VirginiaTech

CS 4604: Introduction to Database Management Systems

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Lecture #3: SQL---Part 1

Last lecture

- Relational Algebra

Quick Quiz: Independence of Operators

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

$$R \bowtie_C = \sigma_C(R \times S)$$

$$R \bowtie S = ??$$

Quick Quiz: Independence of Operators

$$R \bowtie S$$

- Suppose R and S share the attributes A1,A2,..An
- Let L be the list of attributes in R \Union list of attributes in S (so no duplicate attributes)
- Let C be the condition

R.A1 = S.A1 *AND* R.A2 = S.A2 *AND* ….. R.An = S.An

$$R \bowtie S = \pi_L(\sigma_C(R \times S))$$

Quick Aside: RA queries can become long!

- Normal expression:

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

- "Linear" Notation:

$$\text{Pairs(P1, N1, A1, P2, N2, A2)} := \rho_{S1}(Students) \times \rho_{S2}(Students)$$
$$\text{Matched(P1, N1, A1, P2, N2, A2)} := \sigma_{A1=A2}(\text{Pairs(P1, N1, A1, P2, N2, A2)})$$
$$\text{Answer(Name1, Name2)} := \pi_{N1,N2}(\text{Matched(P1, N1, A1, P2, N2, A2)})$$

This lecture

- Structured Query Language (SQL)
  - Pronounced ‘Sequel’

Overview - detailed - SQL

- DML
  - select, from, where, renaming
  - set operations
  - ordering
  - aggregate functions
  - nested subqueries
- other parts: DDL, constraints etc.

Relational Query Languages

- A major strength of the relational model: supports simple, powerful *querying* of data.
- Two sublanguages:
- DDL – Data Definition Language
  - define and modify schema (at all 3 levels)
- DML – Data Manipulation Language
  - Queries can be written intuitively.

Relational languages

- The DBMS is responsible for efficient evaluation.
  - Query optimizer: re-orders operations and generates query plan

The SQL Query Language

- **The most widely used relational query language.**
  - Major standard is SQL-1999 (=SQL3)
    - Introduced "Object-Relational" concepts
    - SQL 2003, SQL 2008 have small extensions
  - SQL92 is a basic subset

SQL (cont'd)

- PostgreSQL has some "unique" aspects (as do most systems).
- XML is the next challenge for SQL.

- Most popular embedded db in the world
  - Iphone (iOS), Android, Chrome….
- (Very) Easy to use: no need to set it up
- Self-contained: data+schema
- DB on your laptop: useful for testing, understanding….

DML

General form

select a1, a2, … an

from r1, r2, … rm

where P

[**order by** ….]

[**group by** …]

[**having** …]

Reminder: mini-U db

STUDENT

Ssn	Name	Address
123	smith	main str
234	jones	forbes ave

CLASS

c-id	c-name	units
4602	s.e.	2
4603	o.s.	2

TAKES

SSN	c-id	grade
123	4613	A
234	4613	B

DML - eg:

find the ssn(s) of everybody called “smith”

select ssn

from student

where name=“smith”

DML - observation

General form

select a1, a2, … an

from r1, r2, … rm

where P

equivalent rel. algebra query?

