SQL and Relational Algebra

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Basics of Relational Algebra

- Four types of operators:
  - Select/Show parts of a single relation: projection and selection.

  - Usual set operations (union, intersection, difference).
  - Combine the tuples of two relations, such as cartesian product and joins.
  - Renaming.

Projection

- The projection operator produces from a relation R a new relation containing only some of R's columns.

- "Delete" (i.e. not show) attributes not in projection list.
- Duplicates eliminated

- To obtain a relation containing only the columns $A_1, A_2, \ldots A_n$ of R

RA: $\pi_{A_1, A_2, \ldots A_n}(R)$

SQL: **SELECT** $A_1, A_2, \ldots A_n$ **FROM** R;

Selection

- The selection operator applied to a relation R produces a new relation with a subset of R's tuples.
- The tuples in the resulting relation satisfy some condition C that involves the attributes of R.
  - with duplicate removal

RA: $\boldsymbol{\sigma}_C$ (R)

SQL: **SELECT** * **FROM** R **WHERE** C;

- The WHERE clause of a SQL command corresponds to **σ**( ).

Union

- The union of two relations R and S is the set of tuples that are in R or in S or in both.
  - R and S must have identical sets of attributes and the types of the attributes must be the same.
  - The attributes of R and S must occur in the same order.

- What is the schema of the result ?

RA: $R \cup S$

SQL:

```
(SELECT * FROM R)
  UNION
(SELECT * FROM S);
```

Union

S1

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

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

$S1 \cup S2$

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

Intersection

- The intersection of two relations R and S is the set of tuples that are in both R and S.
- Same conditions hold on R and S as for the union operator.
  - R and S must have identical sets of attributes and the types of the attributes must be the same.
  - The attributes of R and S must occur in the same order.

RA: $R \cap S$

SQL:
```
(SELECT * FROM R)
 INTERSECT
(SELECT * FROM S);
```

Intersection

S1

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

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

$S1 \cap S2$

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

Difference

- The difference of two relations R and S is the set of tuples that are in R but not in S.
- Same conditions hold on R and S as for the union operator.
  - R and S must have identical sets of attributes and the types of the attributes must be the same.
  - The attributes of R and S must occur in the same order.

RA: $R - S$

SQL:
```
(SELECT * FROM R)
  EXCEPT
(SELECT * FROM S);
```

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

Difference

S1

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

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

$S1 - S2$

sid	sname	rating	age
22	dustin	7	45.0

Cartesian Product

- The Cartesian product (or cross-product or product) of two relations R and S is a the set of pairs that can be formed by pairing each tuple of R with each tuple of S.
  - The result is a relation whose schema is the schema for R followed by the schema for S.

RA: R **X** S

SQL: **SELECT * FROM** R , S ;

Cartesian Product

S1

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

R1

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

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

We rename attributes to avoid ambiguity or we prefix attribute with the name of the relation it belongs to.

Theta-Join

- The theta-join of two relations R and S is the set of tuples in the Cartesian product of R and S that satisfy some condition C.

RA: $R \underset{C}{\infty} S$

SQL:
```
SELECT *
FROM R , S
WHERE C;
```

- $R \underset{C}{\infty} S \;=\; \sigma_C\,(R \times S)$

Theta-Join

S1

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

R1

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

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

(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

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

Natural Join

- The natural join of two relations R and S is a set of pairs of tuples, one from R and one from S, that agree on whatever attributes are common to the schemas of R and S.
- The schema for the result contains the union of the attributes of R and S.
- Assume the schemas R(A,B, C) and S(B, C,D)

RA: R ∞ S

SQL: **SELECT** *
FROM R , S
WHERE R.B = S.B **AND** R.C = S.C;

Operators Covered So far

- Remove parts of a single relation:
  - projection: $\pi_{A,B}(R)$ and `SELECT A, B FROM R`.
  - selection: $\sigma_C(R)$ and `SELECT * FROM R WHERE C`.
  - combining projection and selection:
    - $\pi_{A,B}(\sigma_C(R))$
    - `SELECT A, B FROM R WHERE C`.
- Set operations (R and S must have the same attributes, same attribute tyes, and same order of attributes):
  - union: $R \cup S$ and `(R) UNION (S)`.
  - intersection: $R \cap S$ and `(R) INTERSECT (S)`.
  - difference: $R - S$ and `(R) EXCEPT (S)`.
- Combine the tuples of two relations:
  - Cartesian product: $R \times S$ and `... FROM R, S ...`.
  - Theta-join: $R \underset{C}{\bowtie} S$ and `... FROM R, S WHERE C`.
  - Natural join: $R \bowtie S$; in SQL, list the conditions that the common attributes be equal in the `WHERE` clause.

