SQL – Data Manipulation Language

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Based on Jennifer Widom slides

Operators summary

attribute [NOT] IN Relation

[NOT] attribute IN Relation

[NOT] EXISTS Relation

attribute <comparison> ALL Relation

attribute <comparison> ANY Relation

Comparison may be: <; >; <=; >=; =; <>

ALL and ANY not supported by SQLite

College(cName, state, enr)
Student(sID, sName, GPA, sizeHS)
Apply(sID, cName, major, decision)

Existential quantifier

An existential quantifier (∃) is a quantifier of the form “there exists”

Find colleges with some applications of students with a GPA higher than 3.8

```
SELECT DISTINCT cName
FROM Apply, Student
WHERE Apply.sID=Student.sID AND GPA>3.8;
```

Existential is easy!

cName
Stanford
Berkeley
MIT
Cornell

College(cName, state, enr)
Student(sID, sName, GPA, sizeHS)
Apply(sID, cName, major, decision)

Universal quantifier

A universal quantifier (∀) is a quantifier of the form “for all”

Find colleges with applications of students all having a GPA higher than 3.8

Equivalent

Find colleges that only have applications of students with a GPA higher than 3.8

cName

```
SELECT DISTINCT cName
FROM Apply
WHERE College.cName NOT IN (
        SELECT Apply.cName FROM Apply, Student
        WHERE Apply.sID=Student.sID AND GPA<=3.8);
```

Agenda

~~Introduction~~

~~Basic SQL Statement~~

~~Table Variables and Set Operators~~

~~Subqueries in WHERE clauses~~

Subqueries in FROM and SELECT clauses

The JOIN family of operators

Aggregation

Null values

Data Modification statements

Subqueries in FROM and SELECT

SELECT $A_1, A_2, \ldots, A_n$ →

FROM $R_1, R_2, \ldots, R_m$ →

WHERE condition

Expressions involving subqueries

Subqueries are nested SELECT statements

Subqueries in FROM generate a table to be used in the query

Subqueries in SELECT produce a value that comes out of the query

Subqueries in the FROM clause

```
SELECT  sID, sName, GPA, GPA*(HS/1000) as scaledGPA
FROM    Student
WHERE   GPA*(HS/1000)-GPA>1.0 OR GPA – GPA*(HS/1000) > 1.0;
```

Return all students whose scaledGPA changes GPA by more than 1

Can we simplify this query?

College(cName, state, enr)
Student(sID, sName, GPA, sizeHS)
Apply(sID, cName, major, decision)

sID	sName	GPA	scaledGPA
234	Bob	3.6	5.4
345	Craig	3.5	1.75
567	Edward	2.9	5.8
678	Fay	3.8	0.76
876	Irene	3.9	1.56
765	Jay	2.9	4.35
543	Craig	3.4	6.8

Subqueries in the FROM clause

```
SELECT  sID, sName, GPA, GPA*(HS/1000) as scaledGPA
FROM    Student
WHERE  GPA*(HS/1000)-GPA>1.0 OR GPA – GPA*(HS/1000) > 1.0;
```

```
SELECT  sID, sName, GPA, GPA*(HS/1000) as scaledGPA
FROM    Student
WHERE  abs(GPA*(HS/1000)-GPA)>1.0;
```

College(cName, state, enr)
Student(sID, sName, GPA, sizeHS)
Apply(sID, cName, major, decision)

sID	sName	GPA	scaledGPA
234	Bob	3.6	5.4
345	Craig	3.5	1.75
567	Edward	2.9	5.8
678	Fay	3.8	0.76
876	Irene	3.9	1.56
765	Jay	2.9	4.35
543	Craig	3.4	6.8

Subqueries in the FROM clause

```
SELECT  sID, sName, GPA, GPA*(HS/1000) as scaledGPA
FROM    Student
WHERE  abs(GPA*(HS/1000)-GPA) > 1.0;
```

```
SELECT *
FROM (select  sID, sName, GPA, GPA*(HS/1000) as scaledGPA
        from Student) G
WHERE  abs(scaledGPA - GPA) > 1.0;
```

