CS460: Intro to Database Systems

Class 3: SQL, The Query Language – Part I

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https://bu-disc.github.io/CS660/

Reminder

Project 0 deadline is 9/15 (this Friday)

No grading

Self-assessment assignment

Come to OH (and Labs) if you have questions

Today's course

intuitive way to ask **queries**

unlike *procedural languages* (C/C++, java)

[which specify **how** to solve a problem (or answer a question)]

SQL is a **declarative** **query** language

[we ask **what we want** and the DBMS is going to deliver]

Introduction to SQL

SQL is a relational **query language**

supports **simple** yet **powerful** *querying* of data

It has two parts:

CREATE TABLE

DDL: **Data Definition** Language (define and modify schema)

INSERT/UPDATE/DELETE

DML: **Data Manipulation** Language (**intuitively** query data)

SELECT …
FROM …
WHERE …

Reiterate some terminology

Relation (or table)

Students

name

schema

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@ee	18	3.2

data
(instance)

Row (or tuple)

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@ee	18	3.2

Column (or attribute)

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@ee	18	3.2

Reiterate some terminology

Primary Key (PK)

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@ee	18	3.2

The PK of a relation is the column (or the group of columns) that can uniquely define a row.

In other words:

Two rows **cannot** have the same PK.

DDL – Create Table

optional

optional

optional

```
CREATE TABLE table_name
(   { column_name data_type [ DEFAULT def_expr ]  [ col_constraint [, ... ] ] | table_constraint }
 [, { column_name data_type [ DEFAULT def_expr ]  [ col_constraint [, ... ] ] | table_constraint } ]
 [, …]  )
```

```
CREATE TABLE Students
     (sid CHAR(20),
      name CHAR(20),
      login CHAR(10),
      age INTEGER,
      gpa FLOAT)
```

DDL – Create Table

```
CREATE TABLE table_name
(   { column_name data_type [ DEFAULT def_expr ]  [ col_constraint [, ... ] ] | table_constraint }
 [, { column_name data_type [ DEFAULT def_expr ]  [ col_constraint [, ... ] ] | table_constraint } ]
 [, …]  )
```

Data Types include:

fixed-length character string: **CHAR(n)**

variable-length character string: **VARCHAR(n)**

smallint, **integer**, **bigint**, **numeric**, **real**, **double precision**

date, **time**, **timestamp**, …

serial - unique ID for indexing and cross reference

…

You can also define your own type!! (SQL:1999)

```
CREATE TABLE Students
     (sid CHAR(20),
      name CHAR(20),
      login CHAR(10),
      age INTEGER,
      gpa FLOAT)
```

Create Table (w/column constraints)

```
CREATE TABLE table_name
(   { column_name data_type [ DEFAULT def_expr ]  [ col_constraint [, ... ] ] | table_constraint }
 [, { column_name data_type [ DEFAULT def_expr ]  [ col_constraint [, ... ] ] | table_constraint } ]
 [, …]  )
```

check for every row

can remove

Column Constraints:

[CONSTRAINT constraint_name] { NOT NULL | NULL | UNIQUE | PRIMARY KEY | CHECK (expression) | REFERENCES reftable [(refcolumn)] [ON DELETE action] [ON UPDATE action] }

value should exist in <reftable.refcolumn>

propagate (or not) deletes/updates

expression: must produce a boolean result based on the related column’s value only

action: NO ACTION, CASCADE, SET NULL, SET DEFAULT

Create Table (w/table constraints)

```
CREATE TABLE table_name
(   { column_name data_type [ DEFAULT def_expr ]  [ col_constraint [, ... ] ] | table_constraint }
 [, { column_name data_type [ DEFAULT def_expr ]  [ col_constraint [, ... ] ] | table_constraint } ]
 [, …]  )
```

every constraint can include multiple columns

can remove

Table Constraints:

```
[ CONSTRAINT constraint_name ]
    { UNIQUE ( column_name [, ... ] ) |
      PRIMARY KEY ( column_name [, ... ] ) |
      CHECK ( expression ) |
      FOREIGN KEY ( column_name [, ... ] ) REFERENCES reftable [ ( refcolumn [, ... ] ) ] [ ON
      DELETE action ]          [ ON UPDATE action ] }
```

specify which column

can involve multiple columns

Examples

```
CREATE TABLE Enrolled
  (sid CHAR(20),
   cid CHAR(20),
   semester CHAR(20),
   grade CHAR(2) )
```

Examples

```
CREATE TABLE Enrolled
  (sid CHAR(20),
   cid CHAR(20),
   semester CHAR(20) NOT NULL,
   grade CHAR(2) )
```

Primary Keys in SQL

possibly many *candidate keys* (can be specified using UNIQUE), one of which is chosen as the *primary key*

keys must be defined carefully!

