Principles of Database Systems (CS307)

Lecture 4: More on Retrieving Data; Join

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- Most contents are from slides made by Stéphane Faroult, Dr. Yuxin Ma and the authors of Database System Concepts (7th Edition).
- Their original slides have been modified to adapt to the schedule of CS307 at SUSTech.

get or bring (something) back; regain possession of

More on Retrieving Data

Distinct

Distinct

- No duplicated identifier
  - **Some rules** must be respected if you want to obtain valid results when you apply new operations to result sets
    - They must be mathematical sets, i.e., no duplicates

Distinct

- If we run a query such as the one below
  - Many identical rows
    - In other words, we may be obtaining a table, but it's not a relation because many rows cannot be distinguished

```
select country from movies
where year_released=2000;
```

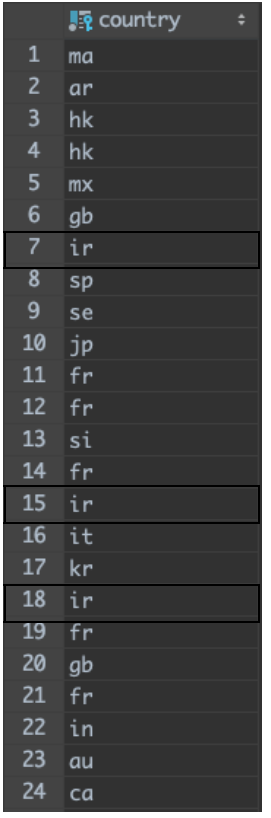
	country
1	ma
2	ar
3	hk
4	hk
5	mx
6	gb
7	ir
8	sp
9	se
10	jp
11	fr
12	fr
13	si
14	fr
15	ir
16	it
17	kr
18	ir
19	fr
20	gb
21	fr
22	in
23	au
24	ca

Duplicated country codes in the query result

- But their original rows are not considered duplicated tuples

Distinct

- The result of the query is in fact completely uninteresting
  - Whenever we are only interested in countries in table movies, there can be only either of two reasons:
    - See a list of countries that have movies
    - Or, for instance, see which countries appear most often



	country
1	ma
2	ar
3	hk
4	hk
5	mx
6	gb
7	ir
8	sp
9	se
10	jp
11	fr
12	fr
13	si
14	fr
15	ir
16	it
17	kr
18	ir
19	fr
20	gb
21	fr
22	in
23	au
24	ca

Duplicated country codes in the query result

- But their original rows are not considered duplicated tuples

Distinct

- If we are only interested in the different countries, there is the special keyword distinct.

```
select distinct country
from movies
where year_released=2000;
```

23 rows

	country
1	si
2	mx
3	cn
4	sp
5	dk
6	gb
7	se
8	tw
9	ar
10	ca
11	pt
12	jp
13	us
14	kr
15	ma
16	de
17	au
18	in
19	hk
20	it
21	gr
22	ir
23	fr

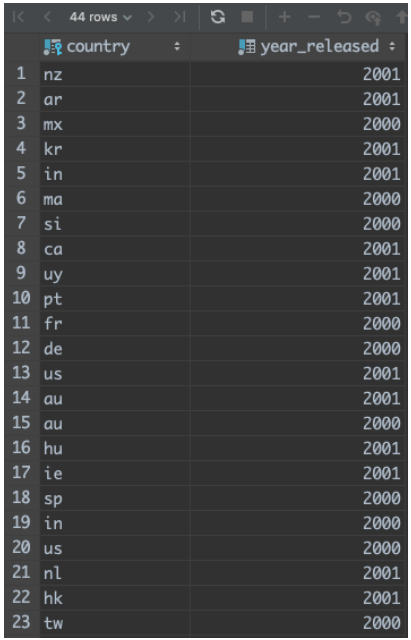
No duplicated results in the country code list now

All of them are different now, and hence it is a relation!

Distinct

- Multiple columns after the keyword distinct
  - It will eliminate those rows where all the selected fields are **identical**
  - The selected combination (country, year_released) will be identical

```
select distinct country, year_released
from movies
where year_released in (2000,2001);
```



44 rows

	country	year_released
1	nz	2001
2	ar	2001
3	mx	2000
4	kr	2001
5	in	2001
6	ma	2000
7	si	2000
8	ca	2001
9	uy	2001
10	pt	2001
11	fr	2000
12	de	2000
13	us	2001
14	au	2001
15	au	2000
16	hu	2001
17	ie	2001
18	sp	2000
19	in	2000
20	us	2000
21	nl	2001
22	hk	2001
23	tw	2000

