Relational Algebra (continued)

Annoucements

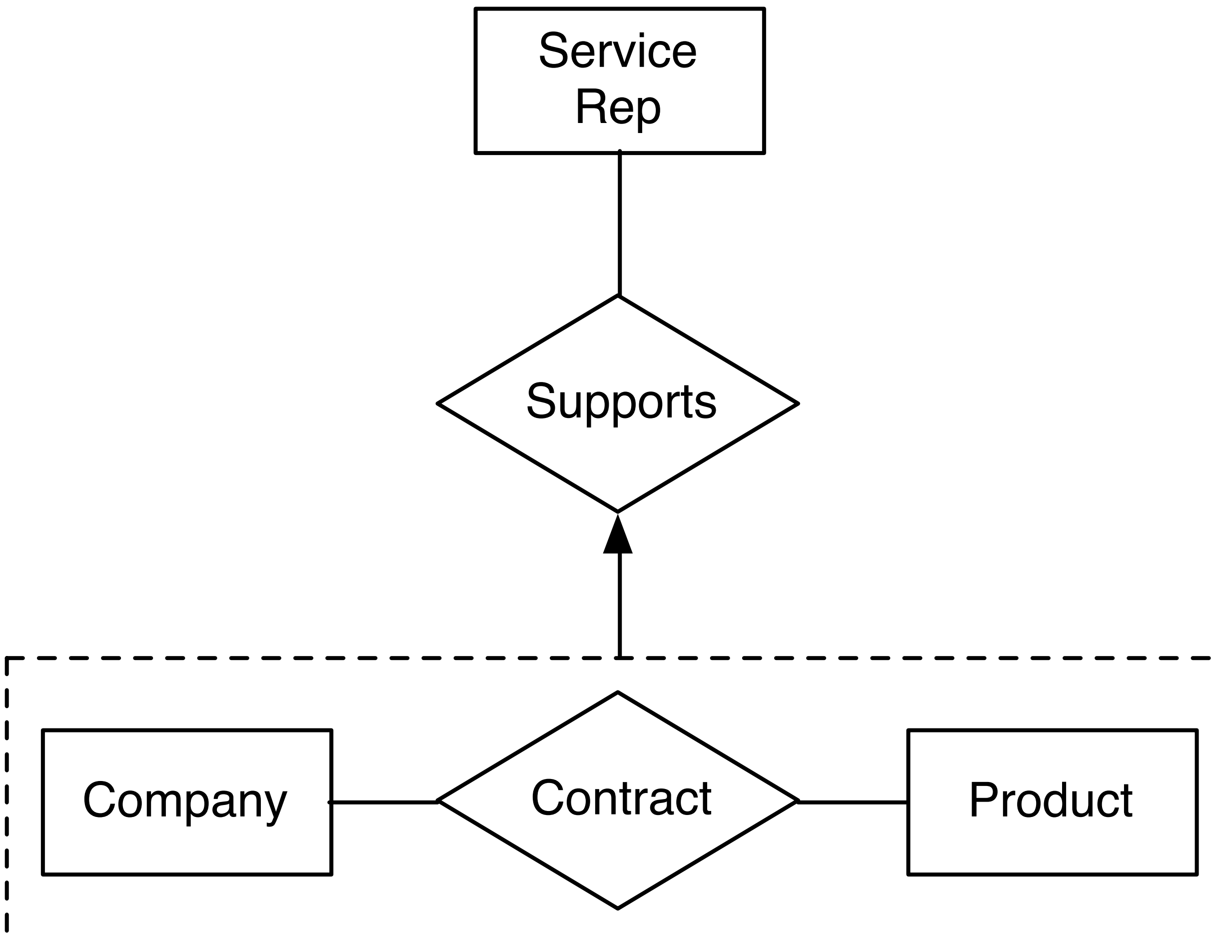
HW1 Due

Project 1 Part 1:

