

Introduction to Database Systems

CSE 414

Lecture 4: SQL Joins and Aggregates

Announcements

- WQ1 due on Tuesday
 - No late days allowed
- HW1 due on Tuesday
 - Submit using script in repo
- WQ2 and HW2 will be out tomorrow
 - Both are 1 week assignments
- Check website for up to date OHs

`Product(pname, price, category, manufacturer)`

`Company(cname, country)`

Joins in SQL

pname	price	category	manufacturer
MultiTouch	199.99	gadget	Canon
SingleTouch	49.99	photography	Canon
Gizom	50	gadget	GizmoWorks
SuperGizmo	250.00	gadget	GizmoWorks

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

Retrieve all Japanese products that cost < \$150

```
SELECT P.pname, P.price  
FROM Product as P, Company as C  
WHERE P.manufacturer=C.cname AND  
C.country='Japan' AND C.price < 150
```

Join Predicate

Selection predicates

`Product(pname, price, category, manufacturer)`

`Company(cname, country)`

Joins in SQL

pname	price	category	manufacturer
MultiTouch	199.99	gadget	Canon
SingleTouch	49.99	photography	Canon
Gizom	50	gadget	GizmoWorks
SuperGizmo	250.00	gadget	GizmoWorks

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

Retrieve all USA companies
that manufacture “gadget” products

Product(pname, price, category, manufacturer)

Company(cname, country)

Joins in SQL

pname	price	category	manufacturer
MultiTouch	199.99	gadget	Canon
SingleTouch	49.99	photography	Canon
Gizom	50	gadget	GizmoWorks
SuperGizmo	250.00	gadget	GizmoWorks

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

Retrieve all USA companies
that manufacture “gadget” products

```
SELECT DISTINCT C.cname
FROM Product as P, Company as C
WHERE C.country='USA' AND P.category = 'gadget'
AND P.manufacturer = cname
```

Why
DISTINCT?

(Inner) joins

```
Product(pname, price, category, manufacturer)
Company(cname, country)
-- manufacturer is foreign key to Company
```

```
SELECT DISTINCT cname
FROM Product, Company
WHERE country='USA' AND category = 'gadget'
AND manufacturer = cname
```

(Inner) joins

```
SELECT DISTINCT cname  
FROM Product, Company  
WHERE country='USA' AND category = 'gadget'  
AND manufacturer = cname
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
Camera	Photo	Hitachi
OneClick	Photo	Hitachi

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

(Inner) joins

```
SELECT DISTINCT cname  
FROM Product, Company  
WHERE country='USA' AND category = 'gadget'  
AND manufacturer = cname
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
Camera	Photo	Hitachi
OneClick	Photo	Hitachi

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

(Inner) joins

```
SELECT DISTINCT cname  
FROM Product, Company  
WHERE country='USA' AND category = 'gadget'  
AND manufacturer = cname
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
Camera	Photo	Hitachi
OneClick	Photo	Hitachi

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

(Inner) joins

```
SELECT DISTINCT cname  
FROM Product, Company  
WHERE country='USA' AND category = 'gadget'  
AND manufacturer = cname
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
Camera	Photo	Hitachi
OneClick	Photo	Hitachi

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

pname	category	manufacturer	cname	country
Gizmo	gadget	GizmoWorks	GizmoWorks	USA

(Inner) joins

```
SELECT DISTINCT cname  
FROM Product, Company  
WHERE country='USA' AND category = 'gadget'  
AND manufacturer = cname
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
Camera	Photo	Hitachi
OneClick	Photo	Hitachi

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

(Inner) joins

```
SELECT DISTINCT cname  
FROM Product, Company  
WHERE country='USA' AND category = 'gadget'  
AND manufacturer = cname
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
Camera	Photo	Hitachi
OneClick	Photo	Hitachi

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

(Inner) joins

```
SELECT DISTINCT cname  
FROM Product, Company  
WHERE country='USA' AND category = 'gadget'  
      AND manufacturer = cname
```

//

```
SELECT DISTINCT cname  
FROM Product JOIN Company ON  
      country = 'USA' AND category = 'gadget'  
      AND manufacturer = cname
```

(Inner) Joins

```
SELECT x1.a1, x2.a2, ... xm.am  
FROM   R1 as x1, R2 as x2, ... Rm as xm  
WHERE  Cond
```