DML - observation

General form

select a1, a2, … an

from r1, r2, … rm

where P

$$\pi_{a1,a2,...an}(\sigma_P(r1 \times r2 \times ... \times rm))$$

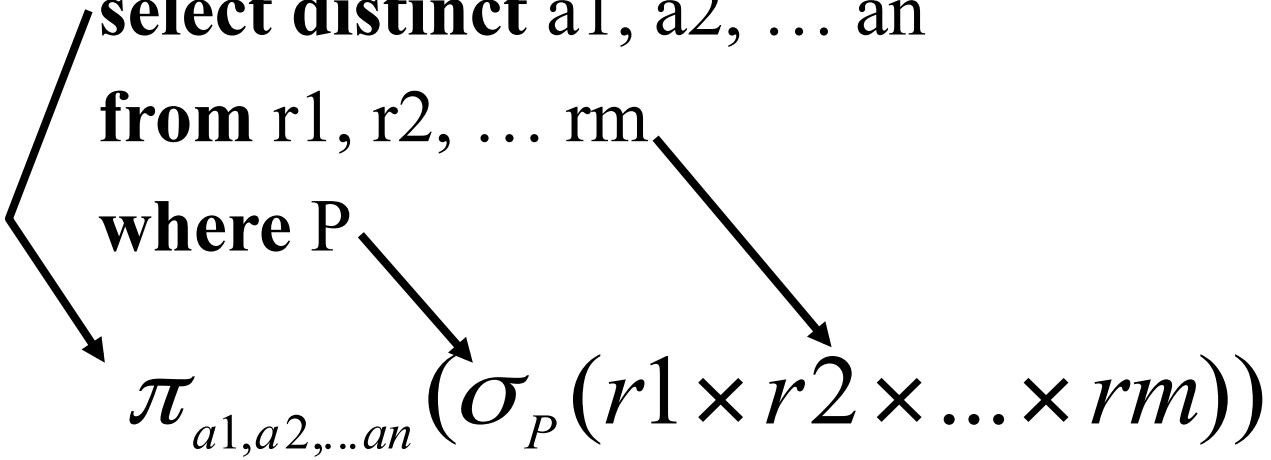
DML – observation – Set VS Bags

General form

select distinct a1, a2, … an

from r1, r2, … rm

where P



$$\pi_{a1,a2,\ldots an}(\sigma_P(r1 \times r2 \times \ldots \times rm))$$

NOTE:

- Relational Algebra is **set semantics** (everything is a set), so removes duplicates automatically.
- SQL is **bag semantics** (everything is a multiset), so removes duplicates only when asked to (using distinct)

select clause

select [**distinct** | **all**] name

from student

where address=“main”

where clause

find ssn(s) of all “smith”s on “main”

select ssn

from student

where address=“main” **and**

name = “smith”

where clause

- boolean operators (**and or not** …)
- comparison operators (<, >, =, …)
- and more…

What about strings?

find student ssns who live on “main” (st or str or street - ie., “main st” or “main str” …)

What about strings?

find student ssns who live on "main" (st or str or street)

select ssn

from student

where address **like** "main%"

%: variable-length don't care

_: single-character don't care

from clause

find names of people taking 4604

STUDENT

Ssn	Name	Address
123	smith	main str
234	jones	forbes ave

CLASS

c-id	c-name	units
4602	s.e.	2
4603	o.s.	2

TAKES

SSN	c-id	grade
123	4613	A
234	4613	B

from clause

find names of people taking 4604

select name

from student, takes

where ???

from clause

find names of people taking 4604

select name

from student, takes

where student.ssn = takes.ssn **and**

takes.c-id = “4604”

renaming - tuple variables

find names of people taking 4604

```
select name
from ourVeryOwnStudent, studentTakingClasses
where ourVeryOwnStudent.ssn =
      studentTakingClasses.ssn
 and  studentTakingClasses.c-id = "4604"
```

renaming - tuple variables

find names of people taking 4604

select name

from ourVeryOwnStudent **as** S,
studentTakingClasses **as** T

where S.ssn =T.ssn

and T.c-id = “4604”

renaming - self-join

- self -joins: find Tom's grandparent(s)

PC	
p-id	c-id
Mary	Tom
Peter	Mary
John	Tom

PC	
p-id	c-id
Mary	Tom
Peter	Mary
John	Tom

renaming - self-join

find grandparents of "Tom" (PC(p-id, c-id))

select gp.p-id

from PC **as** gp, PC

where gp.c-id= PC.p-id

and PC.c-id = "Tom"

renaming - theta join

find course names with more units than 4604

select c1.c-name

from class **as** c1, class **as** c2

where c1.units > c2.units

and c2.c-id = “4604”

renaming - theta join

find course names with more units than 4604

select c1.c-name

from class **as** c1, class **as** c2

where c1.units > c2.units

and c2.c-id = “4604”

Overview - detailed - SQL

- DML
  - select, from, where
  - **set operations**
  - ordering
  - aggregate functions
  - nested subqueries
- other parts: DDL, constraints etc.

set operations

find ssn of people taking both 4604 and 4613

TAKES

SSN	c-id	grade
123	4613	A
234	4613	B

set operations

find ssn of people taking both 4604 and 4613

```
select ssn
from takes
where c-id="4604" and
    c-id="4613"
```

set operations

find ssn of people taking both 4604 and 4613

(select ssn **from** takes **where** c-id="4604")

Intersect

(select ssn **from** takes **where** c-id="4613")

other ops: **union** , **except**

Overview - detailed - SQL

- DML
  - select, from, where
  - set operations
  - **ordering**
  - aggregate functions
  - nested subqueries
- other parts: DDL, constraints etc.