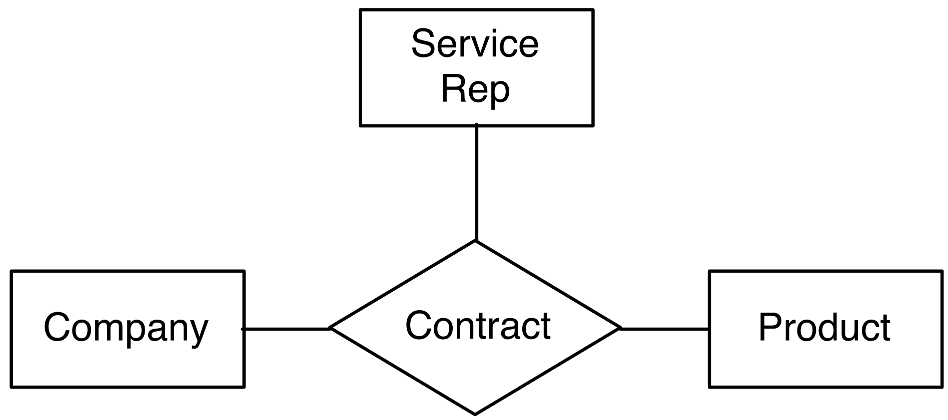
- Passwords for part 2 on front for each user
- All capital letters
- Will provide access to list of Azure codes

Part 2: Available now

Aggregate example: Why not ternary?



Aggregate example: Why not ternary?



Companies buy products with a contract;

all contracts have service reps

Relationship sets: Connects N entities

All entities are required

Cross-Product

S1

sid	name	gpa	age
1	eugene	4	20
2	barak	3	21
3	trump	2	88

R1

sid	rid	day
1	101	10/10
2	102	11/11

S1 x R1 =

(sid)	name	gpa	age	(sid)	rid	day
1	eugene	4	20	1	101	10/10
2	barak	3	21	1	101	10/10
3	trump	2	88	1	101	10/10
1	eugene	4	20	2	102	11/11
2	barak	3	21	2	102	11/11
3	trump	2	88	2	102	11/11

Rename

ρ(<new_name>(<mappings>), Q)

Explicitly defines/changes field names of schema

ρ(C(1 → sid1, 5 → sid2), S1 x R1)