“for a given student and course, there is a single grade”

```
CREATE TABLE Enrolled
  (sid CHAR(20)
   cid  CHAR(20),
   semester CHAR(20) NOT NULL,
   grade CHAR(2),
   PRIMARY KEY (sid,cid))
```

vs.

```
CREATE TABLE Enrolled
   (sid CHAR(20)
    cid  CHAR(20),
    semester CHAR(20) NOT NULL
    grade CHAR(2),
    PRIMARY KEY  (sid),
    UNIQUE (cid, grade))
```

Primary Keys in SQL

possibly many *candidate keys* (can be specified using UNIQUE), one of which is chosen as the *primary key*

keys must be defined carefully!

“for a given student and course, there is a single grade”

```
CREATE TABLE Enrolled
  (sid CHAR(20)
   cid  CHAR(20),
   semester CHAR(20) NOT NULL,
   grade CHAR(2),
   PRIMARY KEY (sid,cid))
```

vs.

```
CREATE TABLE Enrolled
   (sid CHAR(20)
    cid   CHAR(20),
    semester CHAR(20) NOT NULL
    grade CHAR(2),
    PRIMARY KEY  (sid),
    UNIQUE (cid, grade))
```

anything else?

“students can take only one course, and no two students in a course receive the same grade”

Primary Keys in SQL

possibly many *candidate keys* (can be specified using UNIQUE), one of which is chosen as the *primary key*

keys must be defined carefully!

“for a given student and course, there is a single grade”

```
CREATE TABLE Enrolled
  (sid CHAR(20)
   cid  CHAR(20),
   semester CHAR(20) NOT NULL,
   grade CHAR(2),
   ~~PRIMARY KEY (sid,cid))~~
   PRIMARY KEY (sid,cid,semester))
```

“a student cannot take a course again (in a new semester) even if they failed it”

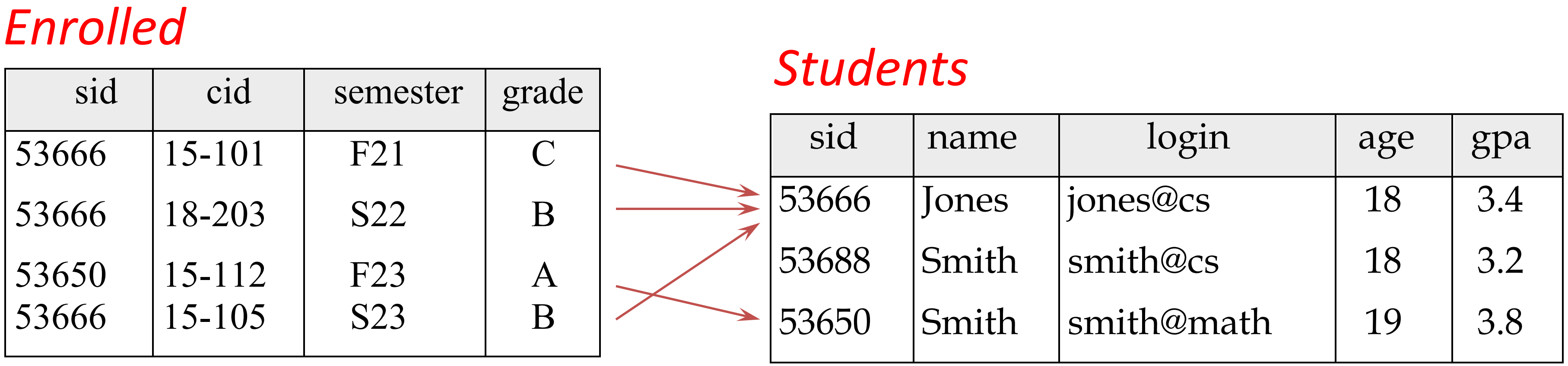
solution?

