Database Systems
(資料庫系統)

12/5/2022

Database #2

Introduction to Computer (計算機概論)

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Administrative Matters

- HW#8 (SQL queries) due on December 12, 2022 (12pm, Wednesday)
- Final exam on December 19, 2022
  - Range: Python programming (lecture 9) - Database (II) (Lecture 15)

Reflection: DB design

- Step 1: Requirements Analysis
  - What data to store in the database?
- Step 2: Conceptual Database Design
  - Come up with the design: Entity-Relation (ER) model
  - Sketch the design with ER diagrams
- Step 3: Logical Database Design
  - Implement the design: relational data model
  - Map ER diagrams to relational tables

Example Table Definitions

Sailors(sid: integer, sname: string, rating: integer, age: real)

Boats(bid: integer, bname: string, color: string)

Reserves(sid: integer, bid: integer, day: date)

SQL: Queries, Constraints, Triggers

Chapter 5

Lecture Outline

- Basic Query
  - *SELECT*
- Set Constructs
  - *UNION, INTERSECT, EXCEPT, IN, ANY, ALL, EXISTS*
- Nested Queries
- Aggregate Operators
  - *COUNT, SUM, AVG, MAX, MIN, GROUP BY, HAVING*
- Null Values
- Integrity Constraints
  - *CHECK, CREATE ASSERTION*
- Triggers
  - *CREATE TRIGGER, FOR EACH ROW*

Example Table Definitions

Sailors(sid: integer, sname: string, rating: integer, age: real)
Boats(bid: integer, bname: string, color: string)
Reserves(sid: integer, bid: integer, day: date)

- Find names of sailors who've reserved boat #103

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


Cross-Product

- Each row of S1 is paired with each row of R1.
- Result schema has one field per field of S1 and R1, with field names `inherited' if possible.
  - Conflict: Both S1 and R1 have a field called sid. referred to solely by position

S1

sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0

R1

sid	bid	day
22	101	10/10/96
58	103	11/12/96

S1 x R1

(sid)	sname	rating	age	(sid)	bid	day
22	dustin	7	45.0	22	101	10/10/96
22	dustin	7	45.0	58	103	11/12/96
31	lubber	8	55.5	22	101	10/10/96
31	lubber	8	55.5	58	103	11/12/96
58	rusty	10	35.0	22	101	10/10/96
58	rusty	10	35.0	58	103	11/12/96

Basic SQL Query

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

- Relation-list: A list of relation names (possibly with range-variable after each name).
- Target-list: A list of attributes of relations in relation-list
- Qualification: conditions on attributes (<, >, =, and, or, not, etc.)
- DISTINCT: optional keyword for duplicate removal.
  - Default = no duplicate removal!

How to evaluate a query?

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

- Conceptual query evaluation using relational operators:
  1) Compute the cross-product of relation-list.
  2) Discard resulting tuples if they fail qualifications.
  3) Delete attributes that are not in target-list. (called column-list)
  4) If DISTINCT is specified, eliminate duplicate rows.
- Only conceptual because of inefficiency computation
  - An optimizer can find better strategy

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

Example of Conceptual Evaluation (1)

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

(1) Compute the cross-product of relation-list.

Sailors

sid	*sname*	*rating*	*age*
22	*dustin*	*7*	*45.0*
31	*lubber*	*8*	*55.5*
58	*rusty*	*10*	*35.0*

X

Reserves

sid	*bid*	*day*
22	*101*	*10/10/96*
58	*103*	*11/12/96*

Example of Conceptual Evaluation (2)

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

(2) Discard tuples if they fail qualifications.

Sailors X Reserves

(sid)	*sname*	*rating*	*age*	*(sid)*	*bid*	*day*
22	*dustin*	*7*	*45.0*	*22*	*101*	*10/10/96*
22	*dustin*	*7*	*45.0*	*58*	*103*	*11/12/96*
31	*lubber*	*8*	*55.5*	*22*	*101*	*10/10/96*
31	*lubber*	*8*	*55.5*	*58*	*103*	*11/12/96*
58	*rusty*	*10*	*35.0*	*22*	*101*	*10/10/96*
58	*rusty*	*10*	*35.0*	*58*	*103*	*11/12/96*

Example of Conceptual Evaluation (3)

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

(3) Delete attribute columns that not in target-list.