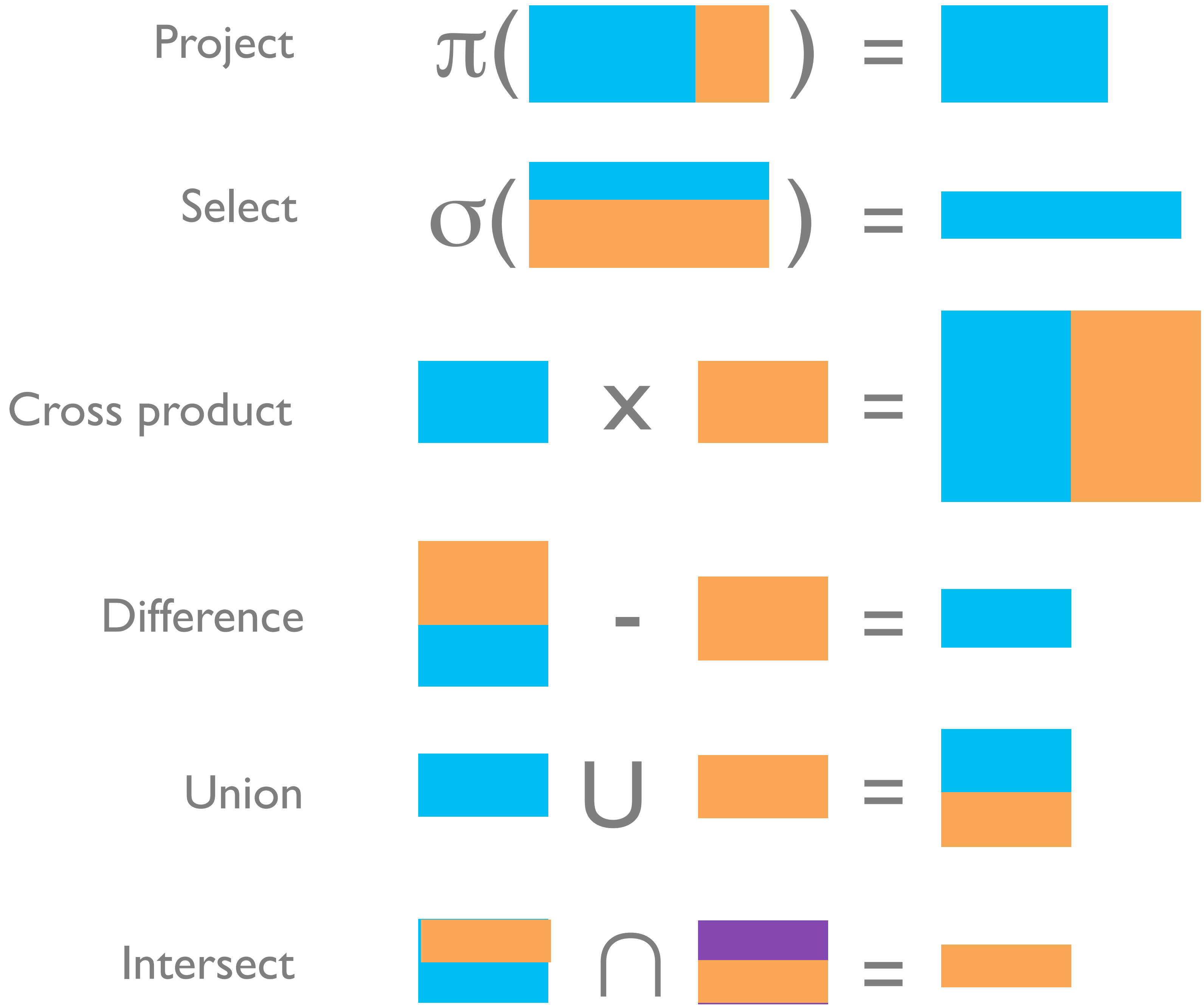
C =

sid1	name	gpa	age	sid2	rid	day
1	eugene	4	20	1	101	10/10
2	barak	3	21	1	101	10/10
3	trump	2	88	1	101	10/10
1	eugene	4	20	2	102	11/11
2	barak	3	21	2	102	11/11
3	trump	2	88	2	102	11/11

How do I know column # in large DB?

You count

Yes, that seems silly, but how else can you assign identifiers automatically?


Project
$\pi($ $)$ =
Select
$\sigma($ $)$ =
Cross product
x =
Difference
- =
Union
∪ =
Intersect
∩ =

Ambiguous names

E.g. Students: (sid, name, …)

Enrolled: (sid, cid, grade)

Qualified names: Use table name: Students.age

Rename: AS (optional): shortcuts, ambiguity, clarity

SELECT S.sid, S.name FROM Students AS S

SELECT S.sid, S.name FROM Students S

Related data: Multiple tables

What does this return?

```
SELECT S.name, E.cid
FROM Students S, Enrolled E
WHERE S.sid = E.sid AND
      E.grade = 'A'
```

Enrolled

sid	cid	grade
1	2	A
1	3	B
2	2	A+

Students

sid	name
1	eugene
2	luis

SELECT ~~S.name, E.cid~~
~~FROM Students S~~, Enrolled E
WHERE ~~S.sid = E.sid AND~~
E.grade = 'A'

Result

name	cid
eugene	2

Multi-Table Semantics

- Modify the FROM clause evaluation
  - 1. FROM clause: compute *cross-product* of Students and Enrolled

Enrolled

sid	cid	grade
1	2	A
1	3	B
2	2	A+

Students

sid	name
1	eugene
2	luis

Cross-product

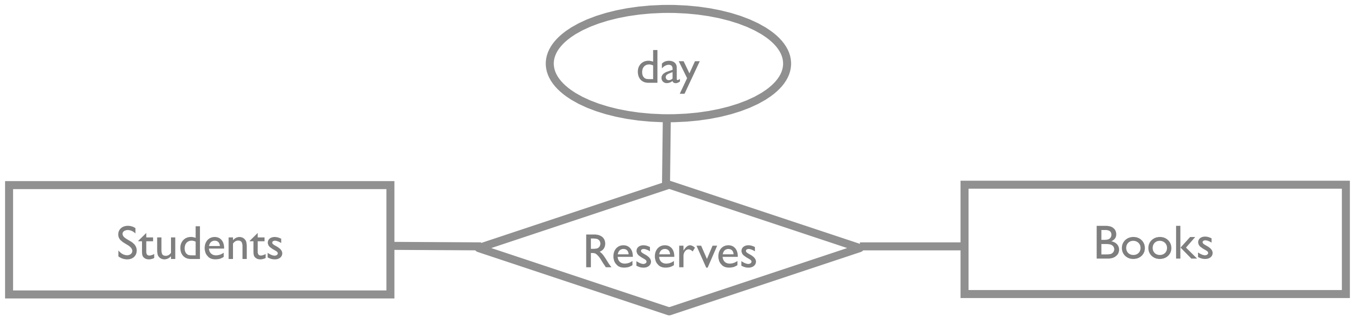
sid	cid	grade	sid	name
1	2	A	1	eugene
1	3	B	1	eugene
2	2	A+	1	eugene
1	2	A	2	luis
1	3	B	2	luis
2	2	A+	2	luis