Foreign Keys in SQL

Example: Only students listed in the Students relation should be allowed to enroll for courses.

sid is a foreign key referring to Students

```
CREATE TABLE Enrolled
(sid CHAR(20),cid CHAR(20),semester CHAR(20), grade CHAR(2),
 PRIMARY KEY (sid,cid),
 FOREIGN KEY (sid) REFERENCES Students )
```



Enrolled

sid	cid	semester	grade
53666	15-101	F21	C
53666	18-203	S22	B
53650	15-112	F23	A
53666	15-105	S23	B

Students

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@cs	18	3.2
53650	Smith	smith@math	19	3.8

Examples

```
CREATE TABLE Enrolled
  (sid CHAR(20),
   cid CHAR(20),
   semester CHAR(20) NOT NULL,
   grade CHAR(2),
   PRIMARY KEY (sid,cid,semester),
   FOREIGN KEY (sid) REFERENCES Students )
```

Examples (General Constraints)

```
CREATE TABLE Enrolled
  (sid CHAR(20),
   cid CHAR(20),
   semester CHAR(20) NOT NULL,
   grade CHAR(2),
   PRIMARY KEY (sid,cid,semester),
   FOREIGN KEY (sid) REFERENCES Students,
   CHECK grade LIKE ‘A’ OR grade LIKE ‘B’
         OR grade LIKE ‘C’ OR grade LIKE ‘D’)
```

Examples (General Constraints)

```
CREATE TABLE Enrolled
  (sid CHAR(20),
   cid CHAR(20),
   semester CHAR(20) NOT NULL,
   grade CHAR(2),
   PRIMARY KEY (sid,cid,semester),
   FOREIGN KEY (sid) REFERENCES Students,
   CONSTRAINT checkGrade
   CHECK (grade LIKE ‘A’ OR grade LIKE ‘B’
         OR grade LIKE ‘C’ OR grade LIKE ‘D’) )
```

Examples (General Constraints)

```
CREATE TABLE Enrolled
  (sid CHAR(20),
   cid CHAR(20),
   semester CHAR(20) NOT NULL,
   grade CHAR(2),
   PRIMARY KEY (sid,cid,semester),
   FOREIGN KEY (sid) REFERENCES Students,
   CONSTRAINT checkNumber
   CHECK ( (SELECT COUNT (sid) FROM Students)
               +
           (SELECT COUNT DISTINCT (cid) FROM Enrolled)
               < 1000 ) )
```

More Examples

```
CREATE TABLE films (
    code         CHAR(5) PRIMARY KEY,
    title        VARCHAR(40),
    did          DECIMAL(3),
    date_prod    DATE,
    kind         VARCHAR(10),
    CONSTRAINT production UNIQUE(date_prod)
    FOREIGN KEY did REFERENCES distributors ON DELETE NO ACTION );


CREATE TABLE distributors (
    did     DECIMAL(3) PRIMARY KEY,
    name    VARCHAR(40)
    CONSTRAINT con1 CHECK (did > 100 AND name <> ‘ ’) );
```

Introduction to SQL

SQL is a relational **query language**

supports **simple** yet **powerful** *querying* of data

It has two parts:

DDL: **Data Definition** Language (define and modify schema)

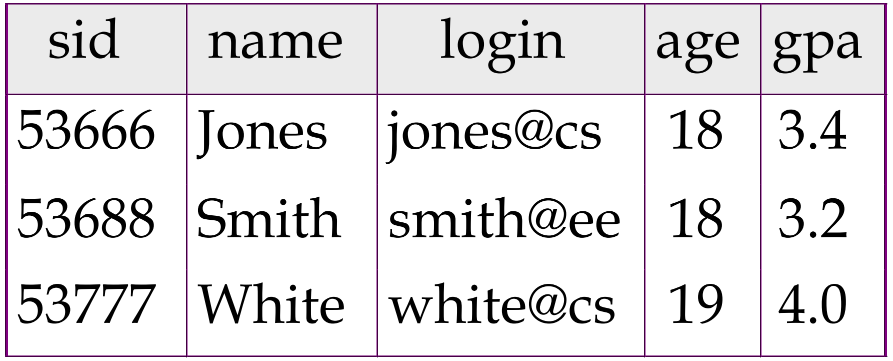
DML: **Data Manipulation** Language (**intuitively** query data)