College(cName, state, enr)
Student(sID, sName, GPA, sizeHS)
Apply(sID, cName, major, decision)

sID	sName	GPA	scaledGPA
234	Bob	3.6	5.4
345	Craig	3.5	1.75
567	Edward	2.9	5.8
678	Fay	3.8	0.76
876	Irene	3.9	1.56
765	Jay	2.9	4.35
543	Craig	3.4	6.8

Subqueries in the SELECT clause

```
SELECT  DISTINCT College.cName, state, GPA
FROM    College, Apply, Student
WHERE   College.cName = Apply.cName
        AND Apply.sID = Student.sID
        AND GPA >= all
        (select GPA from Student, Apply
        where Student.sID = Apply.sID
        and Apply.cName = College.cName);
```

cName	state	GPA
Stanford	CA	3.9
Berkeley	CA	3.9
Cornell	NY	3.9
MIT	MA	3.9

How to rewrite it using a subquery in SELECT?

College(cName, state, enr)
Student(sID, sName, GPA, sizeHS)
Apply(sID, cName, major, decision)

Return colleges paired with the highest GPA of their applicants

Subqueries in the SELECT clause

```
SELECT cName, state,
(SELECT  DISTINCT GPA
FROM     Apply, Student
WHERE  College.cName = Apply.cName
           AND Apply.sID = Student.sID
           AND GPA >= all
           (select GPA from Student, Apply
           where Student.sID = Apply.sID
           and Apply.cName = College.cName)) AS GPA
FROM College;
```

Computes the highest GPA for the college

College(cName, state, enr)
Student(sID, sName, GPA, sizeHS)
Apply(sID, cName, major, decision)

Subqueries in the SELECT clause

Query that returns colleges paired with the name of the applicants

```
SELECT cName, state,
(SELECT  DISTINCT sName
FROM     Apply, Student
WHERE  College.cName = Apply.cName
           AND Apply.sID = Student.sID) AS sName
FROM College;
```

Error. Why?

subquery returns more than 1 row

subquery in SELECT can only return 1 column of 1 tuple

College(<u>cName</u>, state, enr)
Student(<u>sID</u>, sName, GPA, sizeHS)
Apply(<u>sID</u>, <u>cName</u>, <u>major</u>, decision)

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The JOIN family of operators

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Data Modification statements

The JOIN family of operators

SELECT $A_1, A_2, \ldots, A_n$

FROM $R_1, R_2, \ldots, R_m$ → Implicit join

WHERE condition

Explicit Joins

Inner join on *condition*	$\bowtie_\theta$
Natural join	$\bowtie$
Inner join using (*attrs*)	$\bowtie$ explicitly listing the attributes to be equated
Left | Right | Full Outer Join	Combines tuples as in $\bowtie_\theta$ but when they don't match they are added to the result with NULL values

None of these operators adds expressive power to SQL

Inner join on *condition*

College(cName, state, enr)
Student(sID, sName, GPA, sizeHS)
Apply(sID, cName, major, decision)

```
SELECT  DISTINCT sName, major
FROM    Student, Apply
WHERE   Student.sID = Apply.sID;
```

Equivalent to:

```
SELECT  DISTINCT sName, major
FROM    Student INNER JOIN Apply
ON      Student.sID = Apply.sID;
```

INNER JOIN is the DEFAULT JOIN operator in SQL

```
SELECT  DISTINCT sName, major
FROM    Student JOIN Apply
ON      Student.sID = Apply.sID;
```

sName	major
Amy	CS
Amy	EE
Bob	biology
Craig	bioengineering
Craig	CS
Craig	EE
Fay	history
Helen	CS
Irene	CS
Irene	biology
Irene	marine biology
Jay	history
Jay	psychology

Inner join on *condition*: example 2

```
SELECT sName, GPA
FROM   Student, Apply
WHERE Student.sID=Apply.sID AND HS<1000 AND major='CS' AND cName='Stanford';
```

Equivalent to:

```
SELECT sName, GPA
FROM   Student JOIN Apply
ON        Student.sID=Apply.sID
WHERE  HS<1000 AND major='CS' AND cName='Stanford';
```

Equivalent to:

```
SELECT sName, GPA
FROM   Student JOIN Apply
ON        Student.sID=Apply.sID AND HS<1000 AND major='CS' AND cName='Stanford';
```

sName	GPA
Helen	3.7
Irene	3.9

College(<u>cName</u>, state, enr)
Student(<u>sID</u>, sName, GPA, sizeHS)
Apply(<u>sID</u>, <u>cName</u>, <u>major</u>, decision)

