Relational Modeling

Big Data Systems

Dr. Rubi Boim

Motivation (for this course)

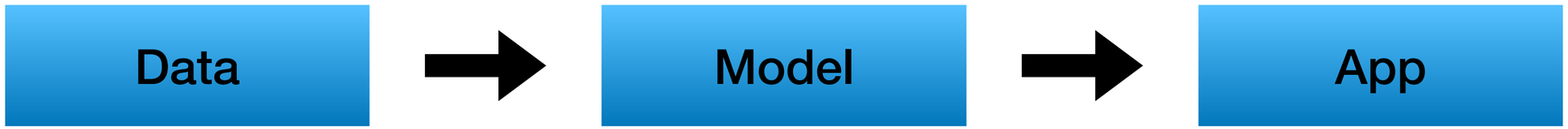
- Data modeling is an important process when creating a relational database

- Data modeling is **the most important** process when creating a **big data database**

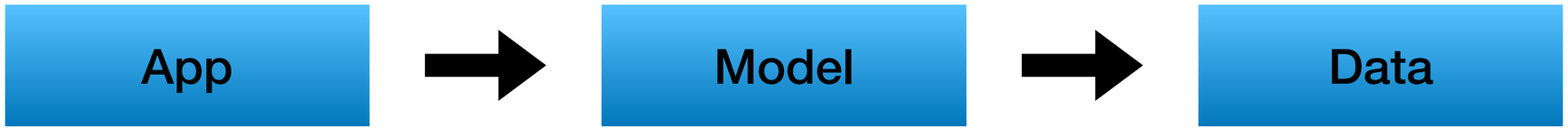
- Modeling for NoSQL is “different” than relational
  understanding relational modeling in crucial for wide column modeling

Relational vs NoSQL - design

- Relational
  focus on entities



- NoSQL
  focus on queries



Relational data modeling

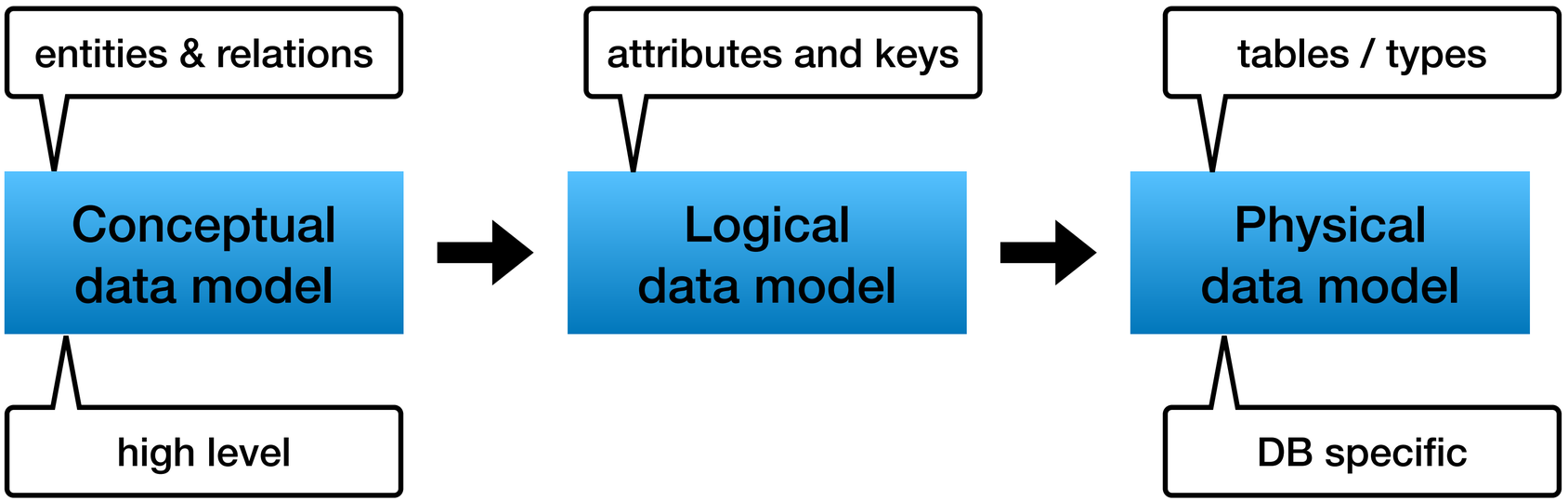
Modeling is an Art

- Multiple ways to solve design problems
- Uncommon use case —> think out of the box