The simplest SQL query

“find all contents of a table”

in this example: “Find all info for all students”

```
SELECT *
  FROM Students S
```



sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@ee	18	3.2
53777	White	white@cs	19	4.0

to find just names and logins, replace the first line:

```
SELECT S.name, S.login
```

Show specific columns

“find name and login for all students”

```
SELECT S.name, S.login
  FROM Students S
```

name	login
Jones	jones@cs
Smith	smith@ee
White	white@cs

this is called: “**project** name and login from table Students”

Show specific rows

“find all 18 year old students”

```
SELECT *
  FROM Students S
 WHERE S.age=18
```

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@ee	18	3.2

this is called: “**select** students with age 18.”

Querying Multiple Relations

can specify a join over two tables as follows:

```
SELECT Students.name, Enrolled.cid
 FROM Students, Enrolled
 WHERE Students.sid=Enrolled.sid
    AND Enrolled.grade=‘B'
```

sid	cid	grade
53831	Carnatic101	C
53831	Reggae203	B
53650	Topology112	A
53666	History105	B

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@ee	18	3.2

result =

Studetns.name	Enrolled.cid
Jones	History105

Basic SQL Query

```
SELECT   [DISTINCT]  target-list
FROM     relation-list
WHERE    qualification
```

relation-list : a list of relations

target-list : a list of attributes of tables in *relation-list*

qualification : comparisons using AND, OR and NOT

comparisons are: <attr> <*op*> <const> or <attr1> <*op*> <attr2>, where *op* is:

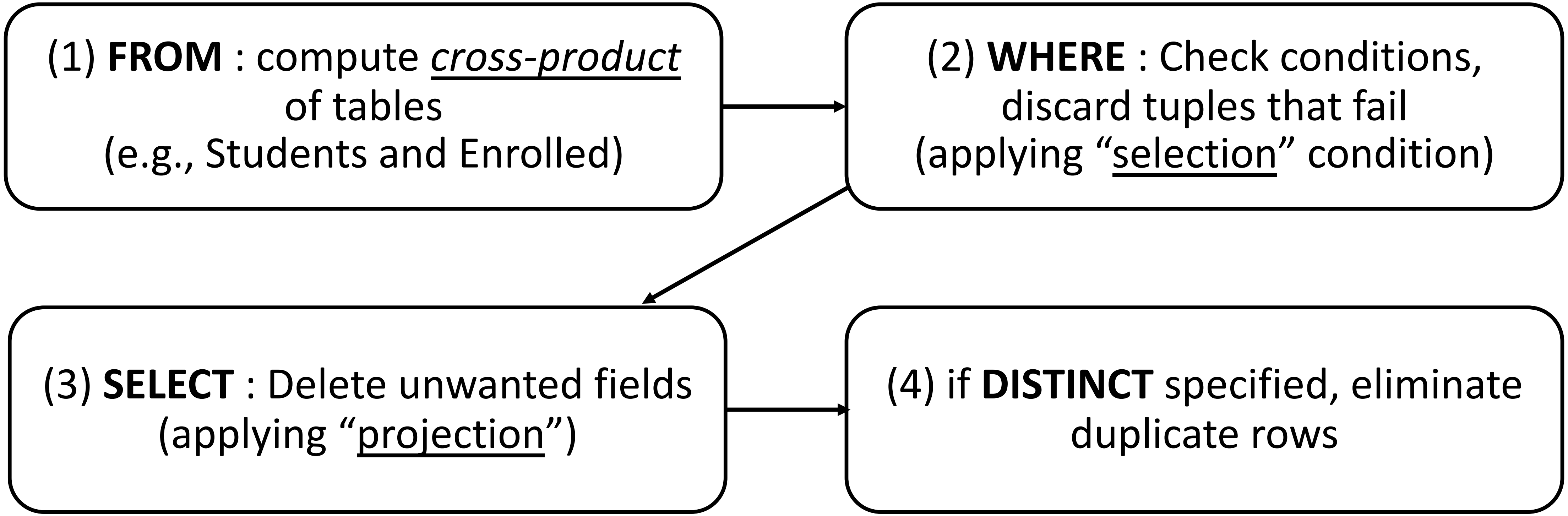
$$<, >, =, \leq, \geq, \neq$$

DISTINCT: *optional,* removes duplicates

By default SQL SELECT does *not* eliminate duplicates! (“multiset”)