Inner join on *condition* with 3 relations

College(cName, state, enr)
Student(sID, sName, GPA, sizeHS)
Apply(sID, cName, major, decision)

```
SELECT  Apply.sID, sName, GPA, Apply.cName, enr
FROM    Apply, Student, College
WHERE  Apply.sID = Student.sID  AND Apply.cName = College.cName;
```

```
SELECT  Apply.sID, sName, GPA, Apply.cName, enr
FROM    Apply JOIN Student JOIN College
ON       Apply.sID = Student.sID  AND Apply.cName = College.cName;
```

→ Runs on SQLite but not in every system

```
SELECT  Apply.sID, sName, GPA, Apply.cName, enr
FROM    (Apply JOIN Student ON Apply.sID = Student.sID) JOIN College
ON       Apply.cName = College.cName;
```

→ Some systems (e.g.: Postgres) requires the join operators to be binary

Interaction between query and processor

SQL systems tend to follow the structure that is provided by the JOIN operators and parenthesis

```
SELECT  Apply.sID, sName, GPA, Apply.cName, enr
FROM    (Apply JOIN Student ON Apply.sID = Student.sID) JOIN College
ON Apply.cName = College.cName;
```


Typically, Apply will be joined with Student first

The order by things are done affects query performance

College(<u>cName</u>, state, enr)

Student(<u>sID</u>, sName, GPA, sizeHS)

Apply(<u>sID</u>, <u>cName</u>, <u>major</u>, decision)

College(cName, state, enr)

Student(sID, sName, GPA, sizeHS)

Apply(sID, cName, major, decision)

Natural join

It joins tables based on the attributes with the same name and keeps only one of those attributes

```
SELECT  DISTINCT sName, major
FROM    Student, Apply
WHERE   Student.sID = Apply.sID;
```


Equivalent to:

```
SELECT  DISTINCT sName, major
FROM    Student NATURAL JOIN Apply;
```

sName	major
Amy	CS
Amy	EE
Bob	biology
Craig	bioengineering
Craig	CS
Craig	EE
Fay	history
Helen	CS
Irene	CS
Irene	biology
Irene	marine biology
Jay	history
Jay	psychology

Natural join with additional conditions

```
SELECT sName, GPA
FROM   Student JOIN Apply
ON Student.sID=Apply.sID
WHERE HS<1000 AND major='CS' AND cName='Stanford';
```

Equivalent to:

sName	GPA
Helen	3.7
Irene	3.9

```
SELECT sName, GPA
FROM   Student NATURAL JOIN Apply
WHERE HS<1000 AND major='CS' AND cName='Stanford';
```

College(cName, state, enr)
Student(sID, sName, GPA, sizeHS)
Apply(sID, cName, major, decision)

Inner join using (*attrs*)

College(cName, state, enr)
Student(sID, sName, GPA, sizeHS)
Apply(sID, cName, major, decision)

Using lists the attributes that should be acquainted across the 2 relations

Only attributes that appear in both relations

```
SELECT sName, GPA
FROM   Student NATURAL JOIN Apply
WHERE HS<1000 AND major='CS' AND cName='Stanford';
```

sName	GPA
Helen	3.7
Irene	3.9

Equivalent to:

```
SELECT sName, GPA
FROM   Student JOIN Apply using(sID)
WHERE HS<1000 AND major='CS' AND cName='Stanford';
```

Better practice than using the natural join

Join with more than 1 instance of a relation

```
SELECT S1.sID, S1.sName, S1.GPA, S2.sID, S2.sName, S2.GPA
FROM   Student S1, Student S2
WHERE S1.GPA=S2.GPA AND S1.sID < S2.sID;
```

Finds pairs of students with the same GPA

```
SELECT S1.sID, S1.sName, S1.GPA, S2.sID, S2.sName, S2.GPA
FROM   Student S1 join Student S2 using(GPA)
ON       S1.sID < S2.sID;
```

→ Error

↓

Using and ON cannot be used in combination

College(cName, state, enr)

Student(sID, sName, GPA, sizeHS)

Apply(sID, cName, major, decision)

