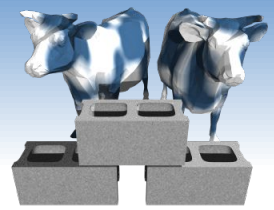
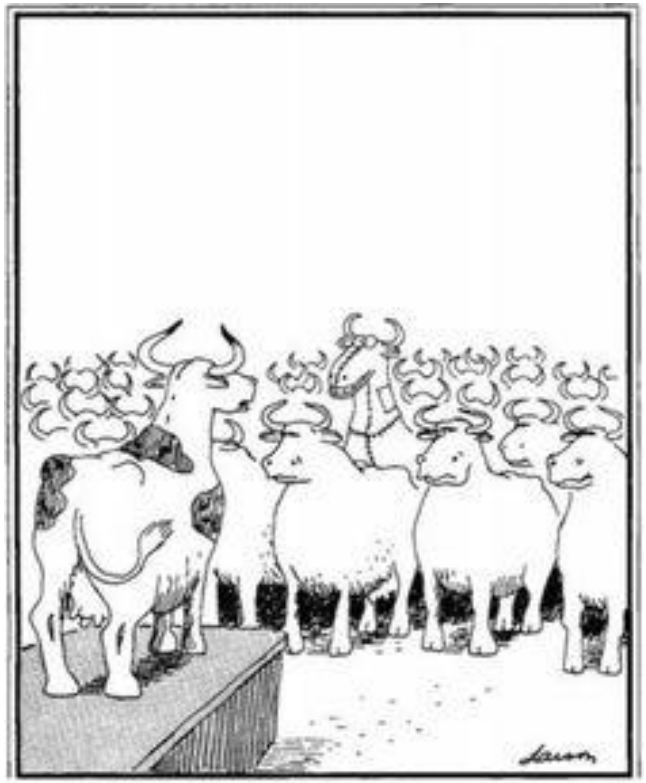


SQL: More Advanced Queries

Problem set #1 is due one week from today.

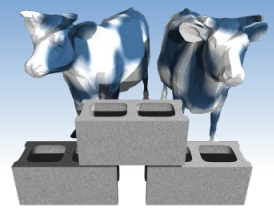
Problem set #2 is coming on Thursday.

Office hours tomorrow



"The revolution has been postponed . . . We've discovered a leak."

Rewriting INTERSECT Using "IN"



Find sid's of sailors who've reserved both a red and a green boat:

```
SELECT  DISTINCT S.sid, S.sname
  FROM  Sailors S, Boats B, Reserves R
 WHERE  S.sid=R.sid AND R.bid=B.bid AND B.color='red'
   AND  S.sid IN (SELECT  S2.sid
                    FROM  Sailors S2, Boats B2, Reserves R2
                   WHERE  S2.sid=R2.sid AND R2.bid=B2.bid
                     AND  B2.color='green')
```

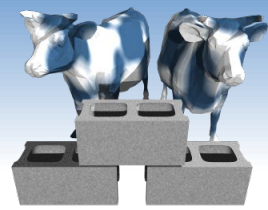
- Similarly, EXCEPT queries re-written using NOT IN.

sid
22
31
74

sid	sname
22	Dustin
31	Lubber

Division in SQL

Find sailors who've reserved all boats.



- Using EXCEPT
- Without EXCEPT:

(1)

```
SELECT  S.sname
FROM  Sailors S
WHERE  NOT EXISTS
        (SELECT  B.bid
        FROM  Boats B
        EXCEPT
        SELECT  R.bid
        FROM  Reserves R
        WHERE  R.sid=S.sid)
```

All boats

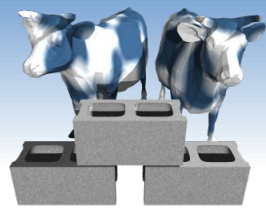
Boats reserved by a given Sailor

(2)

```
SELECT  S.sname
FROM  Sailors S
WHERE  NOT EXISTS
     (SELECT B.bid
      FROM   Boats B
      WHERE NOT EXISTS  ( SELECT R.bid
                          FROM   Reserves R
                          WHERE R.bid=B.bid
                            AND R.sid=S.sid))
```

Sailors S such that ...
there is no boat B without ...
a Reserves tuple showing S reserved B

sname
Dustin



"*Relationally*" *Pure SQL*

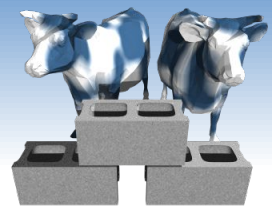
A min() function snuck in on slide 15 of last lecture

Thus far all of the SQL commands I have used (except one) take one or more relations (tables) as an input and produce a new relation as an output.