Multi-Table Semantics

Modify the FROM clause evaluation

1. FROM clause: compute *cross-product* of Students, Enrolled
2. WHERE clause: Check conditions, discard tuples that fail
3. SELECT clause: Delete unwanted fields

Joins (high level)



relation relation relation

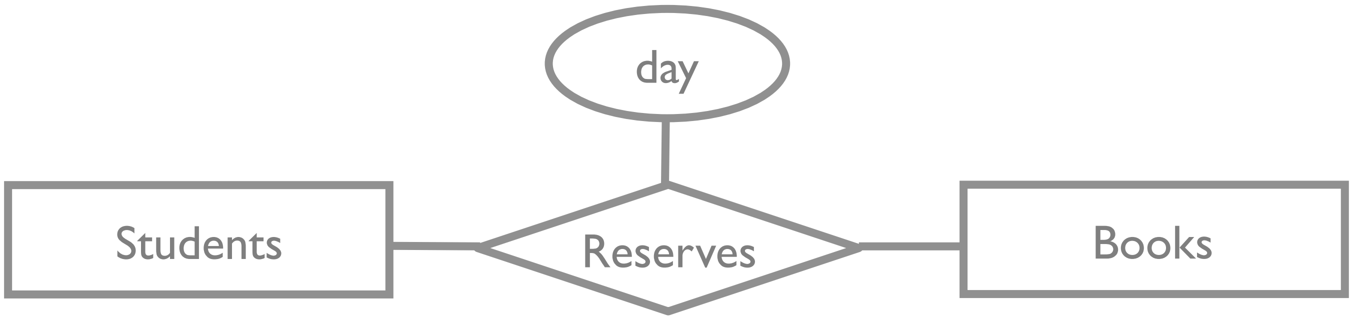
What if you want to query across all three tables?

e.g., all names of students that reserved "The Purple Crayon"

Need to combine these tables

Cross product? But that ignores foreign key references

Joins (high level)



relation relation relation

S1

sid	name	gpa	age
1	eugene	4	20
2	barak	3	21
3	trump	2	88

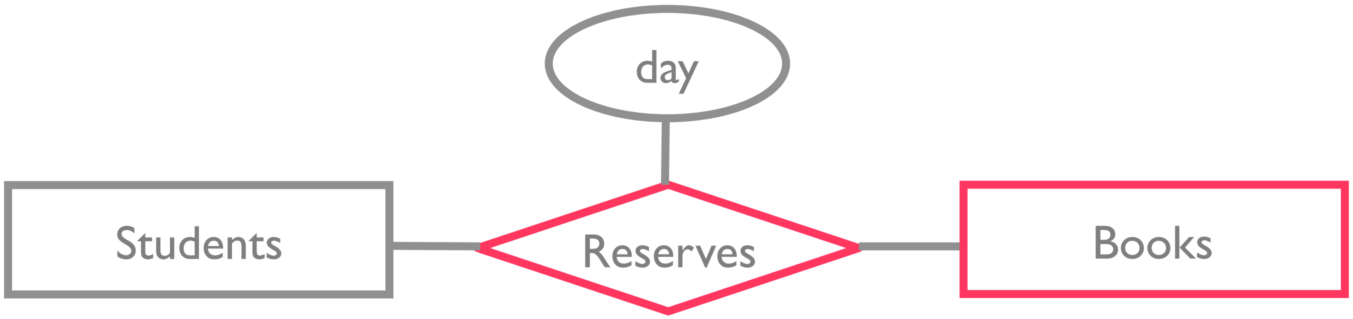
R1

sid	rid	day
1	101	10/10
2	102	11/11

B1

rid	name
101	The Purple Crayon
102	1984

Joins (high level)