✓ tuple in R1

for x1 in R1:

 for x2 in R2:

 ...

 for xm in Rm:

 if Cond(x1, x2...):

 output(x1.a1, x2.a2, ... xm.am)

This is called nested loop semantics since we are interpreting what a join means using a nested loop

Another example

Product(pname, price, category, manufacturer)
Company(cname, country)

-- manufacturer is foreign key to Company

Find US companies that manufacture both
'gadgets' and 'photo' products

Another example

Product(pname, price, category, manufacturer)
Company(cname, country)

-- manufacturer is foreign key to Company

Find US companies that manufacture both
'gadgets' and 'photo' products

```
SELECT DISTINCT z.cname
FROM Product x, Company z
WHERE z.country = 'USA'
    AND x.manufacturer = z.cname
    AND x.category = 'gadget'
    AND x.category = 'photography';
```

individual
tuples

Does this
work?

Another example

Product(pname, price, category, manufacturer)
Company(cname, country)

-- manufacturer is foreign key to Company

Find US companies that manufacture **both**
'gadgets' and 'photo' products

```
SELECT DISTINCT z.cname
FROM Product x, Company z
WHERE z.country = 'USA'
    AND x.manufacturer = z.cname
    AND (x.category = 'gadget'
        OR x.category = 'photography');
```

What about
this?

Another example

Product(pname, price, category, manufacturer)
Company(cname, country)

-- manufacturer is foreign key to Company

Find US companies that manufacture both
'gadgets' and 'photo' products

```
SELECT DISTINCT z.cname
FROM Product x, Product y, Company z
WHERE z.country = 'USA'
    AND x.manufacturer = z.cname
    AND y.manufacturer = z.cname
    AND x.category = 'gadget'
    AND y.category = 'photography';
```

Need to include
Product twice!

Self-Joins and Tuple Variables

Find US companies that manufacture both
‘gadgets’ and ‘photo’ products

- Joining Product with Company is insufficient: need to join Product, with Product, and with Company
- When a relation occurs twice in the FROM clause we call it a self-join; in that case we must use tuple variables (aka table aliases) (why?)

Self-joins

```
SELECT DISTINCT z cname  
FROM Product x, Product y, Company z  
WHERE z.country = 'USA'  
AND x.category = 'gadget'  
AND y.category = 'photo'  
AND x.manufacturer = z cname  
AND y.manufacturer = z cname;
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
SingleTouch	photo	Hitachi
MultiTouch	Photo	GizmoWorks

Company

cname	country
GizmoWorks	USA
Hitachi	Japan

Self-joins

```
SELECT DISTINCT z cname  
FROM Product x, Product y, Company z  
WHERE z.country = 'USA'  
AND x.category = 'gadget'  
AND y.category = 'photo'  
AND x.manufacturer = z cname  
AND y.manufacturer = z cname;
```

Product

X	pname	category	manufacturer
	Gizmo	gadget	GizmoWorks
	SingleTouch	photo	Hitachi
	MultiTouch	Photo	GizmoWorks

Company

cname	country
GizmoWorks	USA
Hitachi	Japan

Self-joins

```
SELECT DISTINCT z cname  
FROM Product x, Product y, Company z  
WHERE z.country = 'USA'  
AND x.category = 'gadget'  
AND y.category = 'photo'  
AND x.manufacturer = z cname  
AND y.manufacturer = z cname;
```

Product

	pname	category	manufacturer
x	Gizmo	gadget	GizmoWorks
y	SingleTouch	photo	Hitachi
	MultiTouch	Photo	GizmoWorks

Company

	cname	country
	GizmoWorks	USA
	Hitachi	Japan

Self-joins

```
SELECT DISTINCT z cname  
FROM Product x, Product y, Company z  
WHERE z.country = 'USA'  
AND x.category = 'gadget'  
AND y.category = 'photo'  
AND x.manufacturer = z cname  
AND y.manufacturer = z cname;
```

Product

X	pname	category	manufacturer
y	Gizmo	gadget	GizmoWorks
	SingleTouch	photo	Hitachi
	MultiTouch	Photo	GizmoWorks

Company

Z	cname	country
	GizmoWorks	USA
	Hitachi	Japan

Self-joins