Sailors X Reserves

(sid)	*sname*	*rating*	*age*	*(sid)*	*bid*	*day*
22	*dustin*	*7*	*45.0*	*22*	*101*	*10/10/96*
22	*dustin*	*7*	*45.0*	*58*	*103*	*11/12/96*
31	*lubber*	*8*	*55.5*	*22*	*101*	*10/10/96*
31	*lubber*	*8*	*55.5*	*58*	*103*	*11/12/96*
58	*rusty*	*10*	*35.0*	*22*	*101*	*10/10/96*
58	*rusty*	*10*	*35.0*	*58*	*103*	*11/12/96*

A Note on Range Variables

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

OR

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

- Really needed range variables only if the same relation appears twice in the FROM clause.

SELECT sname
*FROM Sailors S, **Reserves R1**,*
__Reserves R2__
WHERE S.sid = R1.sid AND
S.sid = R2.sid AND
R1.bid <> R2.bid

Find the sids of sailors who've reserved at least one boat

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

Sailors X Reserves

(sid)	sname	rating	age	(sid)	bid	day
22	dustin	7	45.0	22	101	10/10/96
22	dustin	7	45.0	58	103	11/12/96
31	lubber	8	55.5	22	101	10/10/96
31	lubber	8	55.5	58	103	11/12/96
58	rusty	10	35.0	22	101	10/10/96
58	rusty	10	35.0	58	103	11/12/96

DISTINCT

- Find the names and ages of all sailors

  ```
  SELECT S.sname, S.age
  FROM Sailors S
  ```

- Add *DISTINCT* to this query?
- Replace S.sname by S.sid in the *SELECT* clause?
- Add *DISTINCT* to the above?

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 sailors whose names begin and end with B and contain at least three characters.

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

- *AS* and = are two ways to name fields in result.
- *LIKE* for string matching.
  - `_' for one character
  - `%' for 0 or more characters.

Sid	Sname	Rating	Age
22	Dustin	7	45.0
29	Brutus	1	33.0
31	Lubber	8	55.5
74	Horatio	9	35.0
85	Art	3	25.5
95	Bob	3	20

Age	Age1	Age2
20	15	40

Find sid's of sailors who've reserved a red or a green boats.

```
SELECT  DISTINCT S.sid
FROM    Sailors S, Boats B, Reserves R
WHERE   S.sid=R.sid AND R.bid=B.bid
          AND (B.color='red' OR B.color='green')
```

- *UNION*: work on two *union-compatible* sets of tuples

```
SELECT  S.sid
FROM    Sailors S, Boats B, Reserves R
WHERE   S.sid=R.sid AND R.bid=B.bid AND B.color='red'
UNION
SELECT  S.sid
FROM    Sailors S, Boats B, Reserves R
WHERE   S.sid=R.sid AND R.bid=B.bid AND B.color='green'
```

- Replace *OR* by *AND* in the first version?

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

```
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'
```

- What do we get if we replace *INTERSECT* by *EXCEPT*?
  - *(A Except B)* returns tuples in A but not in B.
  - Find sids of all sailors who have reserved a red boat but not a green boat.

SET Construct: *UNION ALL*

- *UNION, INTERSECT*, and *EXCEPT* delete duplicate by default. **(why?)**
- To retain duplicates, use *UNION ALL, INTERSECT ALL, or EXCEPT ALL*.

Sid	*Sname*
71	*Zorba*
74	*Horatio*
74	*Horatio*
95	*Bob*

INTERSECT ALL

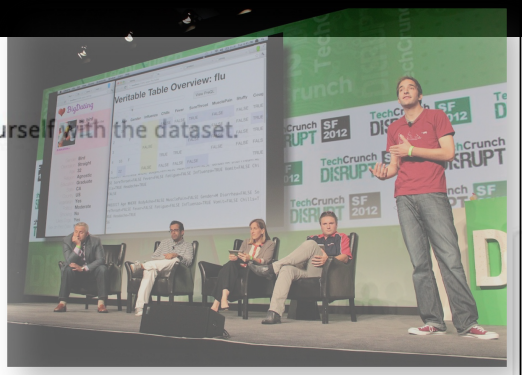
Sid	*Sname*
22	*Dustin*
71	*Zorba*
74	*Horatio*
74	*Horatio*

=

Sid	*Sname*
71	*Zorba*
74	*Horatio*
74	*Horatio*

Prior Knowledge: A Predictive Database For Developers

- http://techcrunch.com/2012/09/11/prior-knowledge-a-predictive-database-for-developers/



Step 1: Understand the data

Take a quick look at the contents of the bank-data.csv file to familiarize yourself with the dataset.