Ordering

find student records, sorted in name order

select *

from student

where

Ordering

find student records, sorted in name order

select *

from student

order by name **asc**

asc is the default

Ordering

find student records, sorted in name order; break ties by reverse ssn

```
select *
from student
order by name, ssn desc
```

Overview - detailed - SQL

- DML
  - select, from, where
  - set operations
  - ordering
  - **aggregate functions**
  - nested subqueries
- other parts: DDL, constraints etc.

Aggregate functions

find avg grade, across all students

select ??

from takes

TAKES

SSN	c-id	grade
123	4613	A
234	4613	B

Aggregate functions

find avg grade, across all students

select avg(grade)

from takes

- result: a single number
- Which other functions?

TAKES

SSN	c-id	grade
123	4613	A
234	4613	B

Aggregate functions

- A: **sum count min max (std)**

Aggregate functions

find total number of enrollments

select count(*)

from takes

TAKES

SSN	c-id	grade
123	4613	A
234	4613	B

Aggregate functions

find total number of students in 4604

select count(*)

from takes

where c-id="4604"

TAKES

SSN	c-id	grade
123	4613	A
234	4613	B

Aggregate functions

find total number of students in each course

select count(*)

from takes

where ???

TAKES

SSN	c-id	grade
123	4613	A
234	4613	B

Aggregate functions

find total number of students in each course

select c-id, **count(*)**

from takes

group by c-id

TAKES

SSN	c-id	grade
123	4613	A
234	4613	B

c-id	count
4613	2

Aggregate functions

find total number of students in each course

```
select c-id, count(*)
from takes
group by c-id
order by c-id
```

TAKES

SSN	c-id	grade
123	4613	A
234	4613	B

c-id	count
4613	2

Aggregate functions

find total number of students in each course, and sort by count, decreasing

```
select c-id, count(*) as pop
from takes
group by c-id
order by pop desc
```

TAKES

SSN	c-id	grade
123	4613	A
234	4613	B

c-id	pop
4613	2

Aggregate functions- ‘having’

find students with GPA > 3.0

SSN	c-id	grade
123	4613	4
234	4613	3

Aggregate functions- 'having'

find students with GPA > 3.0

select ???, **avg**(grade)

from takes

group by ???

SSN	c-id	grade
123	4613	4
234	4613	3

Aggregate functions- 'having'

find students with GPA > 3.0

select ssn, **avg**(grade)

from takes

group by ssn

???

SSN	c-id	grade
123	4613	4
234	4613	3

SSN	avg(grade
123	4
234	3

Aggregate functions- 'having'

find students with GPA > 3.0

select ssn, **avg**(grade)
from takes
group by ssn
having avg(grade)>3.0

SSN	c-id	grade
123	4613	4
234	4613	3

SSN	avg(grade
123	4
~~234~~	~~3~~

'having' <-> 'where' for groups

Aggregate functions- 'having'

find students and GPA,

for students with > 5 courses

```
select ssn, avg(grade)
from takes
group by ssn
having count(*) > 5
```

SSN	c-id	grade
123	4613	4
234	4613	3

SSN	avg(grade
123	4
~~234~~	~~3~~

Drill: Find the age of the youngest sailor for each rating level

(1) The sailors tuples are put into "same rating" groups.

(2) Compute the Minimum age for each rating group.

Sid	*Sname*	*Rating*	*Age*
22	*Dustin*	*7*	*45.0*
31	*Lubber*	*8*	*55.5*
85	*Art*	*3*	*25.5*
32	*Andy*	*8*	*25.5*
95	*Bob*	*3*	*63.5*

Rating	*Age*
3	*25.5*
3	*63.5*
7	*45.0*
8	*55.5*
8	*25.5*

(1)

(2)

Rating	*Age*
3	*25.5*
7	*45.0*
8	*25.5*

Drill: Find the age of the youngest sailor for each rating level

SELECT S.rating, MIN (S.age) as age
FROM Sailors S
GROUP BY S.rating

(1) The sailors tuples are put into "same rating" groups.

(2) Compute the Minimum age for each rating group.