Join with more than 1 instance of a relation

```
SELECT S1.sID, S1.sName, S1.GPA, S2.sID, S2.sName, S2.GPA
FROM   Student S1 join Student S2 using(GPA)
WHERE S1.sID < S2.sID;
```

sID	sName	GPA	sID1	sName1	GPA1
123	Amy	3.9	456	Doris	3.9
123	Amy	3.9	876	Irene	3.9
123	Amy	3.9	654	Amy	3.9
456	Doris	3.9	876	Irene	3.9
456	Doris	3.9	654	Amy	3.9
567	Edward	2.9	765	Jay	2.9
654	Amy	3.9	876	Irene	3.9
543	Craig	3.4	789	Gary	3.4

College(cName, state, enr)

Student(sID, sName, GPA, sizeHS)

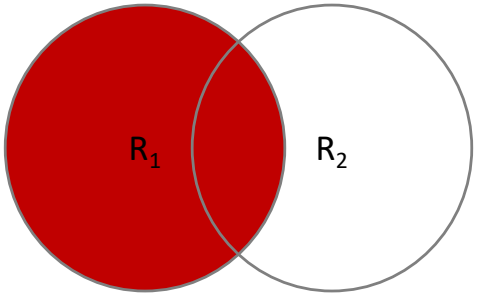
Apply(sID, cName, major, decision)

Left outer join

College(cName, state, enr)
Student(sID, sName, GPA, sizeHS)
Apply(sID, cName, major, decision)

Takes any tuples on the left side and if they don't have a match on a tuple from the right, it is still added to the result and padded with NULL values

Tuples with no matches are *dangling tuples*




```
SELECT sName, sID, cName, major
FROM Student LEFT OUTER JOIN Apply using(sID);
```

LEFT JOIN → abbreviation

Left outer join

College(cName, state, enr)
Student(sID, sName, GPA, sizeHS)
Apply(sID, cName, major, decision)

SELECT sName, sID, cName, major
FROM Student INNER JOIN Apply using(sID);

sName	sID	cName	major
Amy	123	Cornell	EE
Amy	123	Berkeley	CS
Amy	123	Stanford	EE
Amy	123	Stanford	CS
Bob	234	Berkeley	biology
Craig	345	Cornell	EE
Craig	345	Cornell	CS
Craig	345	Cornell	bioengineering
Craig	345	MIT	bioengineering
Fay	678	Stanford	history
…	…	…	…

Students who have applied somewhere

SELECT sName, sID, cName, major
FROM Student LEFT JOIN Apply using(sID);

sName	sID	cName	major
Amy	123	Cornell	EE
Amy	123	Berkeley	CS
Amy	123	Stanford	EE
Amy	123	Stanford	CS
Bob	234	Berkeley	biology
Craig	345	Cornell	EE
Craig	345	Cornell	CS
Craig	345	Cornell	bioengineering
Craig	345	MIT	bioengineering
Doris	456	NULL	NULL
…	…	…	…

Students who have applied somewhere plus students who haven't yet applied anywhere

College(cName, state, enr)

Student(sID, sName, GPA, sizeHS)

Apply(sID, cName, major, decision)

Natural left outer join

```
SELECT sName, sID, cName, major
FROM Student NATURAL LEFT JOIN Apply;
```

sName	sID	cName	major
Amy	123	Cornell	EE
Amy	123	Berkeley	CS
Amy	123	Stanford	EE
Amy	123	Stanford	CS
Bob	234	Berkeley	biology
Craig	345	Cornell	EE
Craig	345	Cornell	CS
Craig	345	Cornell	bioengineering
Craig	345	MIT	bioengineering
Doris	456	NULL	NULL
…	…	…	…

College(cName, state, enr)

Student(sID, sName, GPA, sizeHS)

Apply(sID, cName, major, decision)

Left outer join

How to rewrite the left outer join without using it?

```
SELECT sName, Student.sID, cName, major
FROM Student, Apply
Where Student.sID=Apply.sID
UNION
SELECT sName, sID, NULL, NULL
FROM Student
WHERE sID NOT IN (select sID from Apply)
```

sName	sID	cName	major
Amy	123	Cornell	EE
Amy	123	Berkeley	CS
Amy	123	Stanford	EE
Amy	123	Stanford	CS
Bob	234	Berkeley	biology
Craig	345	Cornell	EE
Craig	345	Cornell	CS
Craig	345	Cornell	bioengineering
Craig	345	MIT	bioengineering
Doris	456	NULL	NULL
…	…	…	…