- 600 rows of customer data
- 7 demographic columns
- One column per financial product available for purchase
  - Savings account (`save_act`)
  - Checking account (`current_act`)
  - Mortgage (`mortgage`)
  - Personal equity plan (`pep`)
- Many missing values — not all values are known for all customers

age	sex	region	income	married	children	car	save_act	current_act	mortgage	pep
22	Male	Rural	8877.07	False	-	False	False	True	False	True
37	Female	Suburban	25304.3	True	2	True	False	False	-	False
66	Female	-	-	-	1	True	True	True	True	True
19	Male	Rural	10953.0	True	3	True	True	True	-	False
-	Male	Inner City	-	-	-	True	True	True	True	False

Nested Queries

- WHERE clause can itself contain an SQL subquery. (Actually, so can FROM and HAVING clauses.)
- Find names of sailors who've reserved boat #103:

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

Subquery: finds sids who have reserved bid 103

- *(x IN B)* returns true when x is in set B.
  - To find sailors who've not reserved #103, use *NOT IN*.
- Nested loops Evaluation
  - For each Sailors tuple, check the qualification by computing the subquery.
  - Does the subquery result change for each new Sailor row?

Nested Queries with Correlation

Correlation: subquery finds all reservations for bid 103 from current sid

```
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 comparison operator, like *IN*.
  - *(EXISTS S)* returns true when *S* is not empty.
- What is the above query in English?
  - Find sailors who have reserved boat #103
- In case of correlation, subquery must be re-computed for each Sailors tuple.

Nested Queries with *UNIQUE*

Sailors(sid: integer, sname: string, rating: integer, age: real)
Boats(bid: integer, bname: string, color: string)
Reserves(sid: integer, bid: integer, day: date)

- (UNIQUE S) returns true if S has no duplicate tuples or S is empty.

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

- What is the above query in English?
  - Finds sailors with at most one reservation for boat #103.
- Replace R.bid with *?
  - Finds sailors with at most one reservation for boat #103 in a given day.
  - (Simplify -> find all sailors)

More on Set-Comparison Operators

- Have seen *IN*, *EXISTS* and *UNIQUE*. Can also use *NOT IN*, *NOT EXISTS*, and *NOT UNIQUE*.
- Also available: *op ANY*, *op ALL*, where *op* can be >, <, =, ≠, ≤, ≥
  - *(a > ANY B)* returns true when *a* is greater than any one element in set *B*.
  - *(a > ALL B)* returns true when *a* is greater than all elements in set *B*.

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

- What is the above query in English?
  - Find sailors whose rating is greater than that of some sailor called Horatio.
- What is the above query in English if > *ANY* is replaced by > *ALL*?
  - Find sailors whose rating is greater than all sailors called Horatio.

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

```
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'
```

- Rewrite *INTERSECT* with *IN*.
  - Strategy?

Rewriting *INTERSECT* Using *IN*

```
SELECT  S.sid
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')
```

Find sids who've reserved a green boat

- Find *sid*'s of Sailors who've reserved red but not green boats (*EXCEPT*)
  - Replace *IN* with *NOT IN*.

Aggregate Operators

- *COUNT (*)*
- *COUNT ([DISTINCT] A)*
  - A is a column
- *SUM ([DISTINCT] A)*
- *AVG ([DISTINCT] A)*
- *MAX (A)*
- *MIN (A)*
- Count the number of sailors

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

Find the average age of sailors with rating = 10

Sailors(sid: integer, sname: string, rating: integer, age: real)

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


Count the number of different sailor names

Sailors(sid: integer, sname: string, rating: integer, age: real)

```
SELECT COUNT (DISTINCT S.sname)
FROM Sailors S
```

Find the age of the oldest sailor

Sailors(sid: integer, sname: string, rating: integer, age: real)