This has limitations. Sometimes we'd like to compute summaries of our tables such as…

- how many rows were returned
- averages over all outputs

SQL's Aggregate Operators



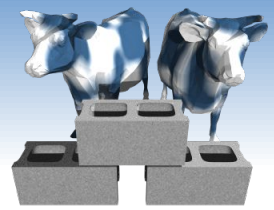
- Significant SQL extension
- Computation and summarization operations
- Appears in *target-list* of query
- Results *aggregate* rather than appear individually
- E.x. How many instances in the sailor relation?

COUNT (*)
COUNT ([DISTINCT] A)
SUM ([DISTINCT] A)
AVG ([DISTINCT] A)
MAX (A)
MIN (A)

single column

```
SELECT COUNT (*)
FROM   Sailors
```

COUNT (*)
10



More examples

- Average age of Sailors with a rating of 10?

```
SELECT  AVG(S.age)
FROM    Sailors S
WHERE   S.rating=10
```

Answer: 25.5

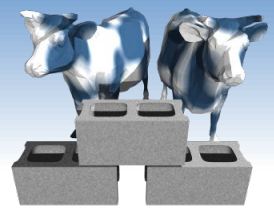
- Names of Sailors having the maximum rating

```
SELECT S.sname, S.rating
FROM   Sailors S
WHERE  S.rating=(SELECT MAX(S2.rating)
                 FROM   Sailors S2)
```

sid	sname	rating	age
22	Dustin	7	45.0
29	Brutus	1	33.0
31	Lubber	8	55.5
32	Andy	8	25.5
58	Rusty	10	35.0
64	Horatio	7	35.0
71	Zorba	10	16.0
74	Horatio	9	35.0
85	Art	3	25.5
95	Bob	3	63.5

Answer:

sname	rating
Rusty	10
Zorba	10



More examples (cont)

- How many distinct ratings for Sailors less than 40 years of age?

```
SELECT COUNT(DISTINCT S.rating)
FROM   Sailors S
WHERE  S.age < 40.0
```

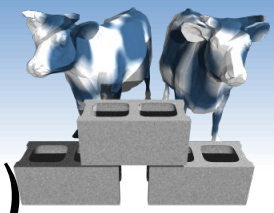
Answer: 6

- How many reservations were made by Sailors less than 40 years old?

```
SELECT  COUNT(*)
FROM    Sailors S, Reserves R
WHERE   S.sid = R.sid AND S.age < 40
```

Answer: 3

sid	sname	rating	age
22	Dustin	7	45.0
29	Brutus	1	33.0
31	Lubber	8	55.5
32	Andy	8	25.5
58	Rusty	10	35.0
64	Horatio	7	35.0
71	Zorba	10	16.0
74	Horatio	9	35.0
85	Art	3	25.5
95	Bob	3	63.5



Find name and age of the oldest sailor(s)

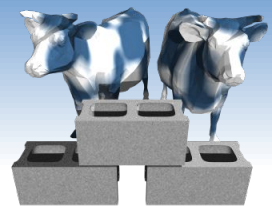
- The first query is incorrect! (Switch the S.age to S.rating to see why)
- Second approach allows for ties

```
SELECT S.sname, MAX(S.age)
FROM   Sailors S
```

sid	sname	rating	age
22	Dustin	7	45.0
29	Brutus	1	33.0
31	Lubber	8	55.5
32	Andy	8	25.5
58	Rusty	10	35.0
64	Horatio	7	35.0
71	Zorba	10	16.0
74	Horatio	9	35.0
85	Art	3	25.5
95	Bob	3	63.5

```
SELECT S.sname, S.age
FROM   Sailors S
WHERE  S.age =
       (SELECT MAX(S2.age)
        FROM  Sailors S2)
```

Let's go SQLing!