Renaming

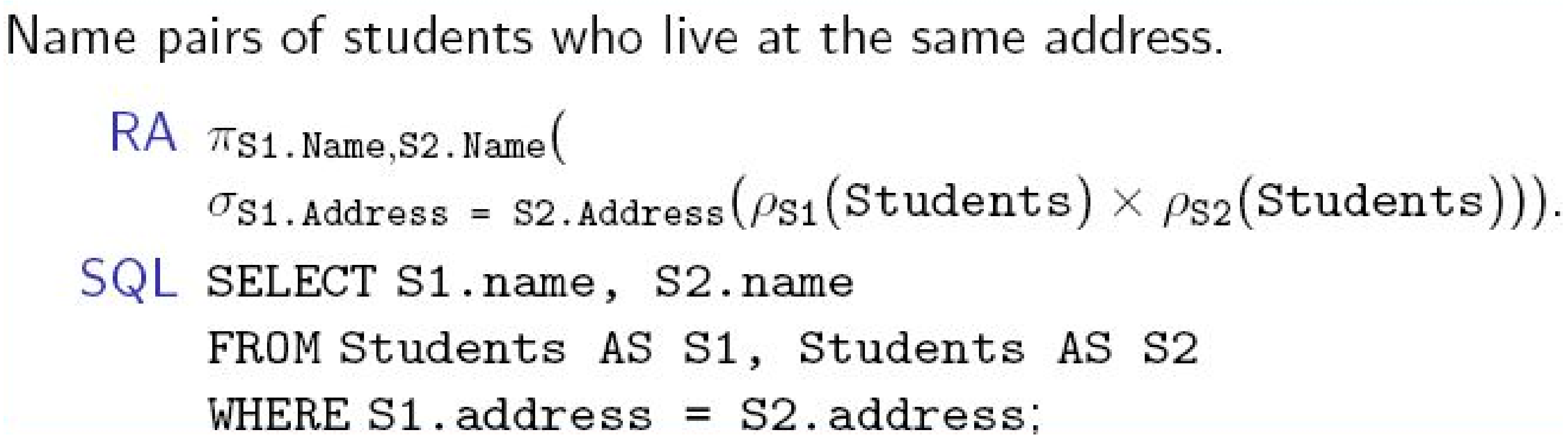
- If two relations have the same attribute, disambiguate the attributes by prefixing the attribute with the name of the relation it belongs to.
- How do we answer the query "Name pairs of students who live at the same address"? `Students(Name, Address)`
  - We need to take the cross-product of Students with itself?
  - How do we refer to the two "copies" of Students?
  - Use the rename operator.

RA: $\rho_{S\ (A1,A2,\ ...\ An)}(R)$: give R the name S; R has n attributes, which are called A1,A2, . . . ,An in S

SQL: Use the **AS** keyword in the **FROM** clause: Students AS Students1 renames Students to Students1.

SQL: Use the **AS** keyword in the **SELECT** clause to rename attributes.

Renaming



Name pairs of students who live at the same address.

RA $\pi_{\texttt{S1.Name,S2.Name}}($
$\sigma_{\texttt{S1.Address = S2.Address}}(\rho_{\texttt{S1}}(\texttt{Students}) \times \rho_{\texttt{S2}}(\texttt{Students}))).$

SQL
```
SELECT S1.name, S2.name
FROM Students AS S1, Students AS S2
WHERE S1.address = S2.address;
```

- Are these correct ?
- No !!! the result includes tuples where a student is paired with himself/herself
- Solution: Add the condition S1.name <> S2.name.

Practicing Relational Algebra

Q1: Find names of sailors who have reserved boat #103

Reserves(sid, bid, day)

Sailors(sid, sname, rating, age)

- Solution 1:

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

- Solution 2 (more efficient)

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

- Solution 3 (using rename operator)

  $P(Temp1\ (\sigma_{bid = 103}\ Reserves))$

  $P(Temp2\ (Temp1 \infty Sailors))$

  $\pi_{sname}(Temp2)$

Q2: Find names of sailors who have reserved a red boat

Reserves(sid, bid, day)

Boats(bid, bname, color)

Sailors(sid, sname, rating, age)

- Solution 1:

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

- Solution 2 (more efficient)

  $\pi_{sname}(\pi_{sid}\ ((\pi_{bid}\sigma_{color\ =\ 'red'}\ Boats) \infty\ Reserves\ ) \infty\ Sailors\ )$

Q3: Find the colors of boats reserved by Lubber

Reserves(sid, bid, day)
Boats(bid, bname, color)

Sailors(sid, sname, rating, age)

- Solution:

$\pi_{color}((\sigma_{sname = \text{'Lubber'}} \text{ Sailor}) \infty \text{ Reserves } \infty \text{ Boats })$

Q4: Find the names of sailors who have reserved at least one boat

Reserves(sid, bid, day)

Boats(bid, bname, color)

Sailors(sid, sname, rating, age)

- Solution:

$$\boldsymbol{\pi_{sname}(Sailor \infty\ Reserves)}$$

Q5: Find the names of sailors who have reserved a red or a green boat

Reserves(sid, bid, day)

Sailors(sid, sname, rating, age)

Boats(bid, bname, color)

- Solution:

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

Q6: Find the names of sailors who have reserved a red <u>and</u> a green boat

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

- Solution:

  ~~$\pi_{sname}(\sigma_{color='red' \text{ and } color = 'green'}\ Boats \infty Reserves \infty Sailors)$~~

A ship cannot have TWO colors at the same time

$$\pi_{sname}(\sigma_{color='red'}\ Boats \infty Reserves \infty Sailors)$$
$$\cap$$
$$\pi_{sname}(\sigma_{color = 'green'}\ Boats \infty Reserves \infty Sailors)$$

Q7: Find the sids of sailors with age over 20 who have not reserved a red boat

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

Strategy ? ? ?

Find all sailors (sids) with age over 20
Find all sailors (sids) who have reserved a red boat
Take their set difference

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