relation relation relation

S1

sid	name	gpa	age
1	eugene	4	20
2	barak	3	21
3	trump	2	88

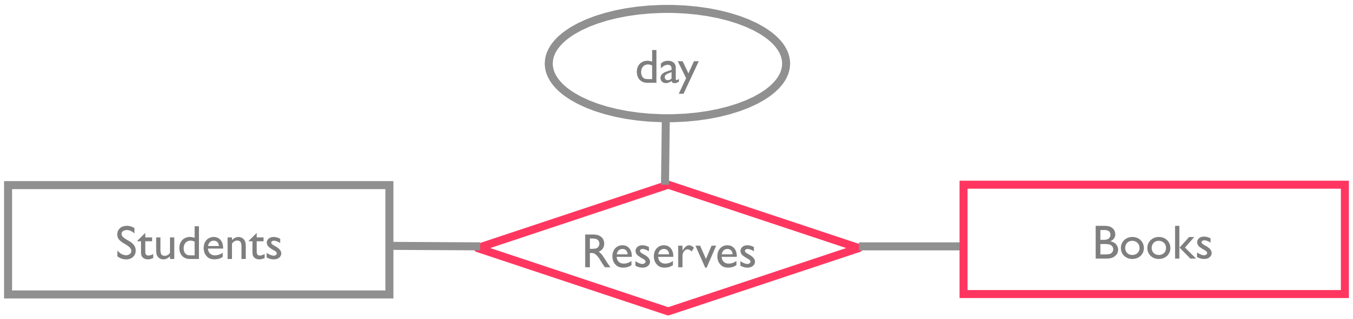
R1

sid	rid	day
1	101	10/10
2	102	11/11

B1

rid	name
101	The Purple Crayon
102	1984

Joins (high level)



relation relation relation

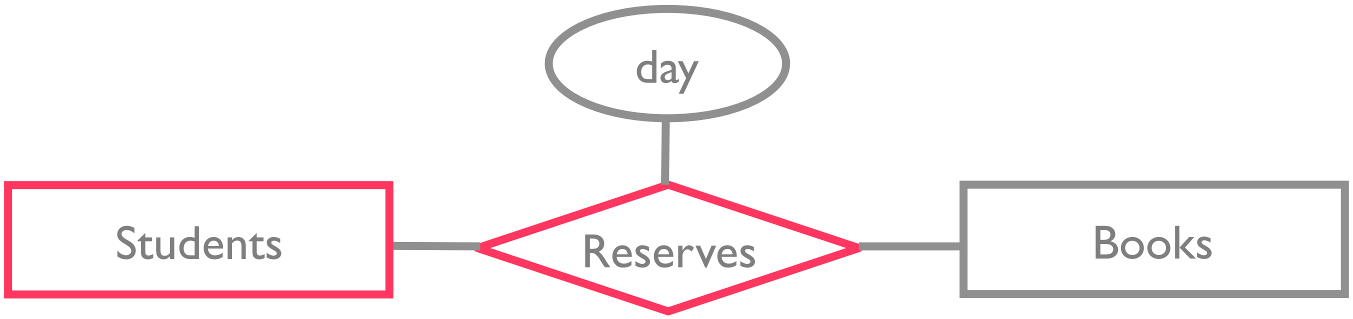
S1

sid	name	gpa	age
1	eugene	4	20
2	barak	3	21
3	trump	2	88

RB1

sid	(rid)	day	(rid)	name
1	101	10/10	101	The Purple Crayon
2	102	11/11	102	1984

Joins (high level)