```
SELECT MAX(S.AGE)
FROM Sailors S
```


Find name and age of the oldest sailor(s)

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

- This is illegal, but why?
  - Cannot combine a column with a value (unless we use *GROUP BY*)

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

- Okay, but not supported in every system
  - Convert a table (of a single aggregate value) into a single value for comparison

GROUP BY and *HAVING*

- So far, aggregate operators are applied to all (qualifying) tuples.
  - Can we apply them to each of several groups of tuples?
- Example: find the age of the youngest sailor for 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 $i = 1, 2, \ldots, 10$:

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


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
7	45.0
8	25.5

(2)

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

(1)

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

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

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.

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
8	25.5

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

Queries With *GROUP BY* and *HAVING*

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

```
SELECT S.rating, MIN (S.age) as age
FROM Sailors S
GROUP BY S.rating
HAVING S.rating > 5
```

- The *target-list* contains (i) attribute names (ii) terms with aggregate operations (e.g., AVG (*S.age*)).
- The attribute list (e.g., *S.rating*) in *target-list* must be in *grouping-list.*
- The attributes in group-qualification must be in *grouping-list.*

Say if Attribute list is not in grouping-list

```
SELECT S.sname, S.rating, AVG
    (S.age) as age
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

Sname	Rating	Age
?	3	44.5
?	8	40.5

Sname	Rating	Age
Art	3	25.5
Bob	3	63.5
Dustin	7	45.0
Lubber	8	55.5
Andy	8	25.5

Say if Group qualification is not in grouping-list

```
SELECT S.rating, AVG (S.age) as age
FROM Sailors S
GROUP BY  S.rating
HAVING S.sname ≠ 'Dustin'
```

Not in group-list

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

Sname	Rating	Age
Art	3	25.5
Bob	3	63.5
Dustin	7	45.0
Lubber	8	55.5
Andy	8	25.5

Conceptual Evaluation

- Without *GROUP BY* and *HAVING*:
  - Compute cross-product of *relation-list*
  - Remove tuples that fail *qualification*
  - Delete unnecessary columns
- With *GROUP BY* and *HAVING*, continue with
  - Partition remaining tuples into groups by the value of attributes in *grouping-list* (specified in *GROUP-BY* clause)
  - Remove groups that fail *group-qualification* (specified in *HAVING* clause).
  - Compute one answer tuple per qualifying group.

For each red boat, find the number of reservations for this boat

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

```
SELECT  B.bid, COUNT (*) AS
    num_reservations
FROM Boats B, Reserves R
WHERE R.bid=B.bid
GROUP BY  B.bid
HAVING B.color='red'
```

- Illegal, why?
  - B.color does not appear in group-list

Find the 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  COUNT(S) > 1
```

- What is wrong?
  - COUNT(S) is counting tuples after the qualification (S.age > 18).
  - Eliminate groups, which have multiple sailors but only one sailor with age > 18.

- How to fix it?
  - Use subquery in the HAVING clause.

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


Table Constraints

- Specify constraints over a single table
  - Useful when more general ICs than keys are involved.

```
CREATE TABLE  Sailors
        ( sid  INTEGER,
        sname  CHAR(10),
        rating  INTEGER,
        age  REAL,
        PRIMARY KEY  (sid),
        CHECK  ( rating >= 1
                AND rating <= 10 )
```

```
CREATE TABLE  Reserves
        ( sname  CHAR(10),
        bid  INTEGER,
        day  DATE,
        PRIMARY KEY  (bid,day),
        CONSTRAINT  noInterlakeRes
        CHECK  (`Interlake' ≠
                ( SELECT  B.bname
                FROM  Boats B
                WHERE  B.bid=bid)))
```

The boat 'Interlake' cannot be reserved

- Constraints can be named.

Assertions: Constraints Over Multiple Tables

- Awkward and wrong!
  - If Sailors is empty, the number of Boats tuples can be anything!
- ASSERTION is the right solution; not associated with either table.