More on Retrieving Data

Aggregate Functions (聚合函数)

Aggregate Functions

- Statistical functions
  - When we are interested in what we might call countrywide characteristics, such as how many movies released, we use Aggregate Functions.
  - Aggregate function will
    - aggregate all rows that share a feature (such as being movies from the same country)
    - and return a characteristic of each group of aggregated rows

Aggregate Functions

- To compute an aggregated result, we'll first retrieve data
  - Here, all rows are in the table

```
select country, year_released, title
from movies;
```

country	year_released	title
de	1985	Das Boot
fr	1997	Le cinquième élément
fr	1946	La belle et la bête
fr	1942	Les Visiteurs du Soir
gb	1962	Lawrence Of Arabia
gb	1949	The Third Man
in	1975	Sholay
in	1955	Pather Panchali
jp	1954	Shichinin no Samurai

Note: Just for demonstration purpose, not the real data in the table movie

Aggregate Functions

- To compute an aggregated result, we'll first retrieve data
  - Here, all rows are in the table
- Then, data will be regrouped according to the value in one or several columns

```
select country, year_released, title
from movies;
```

Grouped according to country

- Rows with the same value will be grouped together

country	year_released	title
de	1985	Das Boot
fr	1997	Le cinquième élément
fr	1946	La belle et la bête
fr	1942	Les Visiteurs du Soir
gb	1962	Lawrence Of Arabia
gb	1949	The Third Man
in	1975	Sholay
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jp	1954	Shichinin no Samurai

Note: Just for demonstration purpose, not the real data in the table movie

Aggregate Functions

- If we want to group by country
  - … and, for each country (group), the aggregate function count(*) tells how many movies there are
    - "how many movies" = "how many rows"

```
select country,
       count(*) number_of_movies
from movies
group by country;
```

- The query result
  - One row for each group
  - The statistical value is attached in another column

	country	number_of_movies
1	fr	571
2	ke	1
3	si	1
4	eg	11
5	nz	23
6	bg	4
7	ru	153
8	gh	1
9	pe	4
10	hr	1
11	sg	5
12	mx	59
13	cn	200

Aggregate Functions

By the way, we can **rename** the column of the aggregate function, like below

- If we want to group by country
  - … and, for each country (group), the aggregate function count(*) tells how many movies there are
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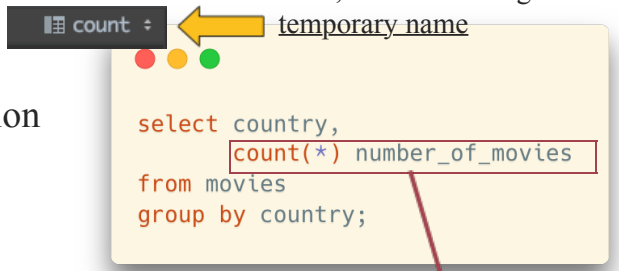
Aggregate Functions

- If we want to group by country
  - … and, for each country (group), the aggregate function count(*) tells how many movies there are
    - "how many movies" = "how many rows"

- The query result
  - One row for each group
  - The statistical value is attached in another column

By the way, we can **rename** the column of the aggregate function, like below

- … or, the client will generate a temporary name



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Aggregate Functions

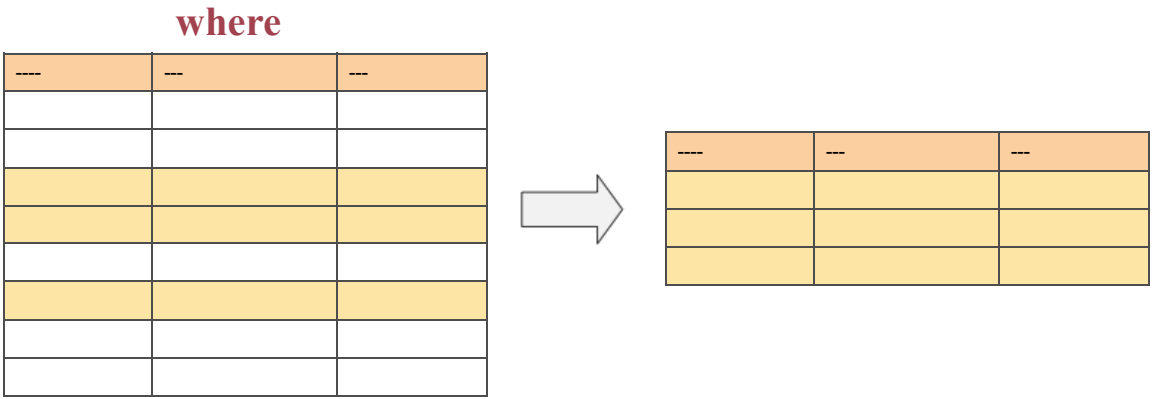
- Group on several columns
  - Any column that is NOT returned by an aggregate function and appears after select must also appear after group by