relation relation relation

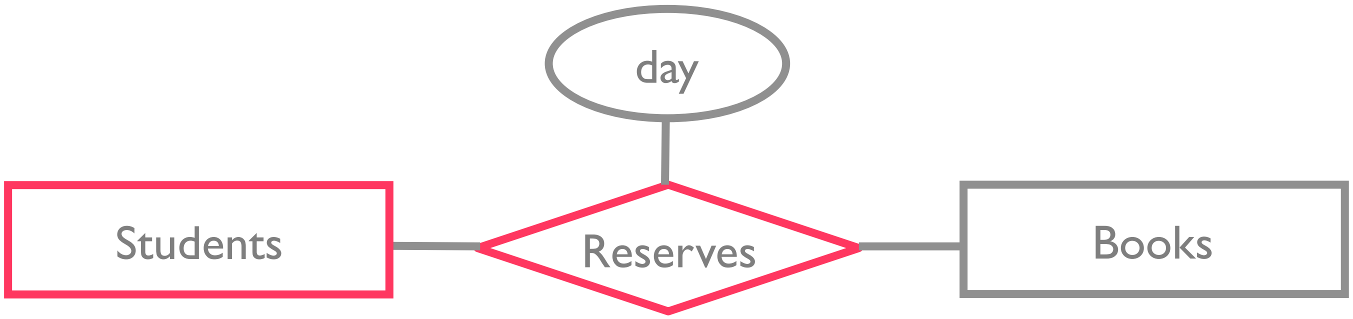
S1

sid	name	gpa	age
1	eugene	4	20
2	barak	3	21
3	trump	2	88

RB1

sid	(rid)	day	(rid)	name
1	101	10/10	101	The Purple Crayon
2	102	11/11	102	1984

Joins (high level)



relation relation relation

SRB1

(sid)	(name)	gpa	age	(sid)	(rid)	day	(rid)	(name)
1	eugene	4	20	1	101	10/10	101	The Purple Crayon
2	barak	3	21	2	102	11/11	102	1984

theta (θ) Join

$$A \bowtie_c B = \sigma_c(A \times B)$$

Most general form

Result schema same as cross product

Often *far* more efficient to compute than cross product

Commutative

$$(A \bowtie_c B) \bowtie_c C = A \bowtie_c (B \bowtie_c C)$$

theta (θ) Join

S1

sid	name	gpa	age
1	eugene	4	20
2	barak	3	21
3	trump	2	88

R1

sid	rid	day
1	101	10/10
2	102	11/11

$S1 \bowtie_{S1.sid \leq R1.sid} R1 =$

(sid)	name	gpa	age	(sid)	rid	day
1	eugene	4	20	1	101	10/10
1	eugene	4	20	2	102	11/11
2	barak	3	21	2	102	11/11

Equi-Join

$$A \bowtie_{attr} B = \pi_{\text{all attrs } \textit{except} \text{ B.attr}}(A \bowtie_{A.attr = B.attr} B)$$

Special case where the condition is attribute equality

Result schema only keeps *one copy* of equality fields

Natural Join ($A \bowtie B$):

Equijoin on *all* shared fields (fields w/ same name)

Equi-Join

S1

sid	name	gpa	age
1	eugene	4	20
2	barak	3	21
3	trump	2	88

R1

sid	rid	day
1	101	10/10
2	102	11/11

$S1 \bowtie_{sid} R1 =$

sid	name	gpa	age	rid	day
1	eugene	4	20	101	10/10
2	barak	3	21	102	11/11

Division

Let us have relations A(x, y), B(y)

$$A/B = \{ \langle x \rangle \mid \forall y \in B \ \langle x,y \rangle \in A \}$$

Find all students that have reserved all books

A/B = all x (students) s.t. for every y (reservation), $\langle x,y \rangle \in A$

Good to ponder, not supported in most systems (why?)

Generalization

- y can be a list of fields in B
- x U y is fields in A

Examples

A

sid	rid
1	1
1	2
1	3
1	4
2	1
2	2
3	2
4	2
4	4

R1

rid
2

R2

rid
2
4

R3

rid
1
2
4

A/R1

A/R2

A/R3

Examples

A

sid	rid
1	1
1	2
1	3
1	4
2	1
2	2
3	2
4	2
4	4

R1

rid
2

sid
1
2
3
4

A/R1

R2

rid
2
4

A/R2

R3

rid
1
2
4

A/R3

Examples

A

sid	rid
1	1
1	2
1	3
1	4
2	1
2	2
3	2
4	2
4	4

R1

rid
2

R2

rid
2
4

R3

rid
1
2
4

sid
1
2
3
4

A/R1

sid
1
4

A/R2

A/R3

Examples

A

sid	rid
1	1
1	2
1	3
1	4
2	1
2	2
3	2
4	2
4	4

R1

rid
2

sid
1
2
3
4

A/R1

R2

rid
2
4

sid
1
4

A/R2

R3

rid
1
2
4

sid
1

A/R3

Is A/B a Fundamental Operation?