First get

1) a SQL interface
2) a dataset

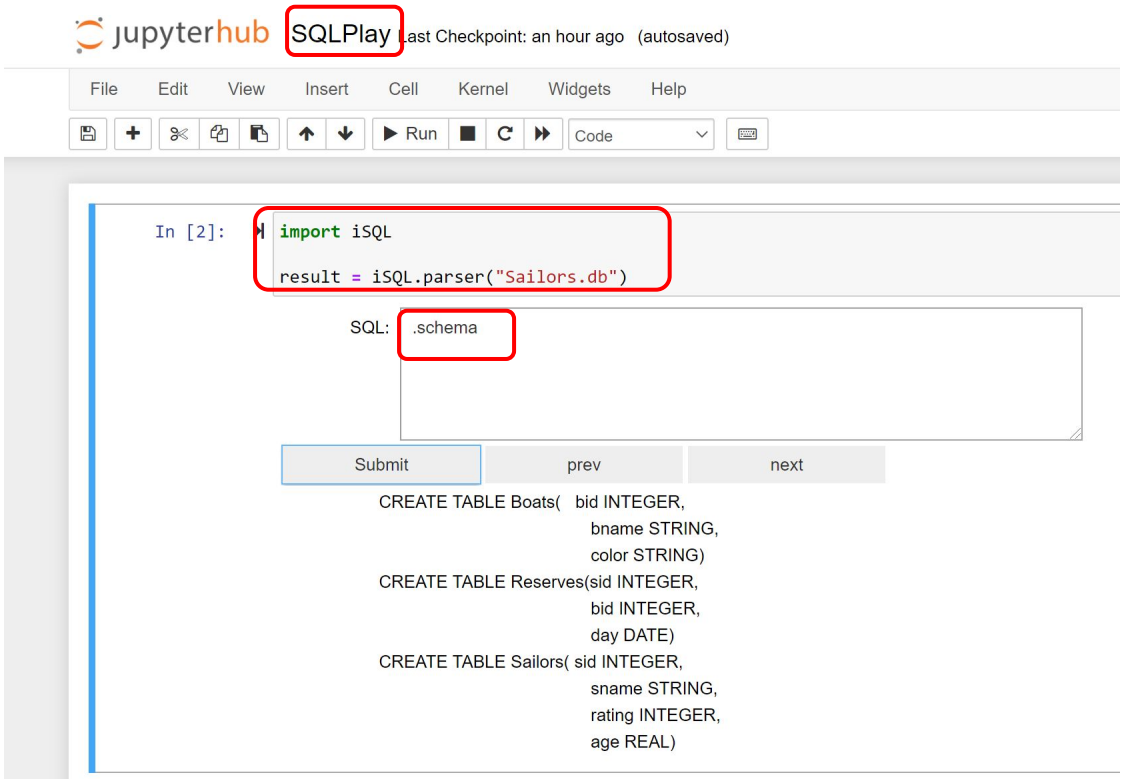
Notes: You should first download each file onto your local computers "Downloads" directory. This might require a [right-click] on the link and selecting "Save link as …". Once downloaded, start your Juypter Hub, and upload both files

Week 15:	
T 11/17	Lecture 28: NoSQL Graph Databases (pdf)
Th 11/19	**Final Exam:** 3pm-6pm

Course Resources

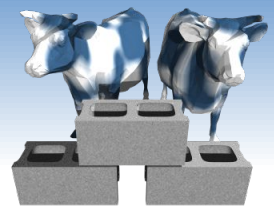
1. A simple interactive SQL interpreter that can be embedded in a Jupyter Notebook. You will need to rename the downloaded file to "iSQL.py"
2. The small Sailor database used for examples in class.
3. AN even smaller, tiny version of the Sailor database used to demonstrate JOINS.