```
SELECT DISTINCT z cname  
FROM Product x, Product y, Company z  
WHERE z.country = 'USA'  
AND x.category = 'gadget'  
AND y.category = 'photo'  
AND x.manufacturer = z cname  
AND y.manufacturer = z cname;
```

Product

X	pname	category	manufacturer
y	Gizmo	gadget	GizmoWorks
	SingleTouch	photo	Hitachi
	MultiTouch	Photo	GizmoWorks

Company

Z	cname	country
GizmoWorks	USA	
Hitachi	Japan	

Self-joins

```
SELECT DISTINCT z cname  
FROM Product x, Product y, Company z  
WHERE z.country = 'USA'  
AND x.category = 'gadget'  
AND y.category = 'photo'  
AND x.manufacturer = z cname  
AND y.manufacturer = z cname;
```

Product

x	pname	category	manufacturer
	Gizmo	gadget	GizmoWorks
y	SingleTouch	photo	Hitachi
	MultiTouch	Photo	GizmoWorks

Company

z	cname	country
	GizmoWorks	USA
	Hitachi	Japan

Self-joins

```
SELECT DISTINCT z cname  
FROM Product x, Product y, Company z  
WHERE z.country = 'USA'  
AND x.category = 'gadget'  
AND y.category = 'photo'  
AND x.manufacturer = z cname  
AND y.manufacturer = z cname;
```

Product

x	pname	category	manufacturer
	Gizmo	gadget	GizmoWorks
y	SingleTouch	photo	Hitachi
	MultiTouch	Photo	GizmoWorks

Company

z	cname	country
	GizmoWorks	USA
	Hitachi	Japan

Self-joins

```
SELECT DISTINCT z cname  
FROM Product x, Product y, Company z  
WHERE z.country = 'USA'  
AND x.category = 'gadget'  
AND y.category = 'photo'  
AND x.manufacturer = z cname  
AND y.manufacturer = z cname;
```

Product

x	pname	category	manufacturer
	Gizmo	gadget	GizmoWorks
	SingleTouch	photo	Hitachi
y	MultiTouch	Photo	GizmoWorks

Company

z	cname	country
	GizmoWorks	USA
	Hitachi	Japan

Self-joins

```
SELECT DISTINCT z cname  
FROM Product x, Product y, Company z  
WHERE z.country = 'USA'  
AND x.category = 'gadget'  
AND y.category = 'photo'  
AND x.manufacturer = z cname  
AND y.manufacturer = z cname;
```

Product

x	pname	category	manufacturer
	Gizmo	gadget	GizmoWorks
	SingleTouch	photo	Hitachi
y	MultiTouch	Photo	GizmoWorks

Company

z	cname	country
	GizmoWorks	USA
	Hitachi	Japan

x.pname	x.category	x.manufacturer	y.pname	y.category	y.manufacturer	z cname	z.country
Gizmo	gadget	GizmoWorks	MultiTouch	Photo	GizmoWorks	GizmoWorks	USA

Self-joins

```
SELECT DISTINCT z cname  
FROM Product x, Product y, Company z  
WHERE z.country = 'USA'  
AND x.category = 'gadget'  
AND y.category = 'photo'  
AND x.manufacturer = z cname  
AND y.manufacturer = z cname;
```

Product

x	pname	category	manufacturer
	Gizmo	gadget	GizmoWorks
	SingleTouch	photo	Hitachi
y	MultiTouch	Photo	GizmoWorks

Company

z	cname	country
	GizmoWorks	USA
	Hitachi	Japan

x.pname	x.category	x.manufacturer	y.pname	y.category	y.manufacturer	z cname	z.country
Gizmo	gadget	GizmoWorks	MultiTouch	Photo	GizmoWorks	GizmoWorks	USA

Joins in SQL

- The join we have just seen is sometimes called an **inner join**
 - Each row in the result **must come from both tables in the join**
- Sometimes we want to include rows from only one of the two table: **outer join**

Employee(id, name)

Sales(employeeID, productID)

Inner Join

Employee

<u>id</u>	name
1	Joe
2	Jack
3	Jill

Sales

<u>employeeID</u>	productID
1	344
1	355
2	544

Retrieve employees and their sales

`Employee(id, name)`

`Sales(employeeID, productID)`

Inner Join

Employee

<u>id</u>	name
1	Joe
2	Jack
3	Jill

Sales

<u>employeeID</u>	productID
1	344
1	355
2	544

Retrieve employees and their sales