Sid	*Sname*	*Rating*	*Age*
22	*Dustin*	*7*	*45.0*
31	*Lubber*	*8*	*55.5*
85	*Art*	*3*	*25.5*
32	*Andy*	*8*	*25.5*
95	*Bob*	*3*	*63.5*

Rating	*Age*
3	*25.5*
3	*63.5*
7	*45.0*
8	*55.5*
8	*25.5*

(1)

(2)

Rating	*Age*
3	*25.5*
7	*45.0*
8	*25.5*

Drill: Find the age of the youngest sailor for each rating level that has at least 2 members

Sid	Sname	Rating	Age
22	Dustin	7	45.0
31	Lubber	8	55.5
85	Art	3	25.5
32	Andy	8	25.5
95	Bob	3	63.5

1. The sailors tuples are put into "same rating" groups.
2. Eliminate groups that have < 2 members.
3. Compute the Minimum age for each rating group.

Rating	Minage
3	25.5
8	25.5

Rating	Age
3	25.5
3	63.5
7	45.0
8	55.5
8	25.5

Drill: Find the age of the youngest sailor for each rating level that has at least 2 members

```
SELECT S.rating, MIN (S.age) as
       minage
FROM Sailors S
GROUP BY S.rating
HAVING COUNT(*) > 1
```

Sid	Sname	Rating	Age
22	Dustin	7	45.0
31	Lubber	8	55.5
85	Art	3	25.5
32	Andy	8	25.5
95	Bob	3	63.5

1. The sailors tuples are put into "same rating" groups.
2. Eliminate groups that have < 2 members.
3. Compute the Minimum age for each rating group.

Rating	Minage
3	25.5
8	25.5

Rating	Age
3	25.5
3	63.5
7	45.0
8	55.5
8	25.5

Overview - detailed - SQL

- DML
  - select, from, where
  - set operations
  - **ordering**
  - aggregate functions
  - **nested subqueries**
- other parts: DDL, constraints etc.

Recap: DML

General form

select a1, a2, … an

from r1, r2, … rm

where P

[**order by** ….]

[**group by** …]

[**having** …]

DML - nested subqueries

find names of students of 4604

select name

from student

where ...

"ssn in the set of people that take 4604"

DML - nested subqueries

find names of students of 15-415

```
select name
from student
where  ……..
   select ssn
   from takes
   where  c-id =“4604”
```

DML - nested subqueries

find names of students of 15-415

```
select name
from student
where  ssn in (
   select ssn
   from takes
   where  c-id =“4604”)
```

DML - nested subqueries

- ‘**in**’ compares a value with a set of values
- ‘**in**’ can be combined other boolean ops
- it is redundant (but user friendly!):

  select name

  from student …..

  where c-id = “4604” ….

DML - nested subqueries

- **'in'** compares a value with a set of values
- **'in'** can be combined other boolean ops
- it is redundant (but user friendly!):

select name
from student, takes
where c-id = "4604" **and**
student.ssn=takes.ssn

DML - nested subqueries

find names of students taking 4604 and living on "main str"

select name

from student

where address="main str" **and** ssn **in**

(**select** ssn **from** takes **where** c-id ="4604")

DML - nested subqueries

- ‘**in**’ compares a value with a set of values
- other operators like ‘**in**’ ??

DML - nested subqueries

find student record with highest ssn

select *

from student

where ssn

is greater than every other ssn

DML - nested subqueries

find student record with highest ssn

select *

from student

where ssn *greater than every*

select ssn **from** student

DML - nested subqueries

find student record with highest ssn

```
select *
from student
where ssn  > all (
    select ssn   from student)
```

almost correct

DML - nested subqueries

find student record with highest ssn

```
select *
from student
where ssn >= all (
    select ssn   from student)
```

DML - nested subqueries

find student record with highest ssn - without nested subqueries?

select S1.ssn, S1.name, S1.address

from student **as** S1, student **as** S2

where S1.ssn > S2.ssn

is not the answer (what does it give?)

DML - nested subqueries

S1

STUDENT		
Ssn	Name	Address
123	smith	main str
234	jones	forbes ave

S2

STUDENT		
Ssn	Name	Address
123	smith	main str
234	jones	forbes ave

S1 x S2

S1. ssn	S2.ssn	….
123	123	…
234	123	…
123	234	
234	234	

S1.ssn>S2.ssn

DML - nested subqueries

select S1.ssn, S1.name, S1.address
from student **as** S1, student **as** S2
where S1.ssn > S2.ssn

gives all but the smallest ssn -

aha!

