THE UNIVERSITY OF MELBOURNE

INFO20003 Database Systems

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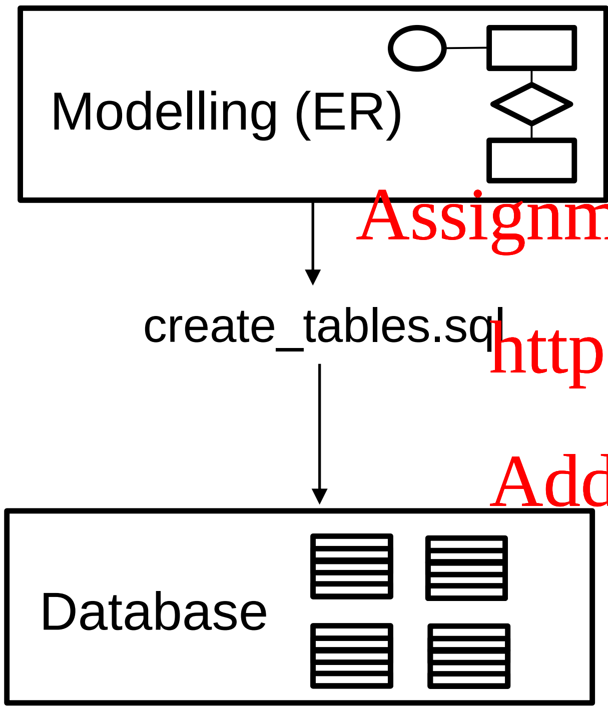
Lecture 07
Relational Algebra

Semester 2 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

- Selection & Projection
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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 a *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

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

Relational Algebra

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

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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

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

S1

sid	sname	rating	age
22	dustin	7	45.0

$S1 - S2$

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

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
22	dustin	7	45.0

$S1 - S2$

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

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

$$S1 \cap S2$$

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

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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*:

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

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 $\bowtie$ 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 perform a natural join a DBMS can:
  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 $\bowtie$ 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 =

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

π 3

S1 $\bowtie$ 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?

Relational Algebra

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

Solution 2: $\pi_{sname}(\sigma_{bid=103}(Reserves \bowtie Sailors))$

Find the names of sailors who have reserved a blue boat

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

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

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

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

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

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

Question 3

Find all pairs of sailors in which the <u>older</u> sailor has a <u>lower</u> 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