution :

1. The name of all dealers who supply 'Red' Parts.

$$\prod_{\text{Dealername}} (\sigma_{\text{course='red'}} (\text{Dealer} \bowtie \text{Part}))$$

2. The name of the dealers who supply both Yellow and Green Parts

$$\prod_{\text{Dealername}} (\sigma_{\text{course='red' OR course='yellow'}} (\text{Dealer} \bowtie \text{Part}))$$

3. The name of the dealers who supply all the Parts.

$$\prod_{\text{Dealername}} (\text{Dealer} \bowtie \text{Part}))$$

(iv)The list of all dealer names

$$\prod_{\text{Dealername}} (\text{Dealer})$$

Review Questions

1. Explain various operators in relational algebra.
2. Write a short note :
   a. Selection operation b. Projection Operator
3. Explain concept of division operation.
4. Explain concept of JOIN operation in relational algebra.
5. Explain various SET operators in relational algebra.
6. Explain concept of product operation in relational algebra.

7. Explain following Relational algebra operators with suitable examples :
   1. Select
   2. Project
   3. Join
   4. Division
   5. Cartesian product

8. Explain following relational algebra operators with example :
   1. Set-difference
   2. Outer join

9. Explain following relational algebra operators with example :
   1. Project
   2. Division
   3. Natural Join
   4. Set Difference.

10. Explain following relational algebra with suitable example : Natural Join.

11. Express Natural Join and Division operator in terms of basic relational algebra operations.

12. Given the following relations :
    Vehicle (reg_no, make, colour)
    Person (eno, name, address)
    Owner (eno, reg_no)
    Write expressions in relational algebra to answer the following queries :
    1. List the names of persons who do not own any car.
    2. List the names of persons who own only Maruti Cars.

13. Consider the relations given below :
    Dealer (Dealer-no, DealerName, address)
    Part (Part-no, Part-name, color)
    Assigned-to (Dealer-no, Part-no, cost)
    Give an expression in relational algebra the following queries :
    1. Find the name of all dealers who supply 'Red' Parts.
    2. Find the name of the dealers who supply both Yellow and Green Parts.
    3. Find the name of the dealers who supply all the Parts.

4.11 University Questions and Answers

May 2015

1. Explain following relational algebra operations with proper examples :
   1. Set Intersection operation
   2. Natural join
   3. Division

(3 Marks)

Dec.2015

2. Describe the following relational algebra operations :
   1. Project
   2. Natural join
   3. Set Intersection

(7 Marks)

3. Describe the following relational algebra operation : Select **(3 Marks)**

Dec. 2016

4. Explain any four relational algebra operations with proper examples. **(10 Marks)**

May 2017

5. Discuss fundamental operations in relational algebra. **(10 Marks)**

Dec. 2017

6. Explain Join Operations in relational algebra. **(5 Marks)**

May 2018

7. Explain different types of relational algebra operations.

Dec. 2018

8. Explain Illustrate relational algebra with example. **(5 Marks)**

May 2019

9. Discuss the basic operations that can perform using relational algebra. **(10 Marks)**

Dec. 2019

10. Explain different types of relational algebra operations. **(10 Marks)**

11. Explain joins and types of joins with suitable example. **(10 Marks)**

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