The combination of the countries and released years will appear in the result

	country	year_released	number_of_movies
1	us	1939	46
2	cn	2016	13
3	nl	2008	1
4	it	1960	10
5	ch	2011	1
6	us	1931	33
7	fr	1961	11
8	cn	2007	5
9	mn	2007	1
10	nz	2010	1
11	de	1974	2
12	au	1978	4
13	us	1935	36
14	eg	1987	1

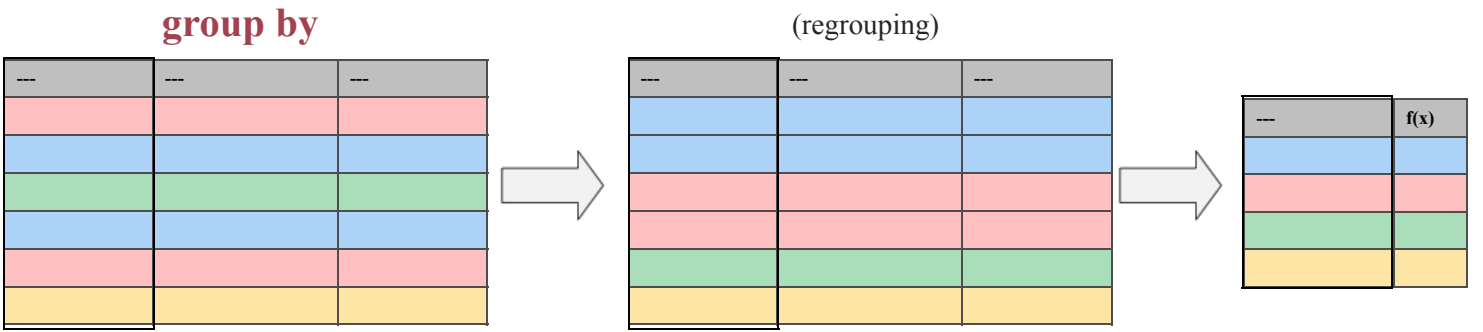
Aggregate Functions

- Beware of some performance implication
  - When you apply a simple where filter, you can start returning rows as soon as you have found a match.



Aggregate Functions

- Beware of some performance implication
  - With a group by, you must regroup rows before you can aggregate them and return results.
    - In other words, you have a preparatory phase that may take time, even if you return few rows in the end.
    - In interactive applications, end-users may not always understand it well.



Aggregate Functions

count(*)/count(col), min(col), max(col), stddev(col), avg(col)

- These aggregate functions exist in almost all products
  - Most products also implement other functions
  - Some work with any datatype, others only work with numerical columns

  - It is strongly recommended to refer to the database manual for details
    - For example, SQLite does not have stddev() for computing the standard deviation

Aggregate Functions

- ***Earliest release year by country?***

```
select country, min(year_released)
oldest_movie from movies group by country;
```

- Such a query answers the question
  - Note that in the demo database years are simple numerical values, but generally speaking min() applied to a date logically returns the earliest one.
  - The result will be a relation: no duplicate, and the key that identifies each row will be the country code (generally speaking, what follows GROUP BY).

country	oldest_movie
fr	1896
ke	2008
si	2000
eg	1949
nz	1981
bg	1967
ru	1924
gh	2012
pe	2004
hr	1970
sg	2002
mx	1933
cn	1913
ee	2007
sp	1933
cl	1926
ec	1999
cz	1949
dk	1910
vn	1992
ro	1964
mn	2007
gb	1916
se	1913
tw	1971
ie	1970
ph	1975
ar	1945
th	1971

Aggregate Functions

- Therefore we can validly apply another relational operation such as the "select" operation (row filtering) and only return countries for which the earliest movie was released before 1940.