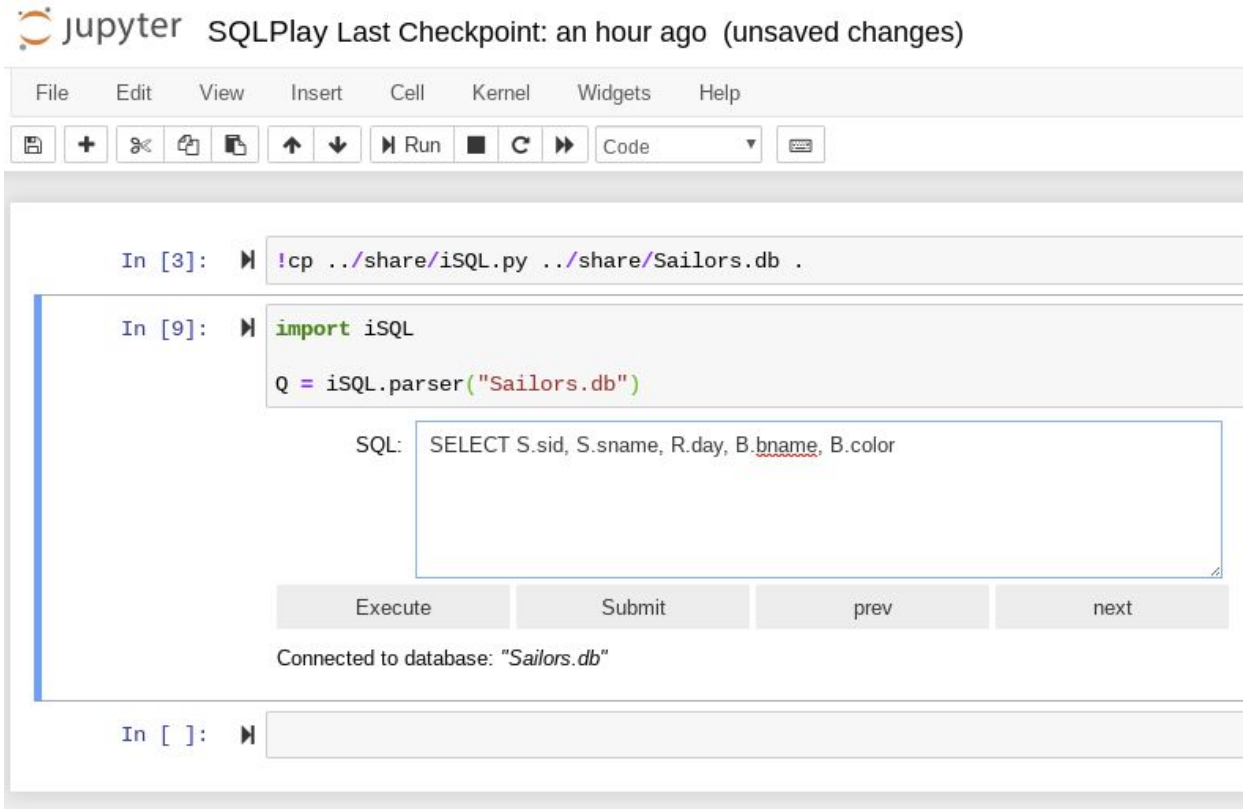
Interactive SQL (iSQL)



1. In your Jupyter hub
2. Create a new Python3 Notebook
3. Copy iSQL.py and Sailors.db to your Notebook directory
4. import and run iSQL
5. Try ".schema"
6. Try "SELECT * FROM Sailors"

A little more...





Generate a list of reservations that includes

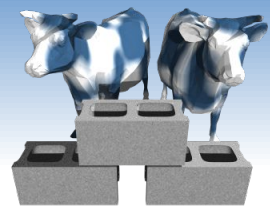
Sailor's id,
Sailor's name,
Reservation date,

Boat's name, and

Boat's color

How many rows are considered in the full cross product of Sailors x Reserves x Boats

What relation determines the actual number of rows?



