VirginiaTech

CS 4604: Introduction to Database Management Systems

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Lecture #3: SQL---Part 1

Announcements---Project

- Goal: design a database system application with a web front-end
- Project Assignment 1 released today
  - Due Feb 3, in class, hardcopy (1 per project group)
  - Total of 3 during the semester
- **Heads-up: Start thinking about groups**
  - same group for rest of the semester
  - You are free to choose your own project members
  - You can post on piazza as well
  - If you like me to assign you to a group, send me email
  - **Min size=2 members, Max size=3 members**. Anything else needs an excellent reason (and my permission)

Annoucements

- Reminder: Handout 1 is also on the website
  - We will discuss it in the next class, for practice
  - Bring a printed copy to class

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

TAKES

SSN	c-id	grade
123	4613	A
234	4613	B

- result: a single number
- Which other functions?

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

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) Compute the Minimum age for each rating group.

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*

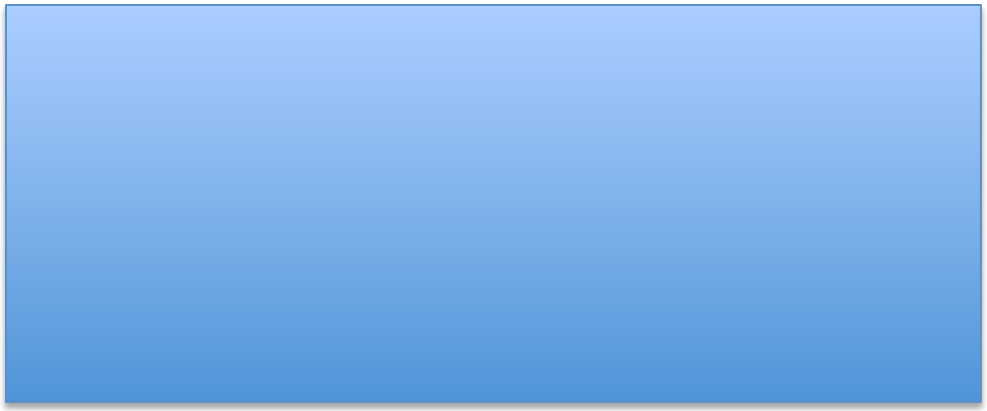
Rating	*Age*
3	*25.5*
3	*63.5*
7	*45.0*
8	*55.5*
8	*25.5*

(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