Nesting Query (嵌套查询)

```
select * from (
    select country,
    min(year_released) oldest_movie
    from movies
    group by country
    ) earliest_movies_per_country
    where oldest_movie < 1940
```

country	oldest_movie
fr	1896
ru	1924
mx	1933
cn	1913
sp	1933
cl	1926
dk	1910
gb	1916
se	1913
ca	1933
hu	1918
jp	1926
us	1907
be	1926
at	1925
br	1931
de	1919
au	1906
in	1932
it	1917
ge	1930

(21 rows)

Aggregate Functions

```
select country,
           count(distinct year_released)
           number_of_years
    from movies group by country;
```

- These two queries are equivalent

```
    select country,
        count(*) number_of_years
        from (select distinct country,
               year_released
         from movies) t
    group by country;
```

Aggregate Functions

- There is a short-hand that makes nesting query unnecessary (in the same way as AND allows multiple filters). You can have a condition on the result of an aggregate with **having.**

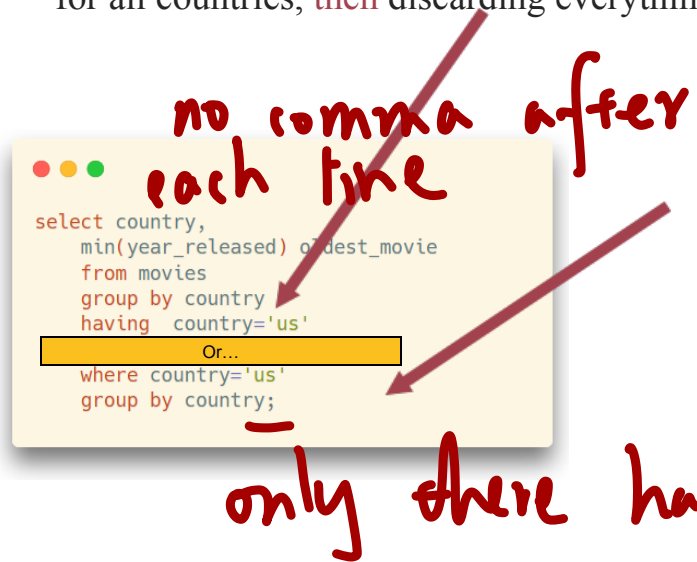
```
select country,
       min(year_released) oldest_movie
    from movies
    group by country
    having min(year_released) < 1940
```

- Now, keep in mind that aggregating rows requires sorting them in a way or another, while sorting is always costly operations that do NOT scale well (Why?).

Aggregate Functions

SORT: Time complexity of sorting algorithms: O(n*log(n))

- The following query is perfectly valid in SQL. What you are doing is aggregating movies for all countries, then discarding everything that is not American:



The efficient way to proceed is of course to select American movies first, and only aggregate them.
SQL Server will do the right thing behind your back. – Query Optimization
Oracle will assume that you have some obscure reason for writing your query that way and will do as told. It can hurt.

Aggregate Functions

- All database management systems have a highly important component that we'll see again, called the "query optimizer".
  - It takes your query, and tries to find the most efficient way to run it.
  - Sometimes it tries to outsmart you, with from time to time unintended consequences
  - Sometimes it optimistically assumes that you know what you are doing
  - ... In all, optimizers may not behave all the same. – So, please reply on yourself, not the optimizer.

Aggregate Functions

- ***How about NULL?***

- When you apply a function or operators to a null, with very few exceptions the result is null because the result of a transformation applied to something unknown is an unknown quantity. What happens with aggregates?

- known + unknown = unknown

Aggregate Functions

- ***How about NULL?***

- Aggregate functions ***ignore*** NULLs

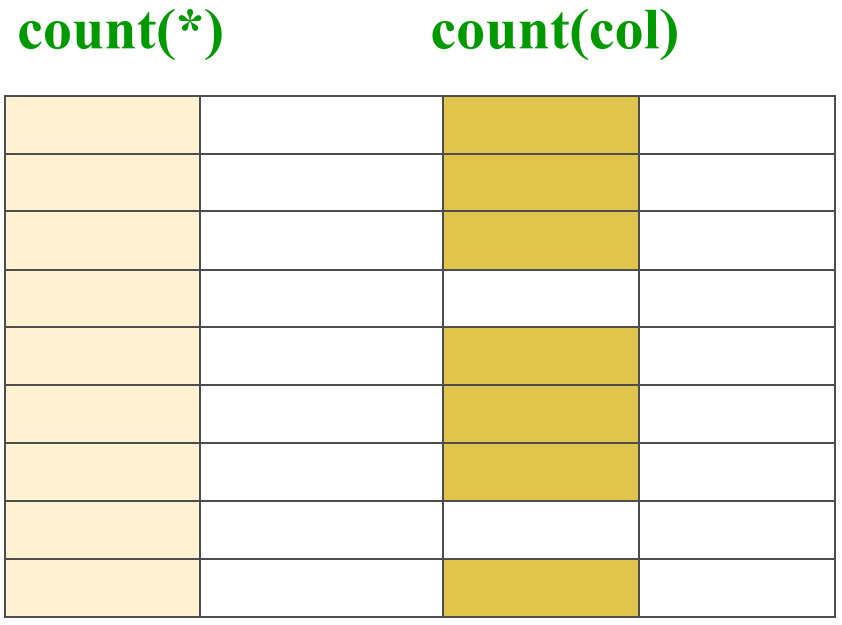
Aggregate Functions

- In this query, the WHERE condition changes nothing to the result (perhaps it makes more obvious that we are dealing with dead people only, but for the SQL engine it's implicit)

```
select max(died) most_recent_death
    from people
    where died is not null;
```