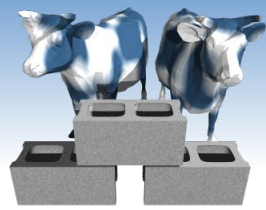
SQL Grouping: Motivation

- So far, we've applied aggregate operators to *all* (qualifying) tuples. Sometimes, we want to apply them to *groups*.
- Consider: *Find the age of the youngest sailor in each rating level.*
  - In general, we don't know how many rating levels exist, and what the rating values for these levels are!
  - Suppose we know that rating values go from 1 to 10; we can write 10 queries that look like this (!):

For i = 1, 2, ... , 10:

```
SELECT MIN(S.age)
FROM   Sailors S
WHERE  S.rating = i
```

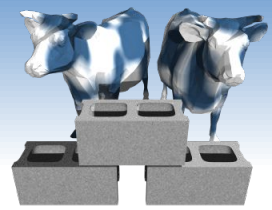
Queries With GROUP BY *and* HAVING



```
SELECT      [DISTINCT]  target-list
FROM        relation-list
WHERE       qualification
GROUP BY    grouping-list
HAVING      group-qualification
```

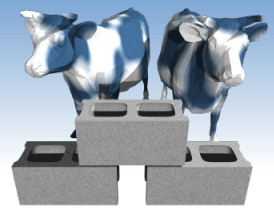
- The *target-list* contains
  (i) attribute names
  (ii) terms with aggregate operations (e.g., MIN (*S.age*)).
- The attribute list (i) must be a subset of *grouping-list*. Intuitively, each answer tuple corresponds to a *group*, and these attributes must have a single value per group. (A *group* is a set of tuples that have the same value for all attributes in *grouping-list*.)

Conceptual Evaluation



- The cross-product of *relation-list* is computed, tuples that fail *qualification* are discarded, *unnecessary* fields are deleted, and the remaining tuples are partitioned into groups by the value of attributes in *grouping-list*.
- The *group-qualification* is then applied to eliminate some groups. Expressions in *group-qualification* must have a *single value per group*!
  - In effect, an attribute in *group-qualification* that is not an argument of an aggregate op also appears in *grouping-list*. (SQL does not exploit primary key semantics here!)
- One answer tuple is generated per qualifying group.

Find age of the youngest sailor with age ≥ 18, for each rating having at least 2 such sailors



```
SELECT   S.rating, MIN(S.age) AS minage
FROM     Sailors S
WHERE    S.age >= 18
GROUP BY S.rating
HAVING   COUNT(*) > 1
```

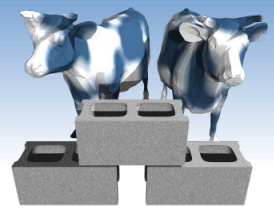
Answer relation:

rating	minage
3	25.5
7	35.0
8	25.5

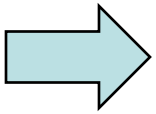
Sailors instance:

sid	sname	rating	age
22	dustin	7	45.0
29	brutus	1	33.0
31	lubber	8	55.5
32	andy	8	25.5
58	rusty	10	35.0
64	horatio	7	35.0
71	zorba	10	16.0
74	horatio	9	35.0
85	art	3	25.5
95	bob	3	63.5
96	frodo	3	25.5

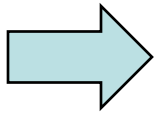
Find age of the youngest sailor with age ≥ 18, for each rating with at least 2 such sailors



rating	age
7	45.0
1	33.0
8	55.5
8	25.5
10	35.0
7	35.0
10	16.0
9	35.0
3	25.5
3	63.5
3	25.5

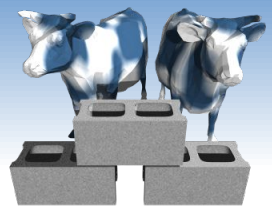


rating	age
1	33.0
3	25.5
3	63.5
3	25.5
7	45.0
7	35.0
8	55.5
8	25.5
9	35.0
10	35.0



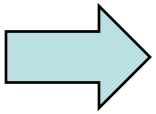
rating	minage
3	25.5
7	35.0
8	25.5

Find age of the youngest sailor with age ≥ 18, for each rating level with at least 2 such sailors, and where every sailor is under 60.