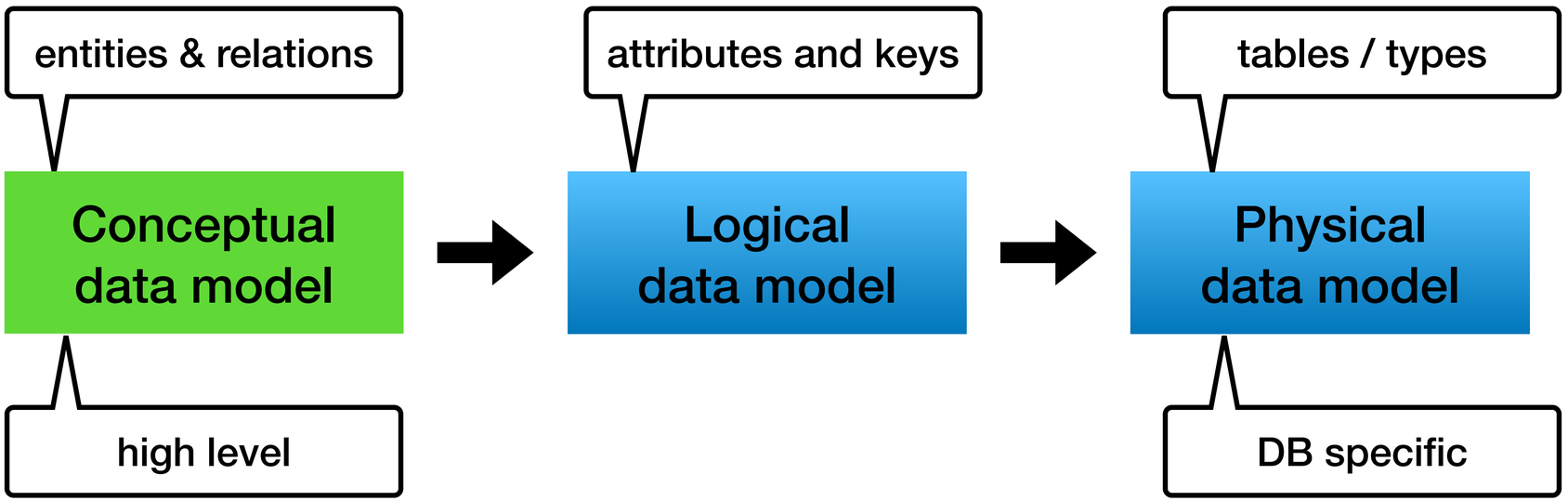
Relational Modeling - general steps

- Map conceptual entities, attributes and their relations
- Map primary and foreign keys
- Define data types
- Create tables

Relational Modeling - 10,000 foot view



Relational Modeling - 10,000 foot view



Conceptual data model

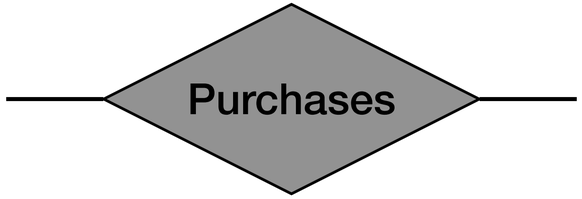
- Abstract view of the world
  server and database types are irrelevant
- Can be defined by non technical teams
  not really in reality…
- Entity / Relationship model (ER)