College(cName, state, enr)

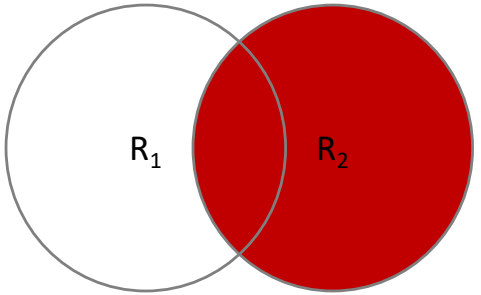
Student(sID, sName, GPA, sizeHS)

Apply(sID, cName, major, decision)

Right outer join

Takes any tuples on the right side and if they don't have a match on a tuple from the left, it is still added to the result and padded with NULL values

We can also use the left outer join for the same effect swapping the order of the relations



SELECT sName, sID, cName, major

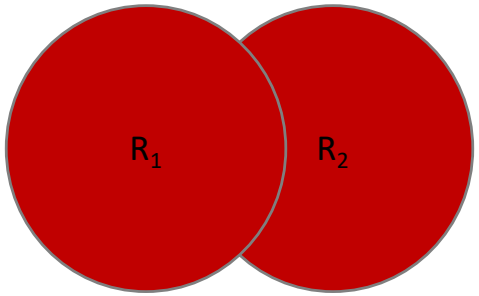
FROM Student RIGHT OUTER JOIN Apply using(sID);

College(cName, state, enr)
Student(sID, sName, GPA, sizeHS)
Apply(sID, cName, major, decision)

Full outer join

To include unmatched tuples from both sides of a join

SELECT sName, sID, cName, major
FROM Student FULL OUTER JOIN Apply using(sID);



Full outer join

College(cName, state, enr)
Student(sID, sName, GPA, sizeHS)
Apply(sID, cName, major, decision)

How can we express a full outer join without using it?

```
SELECT sName, Student.sID, cName, major
FROM Student LEFT JOIN Apply using(sID)
UNION
SELECT sName, Student.sID, cName, major
FROM Student RIGHT JOIN Apply using(sID);
```


Automatically eliminates duplicates

Full outer join

College(cName, state, enr)
Student(sID, sName, GPA, sizeHS)
Apply(sID, cName, major, decision)

How can we express a full outer join without using joins?

```
SELECT sName, Student.sID, cName, major
FROM Student, Apply
Where Student.sID=Apply.sID
UNION
SELECT sName, sID, NULL, NULL
FROM Student
WHERE sID NOT IN (select sID from Apply)
UNION
SELECT NULL, sID, cName, major
FROM Apply
WHERE sID NOT IN (select sID from Student)
```

Outer joins and commutativity

Commutativity (A op B) = (B op A)

Left and Right Outer Joins are not commutative

Full Outer Join is commutative

Outer joins and associativity

Associativity (A op B) op C = A op (B op C)

T1

A	B
1	2

T2

B	C
2	3

T3

A	C
4	5

```
SELECT A, B, C
FROM (T1 natural full outer join T2) natural full outer join T3;
```

A	B	C
1	2	3
4	NULL	5

```
SELECT A, B, C
FROM T1 natural full outer join (T2 natural full outer join T3);
```

A	B	C
4	NULL	5
NULL	2	3
1	2	NULL

Left and right outer joins are not associative either

Outer joins summary

Left outer join

Include the left tuple even if there's no match

Right outer join

Include the right tuple even if there's no match

Full outer join

Include the both left and right tuples even if there's no match

Kahoot time!

Any doubts?

Readings

Jeffrey Ullman, Jennifer Widom, A first course in Database Systems 3rd Edition

- Section 6.1 – Simple Queries in SQL
- Section 6.2 – Queries Involving More Than One Relation
- Section 6.3 - Subqueries
- Section 6.4 – Full-Relation Operations
- Section 6.5 – Database Modifications

Philip Greenspun, SQL for Web Nerds, http://philip.greenspun.com/sql/