Relational Algebra
In-class exercise (I)

R & G, Chapter 4

Summary of Relational Algebra Operations

- **Basic operations**
  1. *Selection* (σ)
  2. *Projection* (π)
  3. *Cross-product* (X)
  4. *Set-difference* (—)
  5. *Union* (U)
- **Compound operations**
  1. Intersection (∩)
  2. Join (⋈)
  3. Division (/)

Selection and Projection

- **Schema**
  - Boats (bid, bname, color)
  - Sailors(sid, sname, rating, age)
  - Reserves(sid, bid, day)
- **Write the relational algebra expressions for the following queries:**

Q1. Find the records in Reserves table for boat of ID 103 (assume bid is of integer data type);

Q2. Find the name of the boats that have red color;

Q3. Find the name of the boats that are either red or green.

Selection and Projection

- **Schema**
  - Boats (<u>bid</u>, bname, color)
  - Sailors(<u>sid</u>, sname, rating, age)
  - Reserves(<u>sid</u>, <u>bid</u>, day)
- **Write the relational algebra expressions for the following queries:**

1. Find "reserve" record for boat of ID 103

$$\sigma_{bid=103}(\text{Reserves})$$

2. Find the name of the boat of red color

$$\pi_{bname}\sigma_{color='red'}(\text{Boats})$$

3. Find the name of the boat that is either red or green

$$\pi_{bname}\sigma_{color='red' \vee color='green'}(\text{Boats})$$

Join (I)

- **Schema**
  - Boats (bid, bname, color)
  - Sailors(sid, sname, rating, age)
  - Reserves(sid, bid, day)

Q4. Find names of sailors who've reserved boat 103

Join (I)

- **Schema**
  - Boats (bid, bname, color)
  - Sailors(sid, sname, rating, age)
  - Reserves(sid, bid, day)

Q4. Find names of sailors who've reserved boat #103

– Solution 1 (selection-after-join):

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

– Solution 2 (selection-before-join):

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

- Both are correct.
- Solution 2 is more efficient than Solution 1, since join tables after selection are smaller.

Join (II)

- **Schema**
  - Boats (bid, bname, color)
  - Sailors(sid, sname, rating, age)
  - Reserves(sid, bid, day)

Q5. Find names of sailors who've reserved a red boat

Join (II)

- **Schema**
  - Boats (bid, bname, color)
  - Sailors(sid, sname, rating, age)
  - Reserves(sid, bid, day)

Q5. Find names of sailors who've reserved a red boat

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

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

- A more efficient way:

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

- Question: is the following expression correct?

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

Join (III)

- **Schema**
  - Boats (bid, bname, color)
  - Sailors(sid, sname, rating, age)
  - Reserves(sid, bid, day)

Q6. Find the colors of boats reserved by the sailor named Lubber

Join (III)

- **Schema**
  - Boats (bid, bname, color)
  - Sailors(sid, sname, rating, age)
  - Reserves(sid, bid, day)

Q6. Find the colors of boats reserved by the sailor named Lubber

- Information about boat color and reservation only available in Boats and Reserves; so need two joins:

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

Join (IV)

- **Schema**
  - Boats (bid, bname, color)
  - Sailors(sid, sname, rating, age)
  - Reserves(sid, bid, day)

Q7. Find the name of sailors who have reserved at least one boat

Join (IV)

- **Schema**
  - Boats (<u>bid</u>, bname, color)
  - Sailors(<u>sid</u>, sname, rating, age)
  - Reserves(<u>sid</u>, <u>bid</u>, day)

Q7. Find the name of sailors who have reserved at least one boat

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

Join + Set Operations (I)

- **Schema**
  - Boats (bid, bname, color)
  - Sailors(sid, sname, rating, age)
  - Reserves(sid, bid, day)

Q8. Find the name of sailors who've reserved a red or a green boat

Join + Set Operations (I)

- **Schema**
  - Boats (bid, bname, color)
  - Sailors(sid, sname, rating, age)
  - Reserves(sid, bid, day)

Q8. Find the name of sailors who've reserved a red or a green boat

– Way of thinking: identify all red or green boats, then find sailors who've reserved one of these boats:

$$\rho(\text{RGboats}, \sigma_{\text{color='red'} \vee \text{color='green'}} (\text{Boats}))$$