ER Model

- Entities

- Attributes

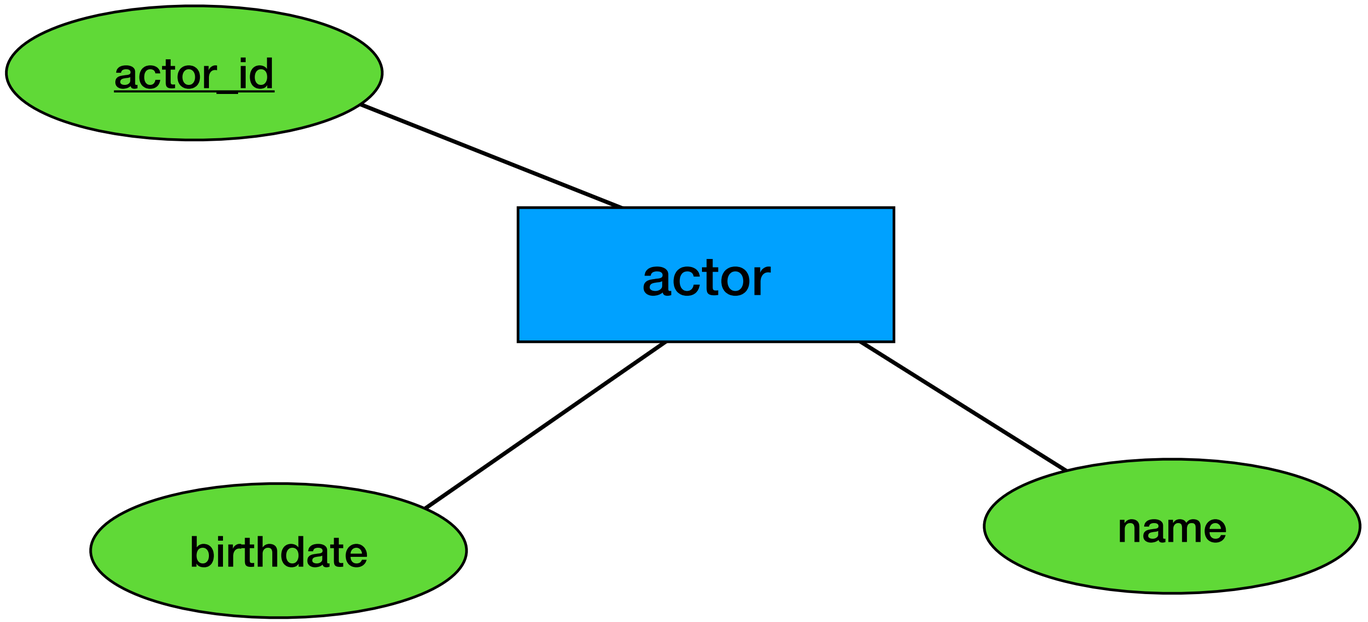
- Relations
  between entities



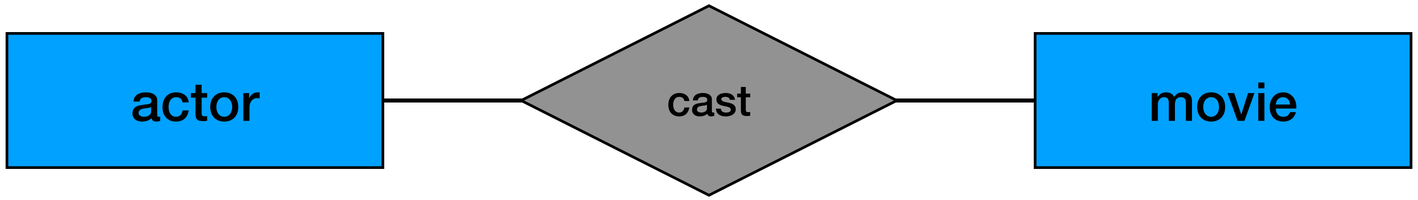
* There are more types like ISA (is a)

Entity

- Each entity must have a key

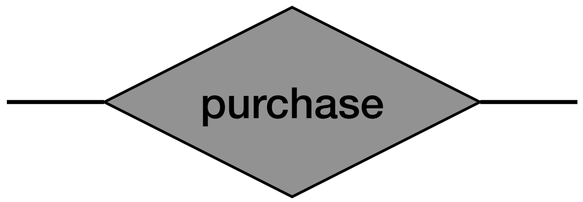


Relation (between entities)