use "is" rather than "=" for null

Aggregate Functions



- Depending on the column you count, the function can therefore return different values. count(*) will always return the number of rows in the result set, because there is always at least one value that is NOT null in a row (otherwise you would not have a row in the first place)

Aggregate Functions

- Counting a mandatory column such as BORN will return the same value as COUNT(*)
  - The third count, though, will only return the number of dead people in the table.

```
select count(*) people_count,
          count(born) birth_year_count,
          count(died) death_year_count
    from people;
```

```
 people_count | birth_year_count | death_year_count
--------------+------------------+------------------
        16489 |            16489 |             5653
(1 row)
```

Aggregate Functions

- **select count(colname)**
- **select count(distinct colname)**

- In some cases, you only want to count distinct values. For instance, you may want to count how many different surnames starting with a Q instead of how many people have a surname starting with a Q.

Aggregate Functions

- How many people are both actors and directors?

credits

Aggregate Functions

movie_id	people_id	credited_as
8	37	D
8	38	A
8	39	A
8	40	A
10	11	A
10	12	A
10	15	D
10	16	A
10	17	A

```
select peopleid,
    credited_as
        from credits;
```

- There is no restriction such as "that have played in a movie that they have directed", so the movieid is irrelevant. But if we remove the movieid, we have tons of duplicates. Not a relation!

Aggregate Functions

- People who appear twice are the ones we want.

```
select distinct
       peopleid, credited_as
    from credits
    where credited_as
         in ('A', 'D');
```

people_id	credited_as
11	D
11	A
12	A
15	A
16	A
17	A
37	D
38	A
39	A

DISTINCT will remove duplicates and provide a true relation. I specify the values for CREDITED_AS because there is no other value now, but you cannot predict the future (someday there may be producers or directors of photography, i.e., some role other than ‘A’ or ‘D’).

Aggregate Functions

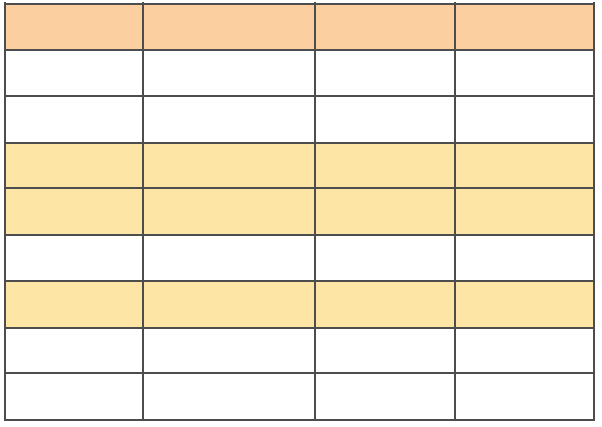
- The HAVING selects only people who appear twice ... and we just have to count them. Mission accomplished.

```
select count(*) number_of_acting_directors
    from (
    select peopleid, count(*) as
number_of_roles
    from ((select distinct peopleid,
credited_as
    from credits where credited_as
    in ('A', 'D')) all_actors_and_directors
    group by peopleid
    number_of_roles = 2) acting_directors;
```