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

Join + Set Operations (I)

- **Schema**
  - Boats (bid, bname, color)
  - Sailors(sid, sname, rating, age)
  - Reserves(sid, bid, day)

Q9. Find the name of sailors who've reserved a red and a green boat

Join + Set operations (II)

- **Schema**
  - Boats (bid, bname, color)
  - Sailors(sid, sname, rating, age)
  - Reserves(sid, bid, day)

Q9. Find the name of sailors who've reserved a red *and* a green boat

– Is the following solution correct?

$$\rho(\text{RGboats}, \sigma_{\text{color='red'} \wedge \text{color='green'}} (\text{Boats}))$$

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

Wrong! There is no boat of both colors.

Join + Set operations (II Cont.)

- **Find the name of sailors who've reserved a red and a green boat**
  - Must use set operations
  - Way of thinking:
    - Identify the set *ReserveRed*: sid of sailors who've reserved red boats,
    - Identify the set *ReserveGreeen*: sid of sailors who've reserved green boats,
    - Find the intersection S of *ReserveRed* and *ReserveGreen* (note S only contains *sid*),
    - Join S with *Sailors* table to get name of sailors

$$\rho(\text{ReserveRed}, \pi_{\text{sid}} \sigma_{\text{color='red'}} (\text{Boats}) \bowtie \text{Reserves})$$
$$\rho(\text{ReserveGreen}, \pi_{\text{sid}} \sigma_{\text{color='green'}} (\text{Boats}) \bowtie \text{Reserves})$$

$$\pi_{\text{sname}} ((\text{ReserveRed} \cap \text{ReserveGreen}) \bowtie \text{Sailors})$$

Join + Set Operations (III)

Q10: Find the name of sailors who are older than 20 and have not reserved a red boat

- Find sids of sailors with age over 20 as set S1
- Find sids of sailors who have reserved a red boat as set S2
- Take the set difference of S1 and S2
- Join with sailors, and return name of the sailors from join result

Join + Set Operations

Q10: Find the name of sailors who are older than 20 and have not reserved a red boat

- Find sids of sailors with age over 20 as set S1
- Find sids of sailors who have reserved a red boat as set S2
- Take the set difference of S1 and S2 as S3
- Join S3 with sailors, and return name of the sailors from join result

– Answer:

$$\rho(S1,\pi_{sid}(\sigma_{age>20}(Sailors)))$$

$$\rho(S2,\pi_{sid}((\sigma_{color='red'}(Boats))\bowtie \mathrm{Re}serves)$$

$$\pi_{sname}(Sailors\bowtie (S1-S2))$$

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

- **Answer 1 (join before set difference)**

$$\rho(T1, \pi_{sid}(\sigma_{age>20}(Sailors) \bowtie Reserves \bowtie Boats))$$

$$\rho(T2, \pi_{sid}(\sigma_{color='red'}(Boats) \bowtie Reserves \bowtie Sailors))$$

$$\pi_{sname}(Sailors \bowtie (T1 - T2))$$

- Is Answer 1 correct? What will it return on the instances below?
- Answer 1 is wrong because T1 does not include those sailors (e.g., Lubber) who have not reserved any boat

Sid	Bid	day
22	101	10/10/96
58	102	11/12/96

Reserves

Bid	Bname	Color
101	Interlake	Blue
102	Interlate	Red
103	Clipper	Green
104	Marine	red

Boats

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

Sailors

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

- **Answer 2 (without using set-difference)**

$$\pi_{sname}(\sigma_{age>20}(Sailors) \bowtie Reserves \bowtie \sigma_{color \neq 'red'}(Boats))$$

  - Is Answer 2 correct? What will it return on the instances below?
  - Answer 2 is wrong because it may return the sailors (e.g., Dustin) who have reserved a red boat and a non-red boat.

Sid	Bid	day
22	101	10/10/96
58	103	11/12/96
22	102	12/10/96

Reserves

Bid	Bname	Color
101	Interlake	Blue
102	Interlate	Red
103	Clipper	Green
104	Marine	red

Boats

Sid	Sname	Rating	Age
22	Dustin	7	45
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Sailors