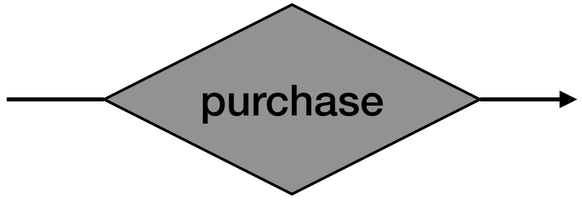


Cardinality (of relation)

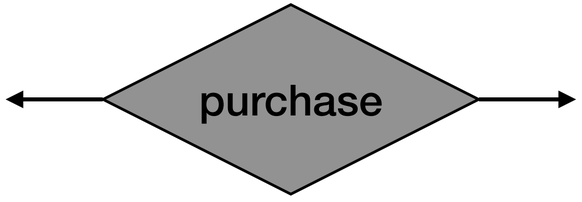
- cardinality is the number of occurrences in one entity which are associated to the number of occurrences in another



many-many



many-one

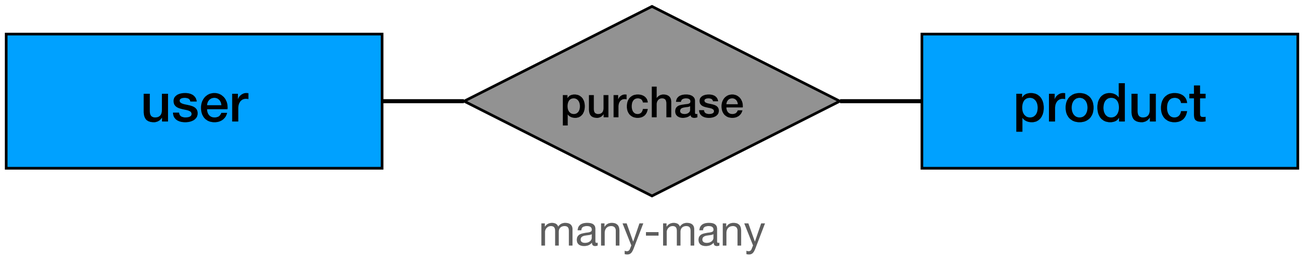


one-one

Many to Many

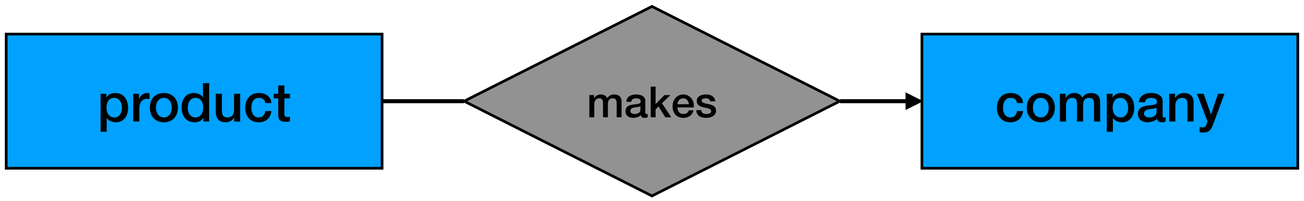
many-many

Many to Many



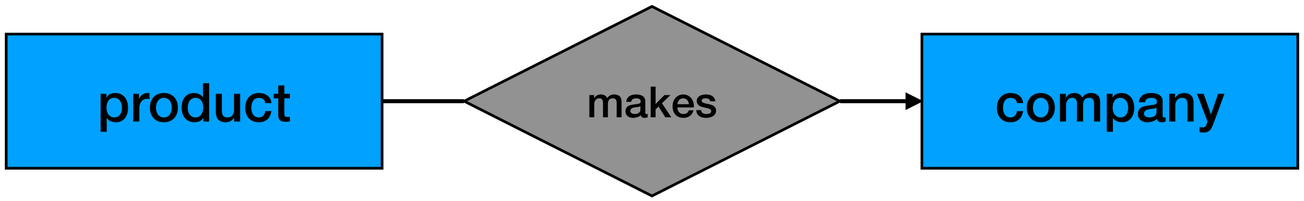
Each user can buy many products
(but each product only once)