no comma at the end of the line

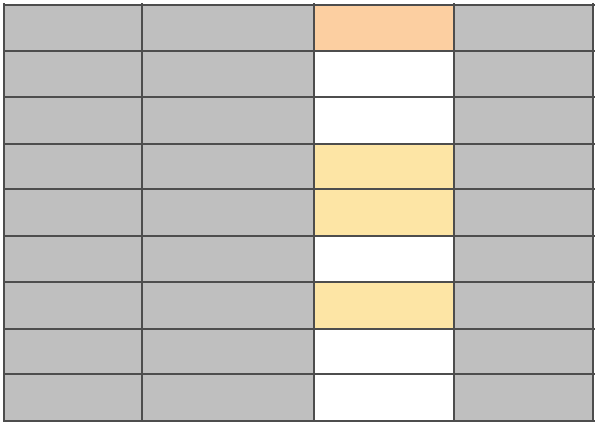
Join

Retrieving Data from Multiple Tables



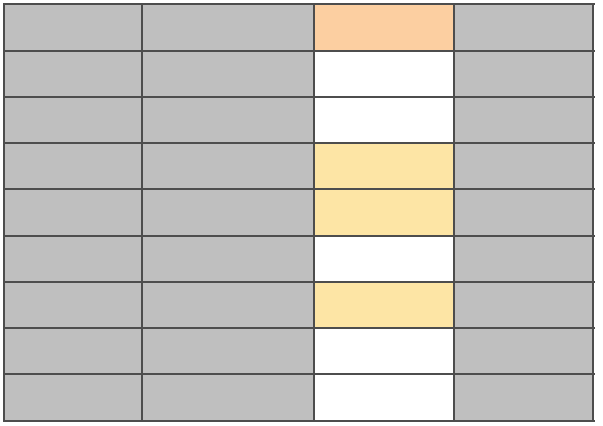
- We have seen the basic operation consisting in filtering rows (an operator called SELECT by Codd)

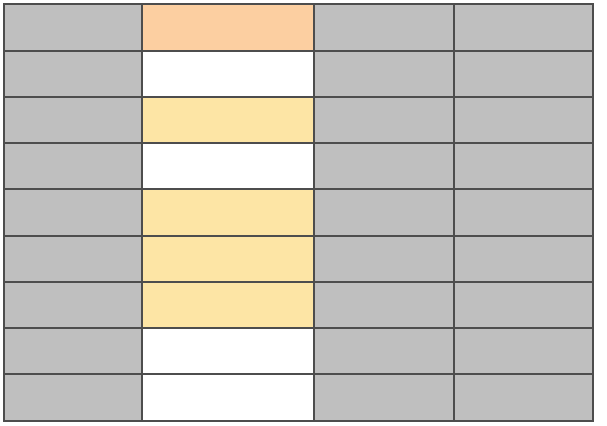
Retrieving Data from Multiple Tables



- We have seen how we can only return some columns (called PROJECT by Codd), and that we must be careful not to return duplicates when we aren't returning a full key.

Retrieving Data from Multiple Tables

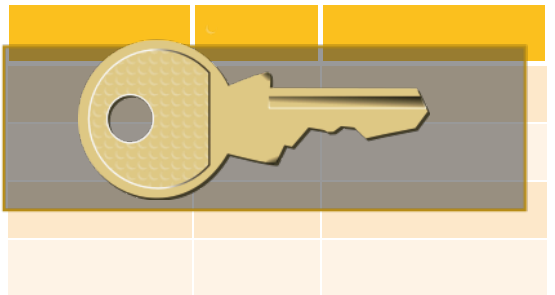




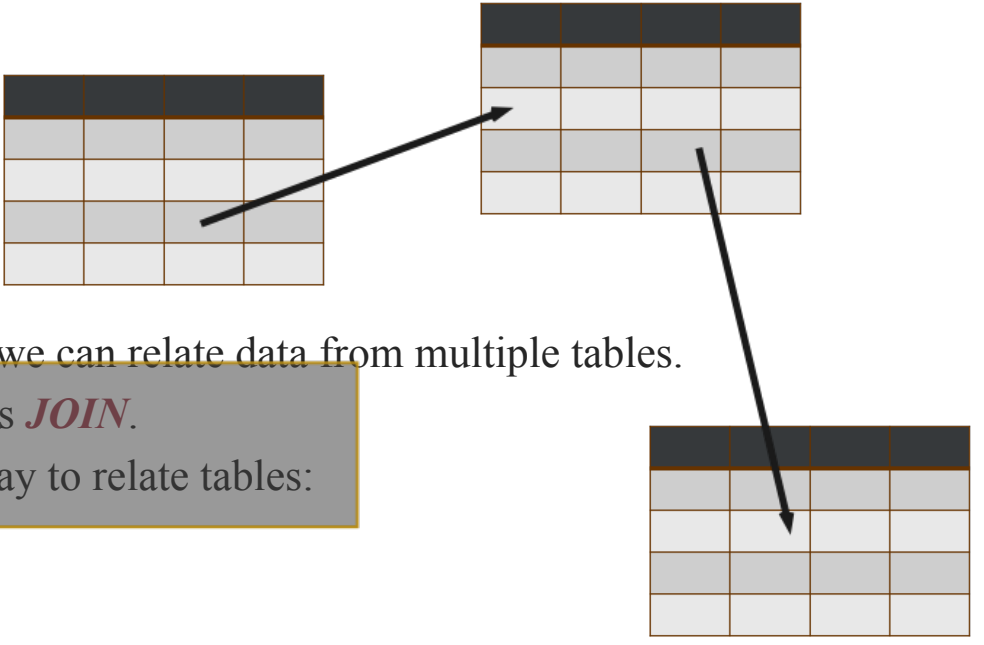
- We have also seen how we can return data that does not exist as such in tables by applying functions to columns.