No. Shorthand like Joins

joins so common, it's natively supported

Hint: Find all *x*s not 'disqualified' by some *y* in *B*.

x value is *disqualified* if

by attaching *y* value from *B* (e.g., create <x, y>)

we obtain an <*x,y*> that is not in *A*.

A

sid	rid
1	1
1	2
1	3
1	4
2	1
2	2
3	2
4	2
4	4

B

rid
2
4

Disqualified =

A/B =

A

sid	rid
1	1
1	2
1	3
1	4
2	1
2	2
3	2
4	2
4	4

B

rid
2
4

$\pi_x(A) \times B$

sid	rid
1	2
1	4
2	2
2	4
3	2
3	4
4	2
4	4

Disqualified = $(\pi_{sid}(A) \times B)$

A/B =

A

sid	rid
1	1
1	2
1	3
1	4
2	1
2	2
3	2
4	2
4	4

B

rid
2
4

$\pi_x(A) \times B$

sid	rid
1	2
1	4
2	2
2	4
3	2
3	4
4	2
4	4

$\pi_x(A) \times B) - A$

sid	rid
2	4
3	4

Disqualified = $((\pi_{sid}(A) \times B) - A)$

A/B =

A

sid	rid
1	1
1	2
1	3
1	4
2	1
2	2
3	2
4	2
4	4

B

rid
2
4

$\pi_{sid}(A) \times B$

sid	rid
1	2
1	4
2	2
2	4
3	2
3	4
4	2
4	4

$(\pi_{sid}(A) \times B) - A$

sid	rid
2	4
3	4

sid
1
4

A/B

$$\text{Disqualified} = \pi_{sid}((\pi_{sid}(A) \times B) - A)$$

$$A/B = \pi_x(A) - \text{Disqualified}$$

Names of students that reserved book 2

$$\pi_{name}(\sigma_{rid=2}(R1) \bowtie S1)$$

Equivalent Queries

$$p(tmp1, \sigma_{rid=2}(R1))$$
$$p(tmp2, tmp1 \bowtie S1)$$
$$\pi_{name}(tmp2)$$

$$\pi_{name}(\sigma_{rid=2}(R1 \bowtie S1))$$

Names of students that reserved db books

Book(rid, type)   Reserve(sid, rid)   Student(sid)

Need to join DB books with reserve and students

$\sigma_{type='db'}$ (Book)

Names of students that reserved db books

Book(rid, type) Reserve(sid, rid) Student(sid)

Need to join DB books with reserve and students

$\sigma_{type='db'}$ (Book) ⋈ Reserve

Names of students that reserved db books

Book(rid, type)   Reserve(sid, rid)   Student(sid)

Need to join DB books with reserve and students

$\sigma_{type='db'}$ (Book) ⋈ Reserve ⋈ Student

Names of students that reserved db books

Book(rid, type)   Reserve(sid, rid)   Student(sid)

Need to join DB books with reserve and students

$\pi_{name}(\sigma_{type='db'}(Book) \bowtie Reserve \bowtie Student)$

Names of students that reserved db books

Book(rid, type) Reserve(sid, rid) Student(sid)

Need to join DB books with reserve and students

$$\pi_{name}(\sigma_{type='db'}(Book) \bowtie Reserve \bowtie Student)$$

More efficient query

$$\pi_{name}(\pi_{sid}((\pi_{rid}\, \sigma_{type='db'}(Book)) \bowtie Reserve) \bowtie Student)$$

Query optimizer can find the more efficient query!

Names of students that reserved db books

Book(rid, type)   Reserve(sid, rid)   Student(sid)

Need to join DB books with reserve and students

$\pi_{name}(\sigma_{type='db'}(Book) \bowtie Reserve \bowtie Student)$

More efficient query

$\pi_{name}(\pi_{sid}((\pi_{rid}\ \sigma_{type='db'}(Book)) \bowtie Reserve) \bowtie Student)$

Query optimizer can find the more efficient query!