```
SELECT *
FROM   Employee E, Sales S
WHERE  E.id = S.employeeID
```

Employee(id, name)

Sales(employeeID, productID)

Inner Join

Employee

<u>id</u>	name
1	Joe
2	Jack
3	Jill

Sales

<u>employeeID</u>	productID
1	344
1	355
2	544

Retrieve employees and their sales

```
SELECT *
FROM Employee E, Sales S
WHERE E.id = S.employeeID
```

<u>id</u>	name	<u>employeeID</u>	productID
1	Joe	1	344
1	Joe	1	355
2	Jack	2	544

Employee(id, name)

Sales(employeeID, productID)

Inner Join

Employee

<u>id</u>	name
1	Joe
2	Jack
3	Jill

Sales

<u>employeeID</u>	productID
1	344
1	355
2	544

Retrieve employees and their sales

Jill is missing

```
SELECT *
FROM Employee E, Sales S
WHERE E.id = S.employeeID
```

<u>id</u>	name	<u>employeeID</u>	productID
1	Joe	1	344
1	Joe	1	355
2	Jack	2	544

`Employee(id, name)`

`Sales(employeeID, productID)`

Inner Join

Employee

<u>id</u>	name
1	Joe
2	Jack
3	Jill

Sales

<u>employeeID</u>	productID
1	344
1	355
2	544

Retrieve employees and their sales

Alternative syntax

```
SELECT *
FROM Employee E
INNER JOIN
Sales S
ON E.id = S.employeeID
```

Jill is missing

<u>id</u>	name	<u>employeeID</u>	productID
1	Joe	1	344
1	Joe	1	355
2	Jack	2	544

Employee(id, name)

Sales(employeeID, productID)

Outer Join

Employee

<u>id</u>	name
1	Joe
2	Jack
3	Jill

Sales

<u>employeeID</u>	productID
1	344
1	355
2	544

Retrieve employees and their sales

Jill is present

```
SELECT *
FROM Employee E
LEFT OUTER JOIN
Sales S
ON E.id = S.employeeID
```

<u>id</u>	name	<u>employeeID</u>	productID
1	Joe	1	344
1	Joe	1	355
2	Jack	2	544
3	Jill	NULL	NULL

Outer joins

Product(name, category)

Purchase(prodName, store)

-- prodName is foreign key

```
SELECT Product.name, Purchase.store  
FROM Product LEFT OUTER JOIN Purchase ON  
Product.name = Purchase.prodName
```

```
SELECT Product.name, Purchase.store  
FROM Product JOIN Purchase ON  
Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

```
SELECT Product.name, Purchase.store  
FROM Product JOIN Purchase ON  
Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

```
SELECT Product.name, Purchase.store  
FROM Product JOIN Purchase ON  
Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz

```
SELECT Product.name, Purchase.store  
FROM Product JOIN Purchase ON  
Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz

```
SELECT Product.name, Purchase.store  
FROM Product JOIN Purchase ON  
Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz

```
SELECT Product.name, Purchase.store  
FROM Product JOIN Purchase ON  
Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz

```
SELECT Product.name, Purchase.store  
FROM Product JOIN Purchase ON  
Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz
Camera	Ritz

```
SELECT Product.name, Purchase.store  
FROM Product JOIN Purchase ON  
Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

```
SELECT Product.name, Purchase.store  
FROM Product JOIN Purchase ON  
Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

```

SELECT Product.name, Purchase.store
FROM Product LEFT OUTER JOIN Purchase ON
Product.name = Purchase.prodName

```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

```

SELECT Product.name, Purchase.store
FROM Product LEFT OUTER JOIN Purchase ON
Product.name = Purchase.prodName

```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz
OneClick	NULL

```

SELECT Product.name, Purchase.store
FROM Product FULL OUTER JOIN Purchase ON
Product.name = Purchase.prodName

```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz
Phone	Foo

Output

Name	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz
OneClick	NULL
NULL	Foo

Outer Joins

```
tableA (LEFT/RIGHT/FULL) OUTER JOIN tableB ON p
```

- Left outer join:
 - Include tuples from tableA even if no match
- Right outer join:
 - Include tuples from tableB even if no match
- Full outer join:
 - Include tuples from both even if no match
- In all cases:
 - Patch tuples without matches using NULL