Query Semantics

Conceptually, a SQL query can be computed:



(1) **FROM** : compute *cross-product* of tables (e.g., Students and Enrolled)

(2) **WHERE** : Check conditions, discard tuples that fail (applying "selection" condition)

(3) **SELECT** : Delete unwanted fields (applying "projection")

(4) if **DISTINCT** specified, eliminate duplicate rows

probably the least efficient way to compute a query!

Query Optimization finds the *same answer* more efficiently

Remember the query and the data

```
SELECT Students.name, Enrolled.cid
  FROM Students, Enrolled
 WHERE Students.sid=Enrolled.sid
     AND Enrolled.grade=‘B'
```

sid	cid	grade
53831	Carnatic101	C
53831	Reggae203	B
53650	Topology112	A
53666	History105	B

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@ee	18	3.2

Step 1 – Cross Product

Combine with cross-product all tables of the **FROM** clause.

S.sid	S.name	S.login	S.age	S.gpa	E.sid	E.cid	E.grade
53666	Jones	jones@cs	18	3.4	53831	Carnatic101	C
53666	Jones	jones@cs	18	3.4	53832	Reggae203	B
53666	Jones	jones@cs	18	3.4	53650	Topology112	A
53666	Jones	jones@cs	18	3.4	53666	History105	B
53688	Smith	smith@ee	18	3.2	53831	Carnatic101	C
53688	Smith	smith@ee	18	3.2	53831	Reggae203	B
53688	Smith	smith@ee	18	3.2	53650	Topology112	A
53688	Smith	smith@ee	18	3.2	53666	History105	B

```
SELECT Students.name, Enrolled.cid
 FROM Students, Enrolled
 WHERE Students.sid=Enrolled.sid
    AND Enrolled.grade=‘B'
```

Step 2 - Discard tuples that fail predicate

Make sure the **WHERE** clause is true!

S.sid	S.name	S.login	S.age	S.gpa	E.sid	E.cid	E.grade
53666	Jones	jones@cs	18	3.4	53831	Carnatic101	C
53666	Jones	jones@cs	18	3.4	53832	Reggae203	B
53666	Jones	jones@cs	18	3.4	53650	Topology112	A
53666	Jones	jones@cs	18	3.4	53666	History105	B
53688	Smith	smith@ee	18	3.2	53831	Carnatic101	C
53688	Smith	smith@ee	18	3.2	53831	Reggae203	B
53688	Smith	smith@ee	18	3.2	53650	Topology112	A
53688	Smith	smith@ee	18	3.2	53666	History105	B

```
SELECT Students.name, Enrolled.cid
 FROM Students, Enrolled
 WHERE Students.sid=Enrolled.sid
   AND Enrolled.grade=‘B'
```

Step 3 - Discard Unwanted Columns

Show only what is on the **SELECT** clause.

S.sid	S.name	S.login	S.age	S.gpa	E.sid	E.cid	E.grade
53666	Jones	jones@cs	18	3.4	53831	Carnatic101	C
53666	Jones	jones@cs	18	3.4	53832	Reggae203	B
53666	Jones	jones@cs	18	3.4	53650	Topology112	A
53666	Jones	jones@cs	18	3.4	53666	History105	B
53688	Smith	smith@ee	18	3.2	53831	Carnatic101	C
53688	Smith	smith@ee	18	3.2	53831	Reggae203	B
53688	Smith	smith@ee	18	3.2	53650	Topology112	A
53688	Smith	smith@ee	18	3.2	53666	History105	B

```
SELECT Students.name, Enrolled.cid
 FROM Students, Enrolled
 WHERE Students.sid=Enrolled.sid
     AND Enrolled.grade=‘B'
```

Now the Details…

We will use these instances of relations in our examples.