Names of students that reserved db books

Book(rid, type) Reserve(sid, rid) Student(sid)

Need to join DB books with reserve and students

$$\pi_{name}(\sigma_{type='db'}(Book) \bowtie Reserve \bowtie Student)$$

More efficient query

$$\pi_{name}(\pi_{sid}((\pi_{rid}\,\sigma_{type='db'}(Book)) \bowtie Reserve) \bowtie Student)$$

Query optimizer can find the more efficient query!

Names of students that reserved db books

Book(rid, type) Reserve(sid, rid) Student(sid)

Need to join DB books with reserve and students

$\pi_{name}(\sigma_{type='db'}(Book) \bowtie Reserve \bowtie Student)$

More efficient query

$\pi_{name}(\pi_{sid}((\pi_{rid}\ \sigma_{type='db'}(Book)) \bowtie Reserve) \bowtie Student)$

Query optimizer can find the more efficient query!

Students that reserved DB or HCI book

1. Find all DB or HCI books
2. Find students that reserved one of those books
   - $p(tmp, (\sigma_{type='DB' \vee type='HCI'} (Book))$
   - $\pi_{name}(tmp \bowtie Reserve \bowtie Student)$

Alternatives

define tmp using UNION (how?)

what if we replaced v with ^ in the query?

Students that reserved a DB and HCI book

Does previous approach work?

$$\rho(tmp, (\sigma_{type='DB' \wedge type='HCI'} (Book))$$

$$\pi_{name}(tmp \bowtie Reserve \bowtie Student)$$

NO

Students that reserved a DB and HCI book

Does previous approach work?

1. Find students that reserved DB books
2. Find students that reversed HCI books
3. Intersection

$$p(tmpDB, \pi_{sid}(\sigma_{type='DB'} Book) \bowtie Reserve)$$
$$p(tmpHCI, \pi_{sid}(\sigma_{type='HCI'} Book) \bowtie Reserve)$$
$$\pi_{name}((tmpDB \cap tmpHCI) \bowtie Student)$$

Students that reserved all books

Use division

Be careful with schemas of inputs to / !

$$p(tmp, (\pi_{sid,rid}\ Reserves) \,/\, (\pi_{rid}\ Books))$$

$$\pi_{name}(tmp \bowtie Student)$$

What if want students that reserved all horror books?

$$p(tmp, (\pi_{sid,rid}\ Reserves) \,/\, (\pi_{rid}(\sigma_{type='horror'}\ Book)\ ))$$

Let’s step back

Relational algebra is expressiveness benchmark

- A language equal in expressiveness as relational algebra is relationally complete

But has limitations

- nulls
- aggregation
- recursion
- duplicates

Equi-Joins are a way of life

Matching of two sets based on shared attributes

Yelp:	Join between your location and restaurants
Market:	Join between consumers and suppliers
High five:	Join between two hands on time and space
Comm.:	Join between minds on ideas/concepts

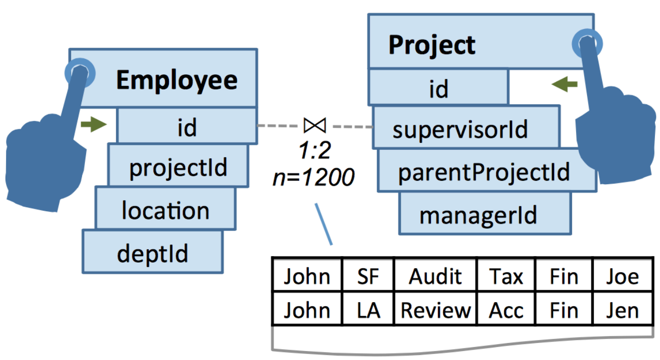
Mat oute

What can we do with RA?

Query by example

Here's my data and examples of the result, *generate the query for me*

Novel relationally complete interfaces



GestureDB. Nandi et al.

Summary

Relational Algebra (RA) operators

Operators are closed

- inputs & outputs are relations

Multiple Relational Algebra queries can be equivalent

- It is operational
- Same semantics but different performance
- Forms basis for optimizations

Next Time

~~Relational Calculus~~

SQL