INFO20003 Database Systems

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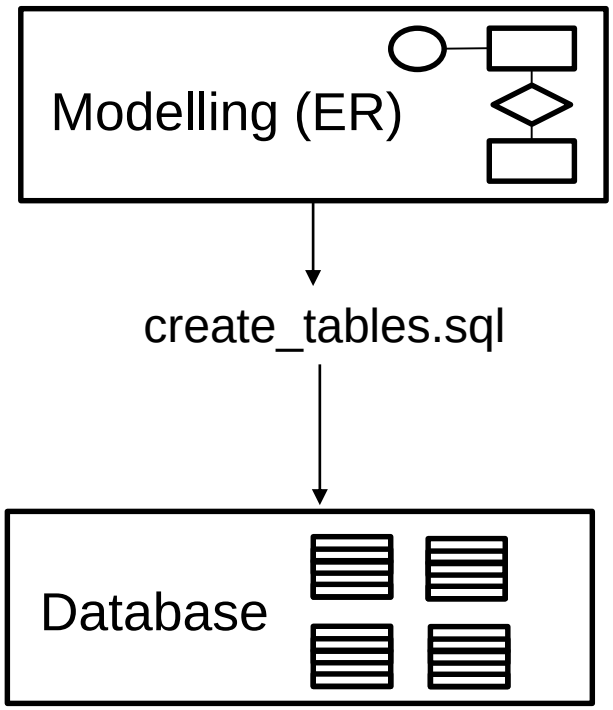
Lecture 07
Relational Algebra

Semester 1 2018, Week 4

What we have done so far



SQL:

- Language for data manipulation
- Allow to create/delete tables, add/update/remove data, etc

Introduced next time

Relational algebra:

- The theory behind SQL
- Makes sure that SQL produces correct answers
- Inputs/outputs are relations

Today

How do we manipulate with this data?

Relational Algebra: 5 Basic Operations

1. **Selection** (σ): Selects a subset of *rows* from relation (horizontal filtering).
2. **Projection** (π): Retains only wanted *columns* from relation (vertical filtering).
3. **Cross-product** (x): Allows us to combine two relations.
4. **Set-difference** (–): Tuples in one relation, but not in the other.
5. **Union** ($\cup$): Tuples in one relation and/or in the other.

Each operation returns a relation, operations can be composed

Coverage : Relational Algebra

- Selection & Projection
- Union, Set Difference & Intersection
- Cross product & Joins
- Examples

Readings: Chapter 4, Ramakrishnan & Gehrke, Database Systems

Example Instances

Reserves (R1)

sid	bid	day
22	101	10/10/96
58	103	11/12/96

Boats

bid	bname	color
101	Interlake	blue
102	Interlake	red
103	Clipper	green
104	Marine	red

Sailors 1 (S1)

sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0

Sailors 2 (S2)

sid	sname	rating	age
28	yuppy	9	35.0
31	lubber	8	55.5
44	guppy	5	35.0
58	rusty	10	35.0

Relational Algebra

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Projection

- Retains only attributes that are in the *projection list*
- *Schema* of result:
  - Only the fields in the projection list, with the same names that they had in the input relation
- Projection operator has to *eliminate duplicates*
  - How do they arise? Why remove them?
  - Note: real systems typically don't do duplicate elimination unless the user explicitly asks for it

Projection Examples

1. *Find ages of sailors :* $\pi_{age}(S2)$
2. *Find names and rating of sailors :* $\pi_{sname,rating}(S2)$

sid	sname	rating	age
28	yuppy	9	35.0
31	lubber	8	55.5
44	guppy	5	35.0
58	rusty	10	35.0

S2

sname	rating
yuppy	9
lubber	8
guppy	5
rusty	10

$\pi_{sname,rating}(S2)$

age
35.0
55.5

Removed duplicates

$\pi_{age}(S2)$

Selection (σ)

- Selects rows that satisfy *selection condition*
- Result is a relation. *Schema* of the result is same as that of the input relation.
- Do we need to do duplicate elimination?
- **Example:**

  Find sailors whose rating is above 8

sid	sname	rating	age
28	yuppy	9	35.0
~~31~~	~~lubber~~	~~8~~	~~55.5~~
~~44~~	~~guppy~~	~~5~~	~~35.0~~
58	rusty	10	35.0

$$\sigma_{rating>8}(S2)$$

sid	sname	rating	age
28	yuppy	9	35.0
58	rusty	10	35.0

$$\sigma_{rating>8}(S2)$$

Conditions

- Conditions are standard arithmetic expressions

  >, <, >=, <=, =, !=

- Conditions are combined with AND/OR clauses

  And: $\wedge$

  Or: $\vee$

- **Example**:

Find sailors whose rating is above 8 and who are younger than 50

$$\sigma_{rating>8 \wedge age<50}(S2)$$

Selection & Projection

- Operations can be combined
- Select rows that satisfy *selection condition* & retain only *certain attributes (columns)*
- **Example:**
  Find names and rating of sailors whose rating is above 8

sid	sname	rating	age
28	yuppy	9	35.0
31	lubber	8	55.5
44	guppy	5	35.0
58	rusty	10	35.0

sname	rating
yuppy	9
rusty	10

$$\pi_{sname,rating}(\sigma_{rating>8}(S2))$$

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Union and Set-Difference

- **Union**: Combines both relations together
- **Set-difference:** Retains rows of one relation that do not appear in the other relation

- These operations take two input relations, which must be *union-compatible*:
  - Same number of fields
  - Corresponding fields have the same type

