Relational Algebra

Chapter 4



What is it?

- Theoretical Foundations of Queries
- Questions to the Database regarding Data

- Queries in Relational Algebra are formulated using a collection of operators
- Examples
 - π
 - σ
 - 🖂



Introduction and Schemas

Assumptions

Sailors

Saliois			
Sid	Sname	Rating	Age
22	Dustin	7	45
31	Lubber	8	55
58	Rusty	10	35
32	Andy	8	25

SidBidDay2210110/10/965810311/12/96

Boats

Bid	Bname	color
101	Interlake	Blue
102	Interlake	red
103	Clipper	Green
104	Marine	red



Relational Algebra

- Foundations of Queries
- Fundamental Properties
 - Every operator accepts a relations (one or two) as input
 - Every operator returns a relation as output
- This property allows formation of complex queries.
- Operators
 - π
 - σ
 - ρ
 - Set operators: $\cup \cap \times$
 - 🖂



Select Operator (σ)

- Formal notation
- $R' = \frac{\sigma}{conditions}(R)$
- Works on the horizontal dimension (tuples)

Sid	Sname	Rating	Age
22	Dustin	7	45
31	Lubber	8	55
58	Rusty	10	35
32	Andy	8	25
17	Рореуе	10	40



Examples on Selection

 $\bullet_{R' = Sailors. age > 40}(Sailors)$

Sid	Sname	Rating	Age
22	Dustin	7	45
31	Lubber	8	55
58	Rusty	10	35
32	Andy	8	25

Sid	Sname	Rating	Age
22	Dustin	7	45
31	Lubber	8	55



Examples on Selection (2)

•
$$R' = Sailors.rating >= 8 (Sailors)$$

and Sailors.age > 50

Sid	Sname	Rating	Age
22	Dustin	7	45
31	Lubber	8	55
58	Rusty	10	35
32	Andy	8	25

Sid	Sname	Rating	Age
31	Lubber	8	55

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- Can apply multiple conditions: AND OR (Λ V)
- Can apply multiple selections instead

•
$$R' = \frac{\sigma}{Sailors.rating \ge 8} (Sailors)$$

• $Final' = \frac{\sigma}{R'.age \ge 50} (R')$

Alias Operator (ho)

- Alias for relation names and/or column names
- $\rho(newName, oldName)$
- Examples
 - $\rho(S, Sailors)$
 - Returns a relation S with the same data as Sailors. Now we can use S instead of Sailors σ

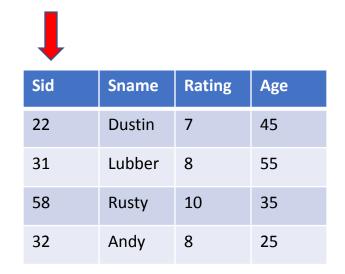
•
$$R' = \frac{S.rating \ge 8}{and S.age > 50}$$
 (S)

- $\rho(S(sid \rightarrow sid1, rating \rightarrow rate), Sailors)$
 - Returns a relation S with the same data as Sailors, with same columns, except sid is now sid1 and rating is now rate.



Project Operator ($\prod R$)

- Formal notation
- $R' = \prod_{columns}(R)$
- Works on the vertical dimension (attributes)
- Will only show unique values.



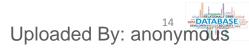


Examples on Projection

- $\rho(S, Sailors)$
- $R' = \prod_{S.sname,s.age}(S)$

Sid	Sname	Rating	Age
22	Dustin	7	45
31	Lubber	8	55
58	Rusty	10	35
32	Andy	8	25

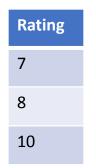
Sname	Age
Dustin	45
Lubber	55
Rusty	35
Andy	25

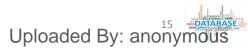


Examples on Projection(2)

- $\rho(S, Sailors)$
- $R' = \prod_{S.rating}(S)$
- Remember: Unique values only!