Reserves

sid	bid	day
22	101	10/10/16
95	103	11/12/16

Sailors

sid	sname	rating	age
22	Dustin	7	45.0
31	Lubber	8	55.5
95	Bob	3	63.5

Boats

bid	bname	color
101	Interlake	blue
102	Interlake	red
103	Clipper	green
104	Marine	red

Another Join Query

```
SELECT  sname
FROM    Sailors, Reserves
WHERE   Sailors.sid=Reserves.sid AND bid=103
```

(sid)	sname	rating	age	(sid)	bid	day
22	dustin	7	45.0	22	101	10/10/16
22	dustin	7	45.0	95	103	11/12/16
31	lubber	8	55.5	22	101	10/10/16
31	lubber	8	55.5	95	103	11/12/16
95	Bob	3	63.5	22	101	10/10/16
95	**Bob**	3	63.5	95	103	11/12/16

Range Variables

can associate “range variables” with the tables in the FROM clause

- a shorthand, like the rename operator from relational algebra
- saves writing, makes queries easier to understand
- “`FROM Sailors, Reserves`”
- “`FROM Sailors S, Reserves R`”

needed when ambiguity could arise

- for example, if same table used multiple times in same FROM (called a “self-join”)
- “`FROM Sailors S1, Sailors S2`”

Range Variables

```
SELECT sname
FROM Sailors,Reserves
WHERE Sailors.sid=Reserves.sid AND bid=103
```

can be
rewritten using
range variables as:

```
SELECT S.sname
FROM Sailors S, Reserves R
WHERE S.sid=R.sid AND bid=103
```

you cannot use the full
table name anymore!

~~SELECT Sailors.sname~~
~~FROM Sailors S, Reserves R~~
~~WHERE S.sid=R.sid AND bid=103~~

Range Variables

```
SELECT sname
FROM Sailors,Reserves
WHERE Sailors.sid=Reserves.sid AND bid=103
```

can be
rewritten using
range variables as:

```
SELECT S.sname
FROM Sailors S, Reserves R
WHERE S.sid=R.sid AND bid=103
```

skipping table name if
the attribute exists in
one table is correct:

```
SELECT sname
FROM Sailors S, Reserves R
WHERE S.sid=R.sid AND bid=103
```

Range Variables

an example requiring range variables (self-join)

```
SELECT S1.sname, S1.age, S2.sname, S2.age
FROM Sailors S1, Sailors S2
WHERE  S1.age > S2.age
```

another one: “*” if you don’t want a projection:

```
SELECT  *
FROM Sailors S
WHERE  S.age > 20
```

Find sailors who have reserved at least one boat

```
SELECT  S.sid
FROM  Sailors S, Reserves R
WHERE  S.sid=R.sid
```

does DISTINCT makes a difference?

what is the effect of replacing *S.sid* by *S.sname* in the SELECT clause?

Would adding DISTINCT to this variant of the query make a difference?

Expressions

Can use arithmetic expressions in SELECT clause
(plus other operations we'll discuss later)

age2=2*S.age

equivalent

Use AS to provide column names

```
SELECT S.age, S.age-5 AS age1, 2*S.age AS age2
FROM   Sailors S
WHERE   S.sname = ‘dustin’
```

Can also have expressions in WHERE clause:

```
SELECT  S1.sname AS name1, S2.sname AS name2
FROM   Sailors S1, Sailors S2
WHERE   2*S1.rating = S2.rating - 1
```

String operations

SQL also supports some string operations

“LIKE” is used for string matching.

```
SELECT  S.age, age1=S.age-5, 2*S.age AS age2
FROM  Sailors S
WHERE  S.sname LIKE ‘B_%B’
```

’_’ stands for any one character

’%’ stands for 0 or more arbitrary characters

More Operations

SQL queries produce new tables

If the results of two queries are **union-compatible**

(same number and types of columns)

then we can apply logical operations

UNION

INTERSECTION

SET DIFFERENCE (called EXCEPT or MINUS)

Find sids of sailors who have reserved a red **or** a green boat

UNION: Can be used to compute the union of any two *union-compatible* sets of tuples (which are themselves the result of SQL queries)

```
SELECT R.sid
FROM Boats B,Reserves R
WHERE R.bid=B.bid AND
(B.color=‘red’ OR B.color=‘green’)
```

VS.

```
SELECT  R.sid
FROM Boats B, Reserves R
WHERE R.bid=B.bid AND B.color=‘red’
UNION SELECT R.sid
      FROM Boats B, Reserves R
      WHERE  R.bid=B.bid AND
             B.color=‘green’
```

Find sids of sailors who have reserved a red **and** a green boat

If we simply replace OR by AND in the previous query, we get the wrong answer. (Why?)