Union

sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0

S1

sid	sname	rating	age
28	yuppy	9	35.0
31	lubber	8	55.5
44	guppy	5	35.0
58	rusty	10	35.0

S2

sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0
44	guppy	5	35.0
28	yuppy	9	35.0

$S1 \cup S2$

Duplicates are removed

Set Difference

sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0

S1

sid	sname	rating	age
28	yuppy	9	35.0
31	lubber	8	55.5
44	guppy	5	35.0
58	rusty	10	35.0

S2

sid	sname	rating	age
22	dustin	7	45.0

$S1 - S2$

Set Difference

sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0

S1

sid	sname	rating	age
28	yuppy	9	35.0
31	lubber	8	55.5
44	guppy	5	35.0
58	rusty	10	35.0

S2

sid	sname	rating	age
22	dustin	7	45.0

$S1 - S2$

sid	sname	rating	age
28	yuppy	9	35.0
44	guppy	5	35.0

$S2 - S1$

Set-difference is not symmetrical

Compound Operator: Intersection

- In addition to the 5 basic operators, there are several additional "Compound Operators"
  - These add no computational power to the language, but are useful shorthands
  - Can be expressed solely with the basic operations

- **Intersection** retains rows that appear in *both* relations
- Intersection takes two input relations, which must be *union-compatible*.
- Q: How to express it using basic operators?

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

Intersection

Example:

Find sailors who appear in both relations S1 and S2

sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0

S1

sid	sname	rating	age
28	yuppy	9	35.0
31	lubber	8	55.5
44	guppy	5	35.0
58	rusty	10	35.0

S2

sid	sname	rating	age
31	lubber	8	55.5
58	rusty	10	35.0

$S1 \cap S2$

Relational Algebra

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Cross Product

- **Cross product** combines two relations:
  - Each row of one input is merged with each row from another input
  - Output is a new relation with all attributes of *both* inputs
  - X is used to denote cross-product
- Example: S1 x R1
  - Each row of S1 paired with each row of R1
- Question: How many rows are in the result?
  - A: card(S1)*card(R1)

Cross Product Example

sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0

S1

sid	bid	day
22	101	10/10/96
58	103	11/12/96

R1

S1 X R1 =

(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

Cross Product: Conflicting names

- *Result schema* has one field per field of S1 and R1, with field names "inherited" if possible.
  - May have *a naming conflict*, i.e. both S1 and R1 have a field with the same name (e.g. sid).
  - In this case, can use the *renaming operator*:

$$\rho\,(C(1 \rightarrow sid1, 5 \rightarrow sid2),\ S1 \times R1)$$

Result relation

C

sid1	sname	rating	age	sid2	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

Compound Operator: Join

- Joins are compound operators involving cross product, selection, and (sometimes) projection.

- Most common type of join is a **natural join** (often just called **join**). R ⋈ S conceptually is a cross product that matches rows where attributes that appear in both relations have equal values (and we omit duplicate attributes).

- To obtain cross product a DBMS must:
  1. Compute R X S
  2. Select rows where attributes that appear in both relations have equal values
  3. Project all unique attributes and one copy of each of the common ones.

Natural Join Example

Example:

Find all sailors (from relation S1) who have reserved a boat

sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0

S1

sid	bid	day
22	101	10/10/96
58	103	11/12/96

R1

S1 ⋈ R1 =

sid	sname	rating	age	bid	day
22	dustin	7	45.0	101	10/10/96
58	rusty	10	35.0	103	11/12/96

Natural Join Example

1

S1 X R1 =

(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

Natural Join Example

1

S1 X R1 =

2

σ

(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

Natural Join Example

1

S1 X R1 =

(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

2 σ

π 3

S1 ⋈ R1=

sid	sname	rating	age	bid	day
22	dustin	7	45.0	101	10/10/96
58	rusty	10	35.0	103	11/12/96

Other Types of Joins

- **Condition Join (or theta-join)** is a cross product with a condition.

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

(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

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

  - Result schema is the same as that of cross-product

- **Equi-Join** is a special case of condition join, where condition *c* contains only *equalities* (e.g. S1.sid = R1.sid)
  - Is this then a natural join? What is different?

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Let's try it...

Boats

bid	bname	color
101	Interlake	Blue
102	Interlake	Red
103	Clipper	Green
104	Marine	Red

Sailors

sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0

Reserves

sid	bid	day
22	101	10/10/96
58	103	11/12/96

Question 1

Find names of sailors who have reserved boat #103

Solution 1:

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

Solution 2:

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

Question 2

Find names of sailors who have reserved a blue boat

- Information about boat color only available in Boats; so need an extra join:

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

- A more efficient solution:

$$\pi_{sname}(\pi_{sid}((\pi_{bid}\sigma_{color='blue'}Boats) \bowtie Res.) \bowtie Sailors)$$

You shouldn't worry about efficiency for now. A DBMS will do this job for us and find alternative 2.

Question 3

Find all pairs of sailors in which the older sailor has a lower rating

Practice at home

1. Find (the name of) all sailors whose rating is above 9
2. Find all sailors who reserved a boat prior to November 1, 1996
3. Find (the names of) all boats that have been reserved at least once
4. Find all pairs of sailors with the same rating

What's Examinable

- Relational Algebra Operations: Selection, Projection, Union, Set, Difference, Intersection, **JOINS**…
- Draw different queries with Relational Algebra operations

Next Lecture

- Introducing SQL