Sid	Sname	Rating	Age
22	Dustin	7	45
31	Lubber	8	55
58	Rusty	10	35
32	Andy	8	25





Mixing Operators

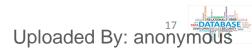
- More useful when mixing selections and projections
- Example
- Get sailor names whose age is greater than 40.
 - $\rho(S, Sailors)$
 - $R' = \prod_{S.sname}(S) R'$ only sname

• Final' =
$$\sigma_{R'.age > 40} \left(R' \right)$$

- Can we do this?!!
- Correct result:
- $\rho(S, Sailors)$

•
$$R' = \frac{\sigma}{S.age > 40}(S)$$

• $Final' = \prod_{S.sname} (R')$

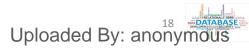


Set Operations: Union

• Union: $R \cup S$ returns a relation instance containing all tuples that occur in *either* relation instance R or relation instance S (or both). R and S must be *union-compatible*, and the schema of the result is defined to be identical to the schema of R.

Two relation instances are said to be **union-compatible** if the following conditions hold:

- they have the same number of the fields, and
- corresponding fields, taken in order from left to right, have the same *domains*.



Set Operations: Intersection and Set Difference

- Intersection: $R \cap S$ returns a relation instance containing all tuples that occur in both R and S. The relations R and S must be union-compatible, and the schema of the result is defined to be identical to the schema of R.
- Set-difference: R-S returns a relation instance containing all tuples that occur in R but not in S. The relations R and S must be union-compatible, and the schema of the result is defined to be identical to the schema of R.



Examples on Set Operators

Sid	Sname	Rating	Age
22	Dustin	7	45
31	Lubber	8	55
58	Rusty	10	35

Sid	Sname	Rating	Age
28	уирру	9	35
31	Lubber	8	55
44	guppy	5	35
58	Rusty	10	35

Sid	Sname	Rating	Age
22	Dustin	7	45
28	уирру	9	35
31	Lubber	8	55
44	guppy	5	35
58	Rusty	10	35

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Examples on Set Operators (2)

Sid	Sname	Rating	Age
22	Dustin	7	45
31	Lubber	8	55
58	Rusty	10	35

Sid	Sname	Rating	Age
28	уирру	9	35
31	Lubber	8	55
44	guppy	5	35
58	Rusty	10	35

Sid	Sname	Rating	Age
31	Lubber	8	55
58	Rusty	10	35



Examples on Set Operators (3)

Sid	Sname	Rating	Age
22	Dustin	7	45
31	Lubber	8	55
58	Rusty	10	35

Sid	Sname	Rating	Age
28	уирру	9	35
31	Lubber	8	55
44	guppy	5	35
58	Rusty	10	35

Sid	Sname	Rating	Age
22	Dustin	7	45



Introduction and Schemas

Assumptions

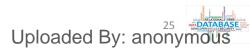
Sailors

Saliois			
Sid	Sname	Rating	Age
22	Dustin	7	45
31	Lubber	8	55
58	Rusty	10	35
32	Andy	8	25

SidBidDay2210110/10/965810311/12/96

Boats

Bid	Bname	color
101	Interlake	Blue
102	Interlake	red
103	Clipper	Green
104	Marine	red



Cross Product:

Cross-product: R×S returns a relation instance whose schema contains all the fields of R (in the same order as they appear in R) followed by all the fields of S (in the same order as they appear in S). The result of R×S contains one tuple ⟨r, s⟩ (the concatenation of tuples r and s) for each pair of tuples r ∈ R, s ∈ S. The cross-product operation is sometimes called Cartesian product.

We will use the convention that the fields of $R \times S$ inherit names from the corresponding fields of R and S. It is possible for both R and S to contain one or more fields having the same name; this situation creates a *naming conflict*. The corresponding fields in $R \times S$ are unnamed and are referred to solely by position.

Example:

Sid	Sname	Rating	Age
22	Dustin	7	45
31	Lubber	8	55
58	Rusty	10	35



Sid	Bid	Day
22	101	10/10/96
58	103	11/12/96

(sid)	sname	rating	age	(sid)	bid	day
22	Dustin	7	45.0	22	101	10/10/96
22	Dustin	7	45.0	58	103	11/12/96
31	Lubber	8	55.5	22	101	10/10/96
31	Lubber	8	55.5	58	103	11/12/96
58	Rusty	10	35.0	22	101	10/10/96
58	Rusty	10	35.0	58	103	11/12/96

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Figure 4.11 $S1 \times R1$



Condition Join

 The most general version of the join operation accepts a join condition c and a pair of relation instances as arguments, and returns a relation instance

 $R \bowtie_c S = \sigma_c(R \times S)$



Condition Join Example

 $S1 \bowtie_{S1.sid < R1.sid} R1$

(sid)	sname	rating	age	(sid)	bid	day
22	Dustin	7	45.0	58	103	11/12/96
31	Lubber	8	55.5	58	103	11/12/96



Equijoin

- A common special case of the join operation R S is when the join condition consists solely of equalities of the form R.name1 = S.name2, that is, equalities between two fields in R and S.
- The schema of the result of an equijoin contains the fields of R (with the same names and domains as in R) followed by the fields of S that do not appear in the join conditions.