DML - nested subqueries

find student record with highest ssn - without nested subqueries?

select S1.ssn, S1.name, S1.address

from student **as** S1, student **as** S2

where S1.ssn < S2.ssn

gives all but the highest - therefore….

DML - nested subqueries

find student record with highest ssn - without nested subqueries?

```
(select * from student)      except
(select S1.ssn, S1.name, S1.address
 from student as S1, student as S2
 where S1.ssn < S2.ssn)
```

DML - nested subqueries

```
(select *  from student)      except
(select S1.ssn, S1.name, S1.address
 from student as S1, student as S2
 where S1.ssn < S2.ssn)
```

```
select *
from student
where ssn  >= all (select ssn   from student)
```

DML - nested subqueries

Drill: Even more readable than

select * **from** student

where ssn >= **all** (**select** ssn **from** student)

DML - nested subqueries

Drill: Even more readable than

```
select *   from student
where ssn  >= all (select ssn   from student)
```

```
select *   from student
where ssn in
(select max(ssn) from student)
```

from clause

Drill: find the ssn of the student with the highest GPA

STUDENT

Ssn	Name	Address
123	smith	main str
234	jones	forbes ave

CLASS

c-id	c-name	units
4602	s.e.	2
4603	o.s.	2

TAKES

SSN	c-id	grade
123	4613	A
234	4613	B

DML - nested subqueries

Drill: find the ssn and GPA of the student with the highest GPA

select ssn, **avg**(grade) **from** takes

~~**where**~~

DML - nested subqueries

Drill: find the ssn and GPA of the student with the highest GPA

select ssn, **avg**(grade) **from** takes

group by ssn

having avg(grade**) ……**

greater than every other GPA on file

DML - nested subqueries

Drill: find the ssn and GPA of the student with the highest GPA

```
select ssn, avg(grade) from takes
group by ssn
having avg( grade) >=   all
    ( select avg( grade )
      from student group by ssn )
```

} all GPAs

DML - nested subqueries

- **'in'** and **'>= all'** compares a value with a set of values
- other operators like these?

DML - nested subqueries

- **<all(), <>all()** ...
- '**<>all**' is identical to '**not in**'
- **>some()**, **>= some** () ...
- '**= some()**' is identical to '**in**'
- **exists**

DML - nested subqueries

Drill for '**exists**': find all courses that nobody enrolled in

select c-id **from** class ….*with no tuples in 'takes'*

TAKES

SSN	c-id	grade
123	4613	A
234	4613	B

CLASS

c-id	c-name	units
4602	s.e.	2
4603	o.s.	2

DML - nested subqueries

Drill for '**exists**': find all courses that nobody enrolled in

```
select c-id from class
where not exists
    (select * from  takes
    where class.c-id = takes.c-id)
```

Correlated vs Uncorrelated

- The previous subqueries did not depend on anything outside the subquery
  - …and thus need to be executed just once.
  - These are called uncorrelated.
- A correlated subquery depends on data from the outer query
  - … and thus has to be executed for each row of the outer table(s)

Correlated Subqueries

- Find course names that have been used for two or more courses.

```
SELECT CourseName
FROM Courses AS First
WHERE CourseName IN
        (SELECT CourseName
        FROM Courses
        WHERE (Number <> First.Number)
        AND (DeptName <> First.DeptName)
        );
```

Evaluating Correlated Subqueries

```
SELECT CourseName
FROM Courses AS First
WHERE CourseName IN
      (SELECT CourseName
      FROM Courses
      WHERE (Number <> First.Number)
      AND (DeptName <> First.DeptName)
      );
```

- Evaluate query by looping over tuples of First, and for each tuple evaluate the subquery.
- Scoping rules: an attribute in a subquery belongs to one of the tuple variables in that subquery's FROM clause, or to the immediately surrounding subquery, and so on.

Overview - detailed - SQL

- DML
  - select, from, where
  - set operations
  - ordering
  - aggregate functions
  - nested subqueries
- other parts: DDL, constraints etc.

(Next Week) Overview - detailed – SQL

- DML
- other parts:
  - views
  - modifications
  - joins
  - DDL
  - Constraints