Retrieving Data from Multiple Tables

- What is REALLY important is that in all cases our result set looks like a clean table, with no duplicates, and a column (or combination of columns) could be used as a key
  - If this is the case, we are safe. This must be true at every stage in a complex query built by successive layers.



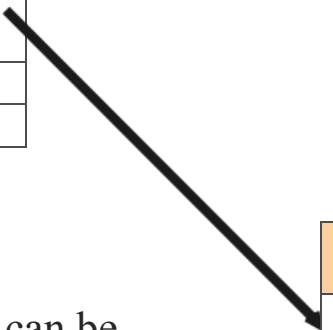
Retrieving Data from Multiple Tables



- It is time now to see how we can relate data from multiple tables.
- This operation is known as ***JOIN***.
- We have already seen a way to relate tables: foreign key constraints.

Retrieving Data from Multiple Tables

movieid	title	country	year_released
1	Casab	us	1942
2	Goodfellas	us	1990
3	Bronenosets Potyomkin	ru	1925
4	Blade Runner	us	1982
5	Annie Hall	us	1977



country_code	country_name	continent
ru	Russia	Europe
us	United States	America
in	India	Asia
gb	United Kingdom	Europe

- The COUNTRY column in MOVIES can be used to retrieve the country name from COUNTRIES.

Retrieving Data from Multiple Tables

- This is done with this type of query. We retrieve, and display as a single set, pieces of data coming from two different tables.

```
select title,
    country_name,
    year_released
    from movies
    join countries
    on country_code = country;
```

title	country_name	year_released
12 stulyev	Russia	1971
Al-mummia	Egypt	1969
Ali Zaoua, prince de la rue	Morocco	2000
Apariencias	Argentina	2000
Ardh Satya	India	1983
Armaan	India	2003
Armaan	Pakistan	1966
Babettes gæstebud	Denmark	1987
Banshun	Japan	1949
Bidaya wa Nihaya	Egypt	1960
Variety	United States	2008
Bon Cop, Bad Cop	Canada	2006
Brilliantovaja ruka	Russia	1969
C'est arrivé près de chez vous	Belgium	1992
Carlota Joaquina - Princesa do Brasil	Brazil	1995
Cicak-man	Malaysia	2006
Da Nao Tian Gong	China	1965
Das indische Grabmal	Germany	1959
Das Leben der Anderen	Germany	2006
Den store gavtyv	Denmark	1956

Retrieving Data from Multiple Tables

movies join countries

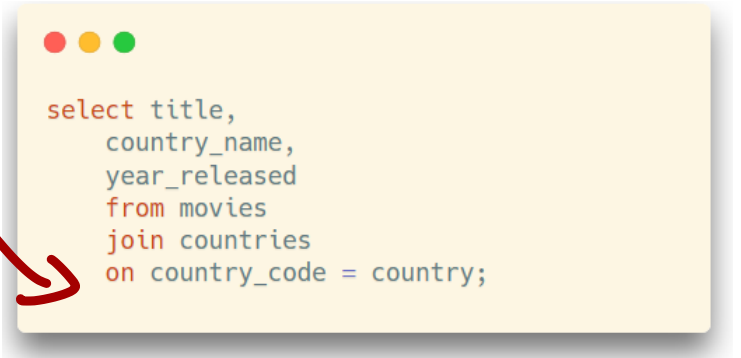
duplicate

- The join operation will create a virtual table with all combinations between rows in Table1 and rows in Table2.
- If Table1 has R1 rows, and Table2 has R2, the huge virtual table has R1xR2 rows.

movieid	title	country	year_released	country_code	country_name	continent
1	Casablanca	us	1942	ru	Russia	Europe
1	Casablanca	us	1942	us	United States	America
1	Casablanca	us	1942	in	India	Asia
1	Casablanca	us	1942	gb	United Kingdom	Europe
1	Casablanca	us	1942	ru	Russia	Europe

Retrieving Data from Multiple Tables

- The join condition tells which values (columns) in each table must match for filtering the results



Retrieving Data from Multiple Tables

movies join countries

movieid	title	country	year_released	country_code	country_name	continent
1	Casablanca	us	1942	ru	Russia	Europe
1	Casablanca	us	1942	us	United States	America
1	Casablanca	us	1942	in	India	Asia
1	Casablanca	us	1942	gb	United Kingdom	Europe
1	Casablanca	us	1942	ru	Russia	Europe

- We use on country_code = country to filter out unrelated rows to make a much smaller virtual table.