Natural Join

- A further special case of the join operation R S is an equijoin in which equalities are specified on all fields having the same name in R and S.
- In this case, we can simply omit the join condition.





	Sailors			Reserves			Boats			
	Sid	Sname	Rating	Age				Bid	Bname	color
	22	Dustin	7	45	Sid	Bid	Day	101	Interlake	Blue
Evamplac	31	Lubber	8	55	22	101	10/10/96	102	Interlake	red
Examples	58	Rusty	10	35	58	103	11/12/96	103	Clipper	Green
	32	Andy	8	25				104	Marine	red

• Find the names of Sailors who have reserved boat id = 103

 $\pi_{sname}((\sigma_{bid=103} Reserves) \bowtie Sailors)$

• Find the names of Sailors who reserved a red boat $\pi_{sname}((\sigma_{color='red'}Boats) \bowtie Reserves \bowtie Sailors)$ $\pi_{sname}(\pi_{sid}((\pi_{bid}\sigma_{color='red'}Boats) \bowtie Reserves) \bowtie Sailors)$

• Find the color of boats reserved by Rusty

 $\pi_{color}((\sigma_{sname='Lubber'}Sailors) \bowtie Reserves \bowtie Boats)$



	Sailors					Reserves			Boats			
	Sid	Sname	Rating	Age				Bid	Bname	color		
	22	Dustin	7	45	Sid	Bid	Day	101	Interlake	Blue		
	31	Lubber	8	55	22	101	10/10/96	102	Interlake	red		
<u>')</u>	58	Rusty	10	35	58	103	11/12/96	103	Clipper	Green		
	32	Andy	8	25				104	Marine	red		

Examples (2)

• Find the names of saliors who have reserved at least one boat

 $\pi_{sname}(Sailors \bowtie Reserves)$

• Find the names of Sailors who reserved a red boat or a green boat

 $\rho(Tempboats, (\sigma_{color='red'}Boats) \cup (\sigma_{color='green'}Boats)) \\ \pi_{sname}(Tempboats \bowtie Reserves \bowtie Sailors)$

 $\rho(Tempboats, (\sigma_{color='red' \lor color='green'}Boats))$ $\pi_{sname}(Tempboats \bowtie Reserves \bowtie Sailors)$

• Find the names of Sailors who reserved a red AND a green boat

 $\rho(Tempred, \pi_{sname}((\sigma_{color='red'}Boats) \bowtie Reserves \bowtie Sailors)))$ $\rho(Tempgreen, \pi_{sname}((\sigma_{color='green'}Boats) \bowtie Reserves \bowtie Sailors)))$ $Tempred \cap Tempgreen$



	Sailors			Reserves			Boats			
	Sid	Sname	Rating	Age				Bid	Bname	color
	22	Dustin	7	45	Sid	Bid	Day	101	Interlake	Blue
Evamplac	31	Lubber	8	55	22	101	10/10/96	102	Interlake	red
Examples	58	Rusty	10	35	58	103	11/12/96	103	Clipper	Green
	32	Andy	8	25				104	Marine	red

 Find the sids of sailors with age over 20 who have not reserved a red boat

 $\pi_{sid}(\sigma_{age>20}Sailors) - \\\pi_{sid}((\sigma_{color='red'}Boats) \bowtie Reserves \bowtie Sailors)$



Sid	Bid	Day
22	101	10/10/96
58	103	11/12/96
22	107	1/2/98

• Find the sids of sailors who reserved at least two different boats

Sid	Bid	Day	Sid'	Bid'	Day'
22	101	10/10/96	22	101	10/10/96
22	101	10/10/96	58	103	11/12/96
22	101	10/10/96	22	107	1/2/98
58	103	11/12/96	22	101	10/10/96
58	103	11/12/96	58	103	11/12/96
58	103	11/12/96	22	107	1/2/98
22	107	1/2/98	22	101	10/10/96
22	107	1/2/98	58	103	11/12/96
22	107	1/2/98	22	107	1/2/98

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Examples (4)