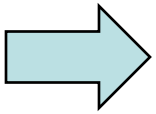


HAVING COUNT (*) > 1 AND MAX(S.age) < 60

rating	age
7	45.0
1	33.0
8	55.5
8	25.5
10	35.0
7	35.0
10	16.0
9	35.0
3	25.5
3	63.5
3	25.5

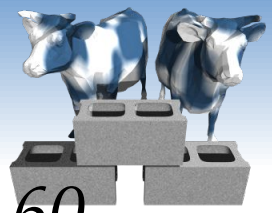


rating	age
1	33.0
3	25.5
3	63.5
3	25.5
7	45.0
7	35.0
8	55.5
8	25.5
9	35.0
10	35.0



rating	minage
7	35.0
8	25.5

Find age of the youngest sailor with age ≥ 18, for each rating with at least 2 sailors between 18 and 60.



```
SELECT   S.rating, MIN(S.age) AS minage
FROM     Sailors S
WHERE    S.age >= 18 AND S.age <= 60
GROUP BY S.rating
HAVING   COUNT(*) > 1
```

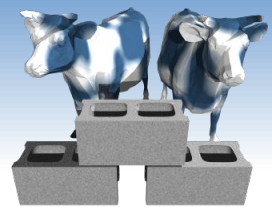
Sailors instance:

sid	sname	rating	age
22	dustin	7	45.0
29	brutus	1	33.0
31	lubber	8	55.5
32	andy	8	25.5
58	rusty	10	35.0
64	horatio	7	35.0
71	zorba	10	16.0
74	horatio	9	35.0
85	art	3	25.5
95	bob	3	63.5
96	frodo	3	25.5

Answer relation:

rating	minage
7	35.0
8	25.5

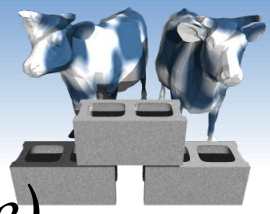
For each red boat, find the number of times it has been reserved



```
SELECT   B.bid, COUNT(*) AS scount
FROM     Sailors S, Boats B, Reserves R
WHERE    S.sid=R.sid AND R.bid=B.bid AND B.color='red'
GROUP BY B.bid
```

- Grouping over a join of three relations.
- What do we get if we remove *B.color='red'* from the WHERE clause and add a HAVING clause with this condition?
- What if we drop Sailors and the condition involving S.sid?

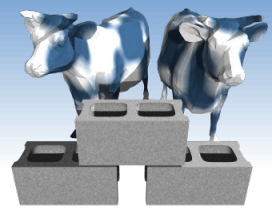
Find age of the youngest sailor with age > 18, for each rating with at least 2 sailors (of any age)



```
SELECT   S.rating, MIN(S.age)
FROM     Sailors S
WHERE    S.age >= 18
GROUP BY S.rating
HAVING  1 < (SELECT COUNT(*)
             FROM   Sailors S2
             WHERE  S.rating=S2.rating)
```

- Shows HAVING clause can also contain a subquery.
- Compare this with the query where we considered only ratings with 2 sailors over 18!
- What if HAVING clause is replaced by:
  - HAVING COUNT(*) >1

Find the rating for which the average age is the minimum over all ratings



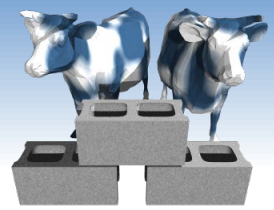
- Aggregate operations cannot be nested! WRONG:

```
SELECT S.rating
FROM   Sailors S
WHERE  S.age = (SELECT MIN(AVG(S2.age)) FROM Sailors S2)
```

- Correct solution:

```
SELECT rating
FROM   (SELECT S.rating, AVG(S.age) AS aveage
        FROM     Sailors S
        GROUP BY S.rating)
WHERE aveage = (SELECT MIN(aveage)
                FROM (SELECT S.rating, AVG(S.age) AS aveage
                      FROM   Sailors S
                      GROUP BY S.rating))
```

Summary



- SQL was an important factor in the early acceptance of the relational model; more natural than earlier, procedural query languages.
- Many alternative ways to write a query; optimizer should look for most efficient evaluation plan.
  - In practice, users need to be aware of how queries are optimized and evaluated for best results.