Instead, could use a self-join:

```
SELECT R1.sid
FROM Boats B1, Reserves R1,
     Boats B2, Reserves R2
WHERE R1.sid=R2.sid
  AND R1.bid=B1.bid
  AND R2.bid=B2.bid
  AND (B1.color=‘red’ AND B2.color=‘green’)
```

AND Continued…

INTERSECT: discussed in the book. Can be used to compute the intersection of any two *union-compatible* sets of tuples

Also in text: EXCEPT

(sometimes called MINUS)

Included in the SQL/92 standard, but some systems do not support them

Key field!

```
SELECT S.sid
FROM Sailors S, Boats B,
     Reserves R
WHERE S.sid=R.sid
      AND R.bid=B.bid
      AND B.color=‘red’
INTERSECT
SELECT S.sid
FROM Sailors S, Boats B,
     Reserves R
WHERE S.sid=R.sid
     AND R.bid=B.bid
     AND B.color=‘green’
```

Your turn …

1. Find (the names of) all sailors who are over 50 years old
2. Find (the names of) all boats that have been reserved at least once
3. Find all sailors who have not reserved a red boat (hint: use “EXCEPT”)
4. Find all pairs of same-color boats
5. Find all pairs of sailors in which the older sailor has a lower rating

Reserves (sid, bid, day) **Sailors** (sid, sname, rating, age)

Boats (bid, bname, color)

1. Find (the names of) all sailors who are over 50 years old

```
SELECT S.sname
FROM   Sailors S
WHERE  S.age > 50
```

Reserves (sid, bid, day) **Sailors** (sid, sname, rating, age)

Boats (bid, bname, color)

2. Find (the names of) all boats that have been reserved at least once

```
SELECT DISTINCT B.bname
FROM   Boats B, Reserves R
WHERE  R.bid=B.bid
```

Reserves (sid, bid, day) **Sailors** (sid, sname, rating, age)

Boats (bid, bname, color)

3. Find all sailors who have not reserved a red boat

```
SELECT S.sid
FROM   Sailors S
EXCEPT
SELECT R.sid
FROM   Boats B,Reserves R
WHERE  R.bid=B.bid
       AND B.color=‘red’
```

Reserves (sid, bid, day) **Sailors** (sid, sname, rating, age)

Boats (bid, bname, color)

4. Find all pairs of same-color boats

```
SELECT B1.bname, B2.bname
FROM   Boats B1, Boats B2
WHERE  B1.color = B2.color
       AND B1.bid < B2.bid
```

Reserves (sid, bid, day) **Sailors** (sid, sname, rating, age)

Boats (bid, bname, color)

5. Find all pairs of sailors in which the older sailor has a lower rating

```
SELECT S1.sname, S2.sname
FROM   Sailors S1, Sailors S2
WHERE  S1.age > S2.age
       AND S1.rating < S2.rating
```

Nested Queries

powerful feature of SQL:

WHERE clause can itself contain an SQL query!

Actually, so can FROM and HAVING clauses.

Names of sailors who have reserved boat #103

```
SELECT  S.sname
FROM  Sailors S
WHERE  S.sid IN (SELECT R.sid
                 FROM  Reserves R
                 WHERE  R.bid=103)
```

Nested Queries

to find sailors who have *not* reserved #103, use NOT IN.

To understand semantics of nested queries:

think of a ***nested loops*** evaluation

for each Sailors tuple

check the qualification by computing the subquery

Nested Queries with Correlation

Find names of sailors who have reserved boat #103

```
SELECT  S.sname
FROM  Sailors S
WHERE EXISTS (SELECT  *
              FROM  Reserves R
              WHERE R.bid=103 AND S.sid=R.sid)
```

EXISTS is another set operator, like IN (also NOT EXISTS)

If EXISTS UNIQUE is used, and * is replaced by *R.bid*, finds sailors with at most one reservation for boat #103.