```
CREATE TABLE  Sailors
        ( sid  INTEGER,
        sname  CHAR(10),
        rating  INTEGER,
        age  REAL,
        PRIMARY KEY  (sid),
        CHECK
        ( (SELECT COUNT (S.sid) FROM Sailors S)
        + (SELECT COUNT (B.bid) FROM Boats B) < 100 )
```

Number of boats plus number of sailors is < 100

```
CREATE ASSERTION  smallClub
CHECK
( (SELECT COUNT (S.sid) FROM Sailors S)
+ (SELECT COUNT (B.bid) FROM Boats B) < 100 )
```


Triggers

- Trigger: procedure that starts automatically if specified changes occur to the DBMS
- A trigger has three parts:
  - Event (activates the trigger)
  - Condition (tests whether the triggers should run)
  - Action (what happens if the trigger runs)

```
CREATE TRIGGER incr_count AFTER INSERT ON Students // Event
WHEN (new.age < 18)  // Condition
FOR EACH ROW
    BEGIN   // ACTION: a procedure in Oracle's PL/SQL syntax
          count := count + 1
    END
```

References

- Deutsch, Donald R., "The SQL Standard: How it Happened," Annals of the History of Computing, IEEE , vol.35, no.2, pp.72,75, April-June 2013

Starwar Exercises

char(name, race, homeworld, affiliation)
planets(name, type, affiliation)
timetable(cname, pname, movie, arrival, departure)

Which planet does Princess Leia go to in movie3?

```
SELECT distinct pname
FROM timetable
WHERE cname ='Princess Leia' and movie=3
```

Starwar Exercises

char(name, race, homeworld, affiliation)
planets(name, type, affiliation)
timetable(cname, pname, movie, arrival, departure)

- How many people stay on Dagobah in movie 3?

```
SELECT count(*)
FROM timetable, characters
WHERE movie=3 and pname ='Dagobah' and
    timetable.cname=characters.name and
    characters.race='Human'
```


Starwar Exercises

char(name, race, homeworld, affiliation)
planets(name, type, affiliation)
timetable(cname, pname, movie, arrival, departure)

- Who has been to his/her homeworld in movie 2?

```
SELECT distinct c.name
FROM characters c, timetable t
WHERE c.name=t.cname and t.pname=c.homeworld and
    movie=2
```

Starwar Exercises

char(name, race, homeworld, affiliation)
planets(name, type, affiliation)
timetable(cname, pname, movie, arrival, departure)

- Find all characters that have been on all planets of rebels.

```
SELECT name
FROM characters c
WHERE not exists (
    SELECT p.name FROM planets p
    WHERE affiliation='rebels' and p.name NOT IN
        (SELECT pname from timetable t where
        t.cname=c.name and t.pname=p.name))
```


Starwar Exercises

char(name, race, homeworld, affiliation)
planets(name, type, affiliation)
timetable(cname, pname, movie, arrival, departure)

- Find distinct names of the planets visited by those of race "droid".

```
SELECT distinct t.pname
FROM characters c, timetable t
WHERE c.name=t.cname and c.race='droid'
```

Starwar Exercises

char(name, race, homeworld, affiliation)
planets(name, type, affiliation)
timetable(cname, pname, movie, arrival, departure)

- For each character and for each neutral planet, how much time total did the character spend on the planet?

```
SELECT c.name, p.name, SUM(t.departure-t.arrival+1) as amount
FROM characters c, timetable t, planets p
WHERE t.cname=c.name and t.pname=p.name and p.affiliation='neutral'
GROUP BY c.name, p.name
```


Division in SQL

- Find sailors who've reserved all boats.
- Strategy?
  - Find all boats that have been reserved by a sailor
  - Compare with all boats
  - Do the sailor's reserved boats include all boats?
    - Yes → include this sailor
    - No → exclude this sailor

```
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))
```

(A EXCEPT B) returns tuples in A but not in B.

Division in SQL

- Can you do it the hard way, without *EXCEPT* & with *NOT EXISTS*?
- Strategy:
  - For each sailor, check that there is no boat that has not been reserved by this sailor.

```
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

sid	*sname*	*rating*	*age*
22	*dustin*	*7*	*45.0*
31	*lubber*	*8*	*55.5*

Boats

bid	*bname*	*color*
101	*xyz*	*red*
103	*abc*	*green*

Reserves

sid	*bid*	*day*
22	*101*	*10/10/96*
31	*101*	*11/12/96*
31	*103*	*12/12/96*