Retrieving Data from Multiple Tables

- From this virtual table
  - Retrieve some columns and apply filtering conditions to any column

```
select title,
    country_name,
    year_released
    from movies
    join countries
    on country_code = country
    where country_code <> 'us';
```

movieid	title	country	year_released	country_code	country_name	continent
1	Casablanca	us	1942	us	United States	America
2	Goodfellas	us	1990	us	United States	America
3	Bronenosets Potyomkin	ru	1925	ru	Russia	Europe
4	Blade Runner	us	1982	us	United States	America

Natural Join

- What if we do not specify the column?
  - Natural join (same name & same type & only one column in each table)

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select * from people natural join credits;

-- The same as:
select *
from people join credits
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-- Or use "using"
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from people join credits using(peopleid);
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(Maybe) A Good Practice in Writing Queries

- It is preferred not to depend on how database designers name their columns
  - It can be a good practice to use a single (and sometimes straightforward) syntax that works all the time

Keep it simply stupid

```sql
-- Natural join (can sometimes be dangerous)
select * from people natural join credits;

-- The same as:
select *
from people join credits
on people.peopled = credits.peopleid;

-- Or use "using"
select *
from people join credits using(peopleid);

-- A better practice: just write all of them in a unified way
select *
from people join credits
on people. peopled = credits.peopleid;
```

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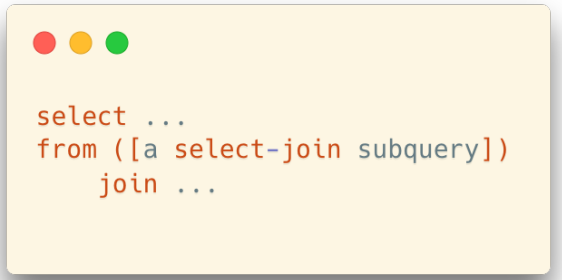
```sql
select *
from people p1 join people p2  -- rename the tables, or you cannot refer to them respectively
on p1.first_name = p2.first_name  -- p1=the first people table; p2=the second people table
where p1.peopleid <> p2.peopleid;  -- remember to filter out the rows with the same person
```

Join in a Subquery

- A join can as well be applied to a subquery seen as a virtual table
  - … as long as the result of this subquery is a valid relation in Codd's sense



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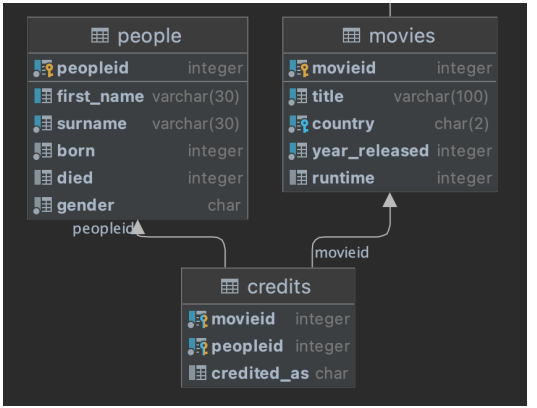

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  - Joins between 10 or 15 tables are not uncommon, and queries generated by programs often do much worse.
  - Example: Show names of actors and directors for Chinese movies

```
select m.title, c.credited_as, p.first_name, p.surname
from
     movies m join credits c on m.movieid = c.movieid join people p on c.peopleid = p.peopleid
where m.country = 'cn';
```

《人类简史》

近来，数学符号已经带来另一种更革命性的文字系统，计算机所使用的二进制程序语言，全部只有两个符号：0 与 1。就像现在我用键盘打到计算机上的所有文字，也都是由 0 和 1 的组合所呈现。

* * *

文字本来应该是人类意识的仆人，但现在正在反仆为主。计算机并不能理解智人如何说话、感觉和编织梦想，所以我们现在反而是用一种计算机能够理解的数字语言来教智人如何说话、感觉和编织梦想。

而且这还没完。人工智能的领域还希望能够完全在计算机二进制的程序语言上创造一种新的智能。像科幻电影《黑客帝国》或《终结者》，就都预测着总有一天这些二进制语言会抛下人性给它们的枷锁，而人类想要反扑的时候，它们就会试图消灭人类。