UNIQUE checks for duplicate tuples in a subquery;

Subquery must be recomputed for each Sailors tuple.

Think of subquery as a function call that runs a query!

More on Set-Comparison Operators

We've already seen IN, EXISTS and UNIQUE. Can also use NOT IN, NOT EXISTS and NOT UNIQUE.

Also available: *op* ANY, *op* ALL

Find sailors whose rating is greater than that of some sailor called Horatio:

```
SELECT   *
FROM  Sailors S
WHERE  S.rating > ANY (SELECT  S2.rating
                        FROM  Sailors S2
                       WHERE S2.sname='Horatio')
```

Rewriting INTERSECT Queries Using IN

Find sids of sailors who have reserved both a red and a green boat

```
SELECT  R.sid
FROM Boats B, Reserves R
WHERE R.bid=B.bid
      AND B.color=‘red’
      AND R.sid IN (SELECT R2.sid
                    FROM  Boats B2, Reserves R2
                    WHERE  R2.bid=B2.bid
                    AND  B2.color=‘green’)
```

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

How would you change this to find *names* (not *sids*) of Sailors who’ve reserved both red and green boats?

Query #3 revisited …

3. Find all sailors who have not reserved a red boat
   (this time, without using “EXCEPT”)

Reserves (sid, bid, day) **Sailors** (sid, sname, rating, age)
Boats (bid, bname, color)

Answer …

3. Find all sailors who have not reserved a red boat

```
SELECT S.sid
FROM   Sailors S
WHERE  S.sid NOT IN
          (SELECT R.sid
           FROM Reserves R, Boats B
           WHERE R.bid = B.bid
                 AND B.color = ‘red’)
```

Reserves (sid, bid, day) **Sailors** (sid, sname, rating, age)

Boats (bid, bname, color)

Another Correct Answer …

3. Find all sailors who have not reserved a red boat

```
SELECT S.sid
FROM   Sailors S
WHERE  NOT EXISTS
          (SELECT *
           FROM Reserves R, Boats B
           WHERE R.sid = S.sid
                 AND R.bid = B.bid
                 AND B.color = ‘red’)
```

Reserves (sid, bid, day) **Sailors** (sid, sname, rating, age)

Boats (bid, bname, color)

Division (“for all”) in SQL

Find sailors who have reserved all boats.

Sailors S for which ...

```
SELECT S.sname
FROM   Sailors S    there is no boat B without ...
WHERE  NOT EXISTS  (SELECT  B.bid
                     FROM   Boats B
                     WHERE  NOT EXISTS (SELECT  R.bid
                                         FROM   Reserves R
                                         WHERE  R.bid=B.bid
                          a Reserves tuple AND  R.sid=S.sid))
                        showing S reserved B
```

Division (“for all”) in SQL - alternative

Find sailors who have reserved all boats.

```
 Sailors S for which ...
SELECT S.sname
FROM   Sailors S  there is no boat B without ...
WHERE  NOT EXISTS (SELECT   B.bid
                    FROM   Boats B
                    EXCEPT                  (SELECT  R.bid
                                             FROM   Reserves R
                                             WHERE  R.bid=B.bid
                          a Reserves tuple   AND    R.sid=S.sid))
                             showing S reserved B
```

Aggregate Operators

Significant extension of relational algebra.

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

single column

```
SELECT  COUNT (*)
FROM  Sailors S

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

SELECT  COUNT (DISTINCT S.rating)
FROM  Sailors S
WHERE S.sname=‘Bob’
```

Aggregate Operators

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

single column

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

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

Find name and age of the oldest sailor(s)

The first query is incorrect!

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

Third query equivalent to second query

allowed in SQL/92 standard, but not supported in some systems.

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

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

ARGMAX?

The Sailor with the highest rating

What about ties for highest?

```
SELECT *
FROM   Sailors S
WHERE  S.rating >= ALL
   (SELECT  S2.rating
    FROM    Sailors S2)
```

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

```
SELECT *
FROM   Sailors S
ORDER BY rating DESC
LIMIT 1;
```