Many to One



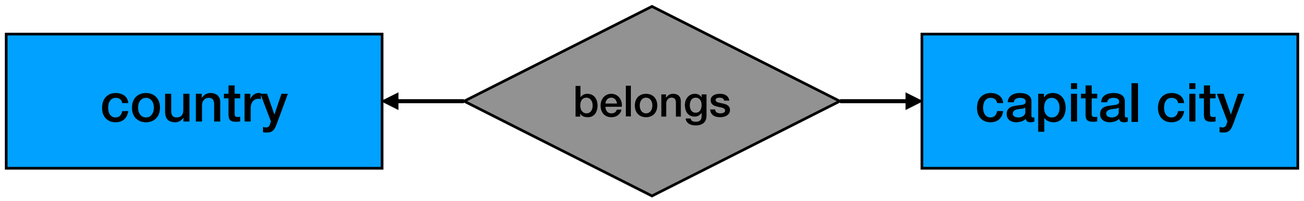
many-one

Many to One



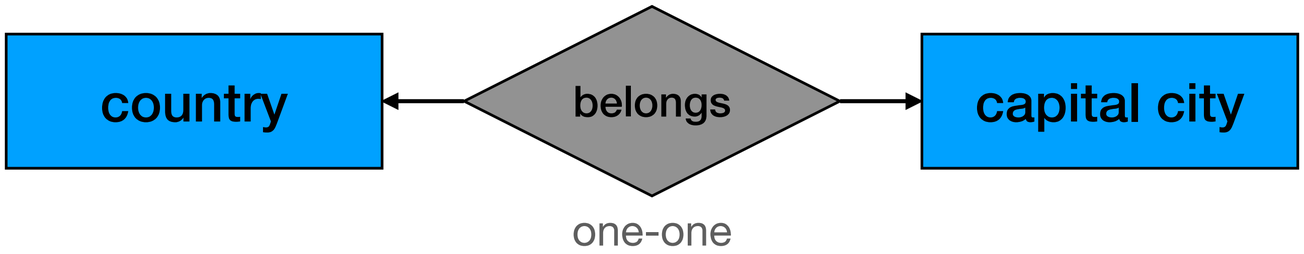
Each product is made by one company

One to One



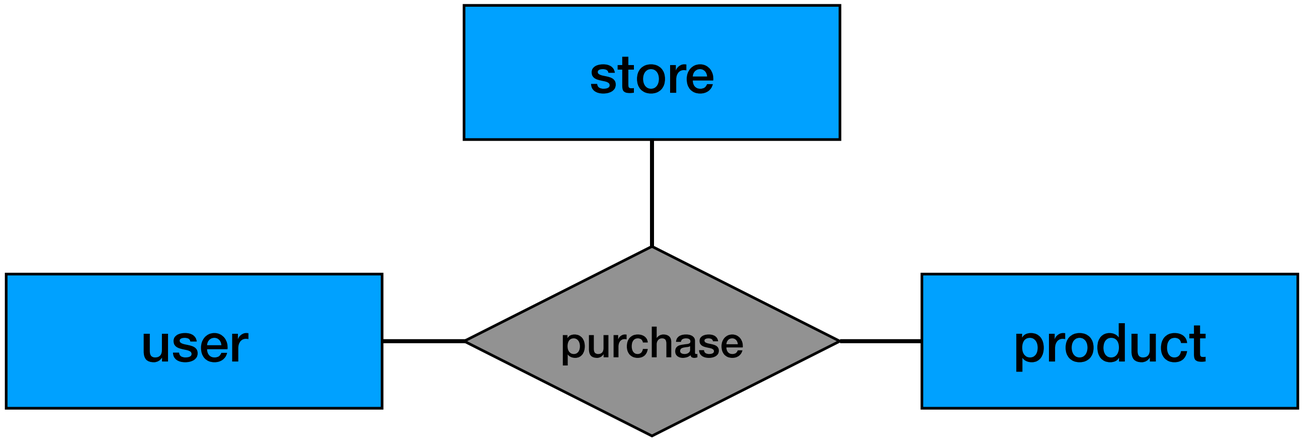
one-one

One to One

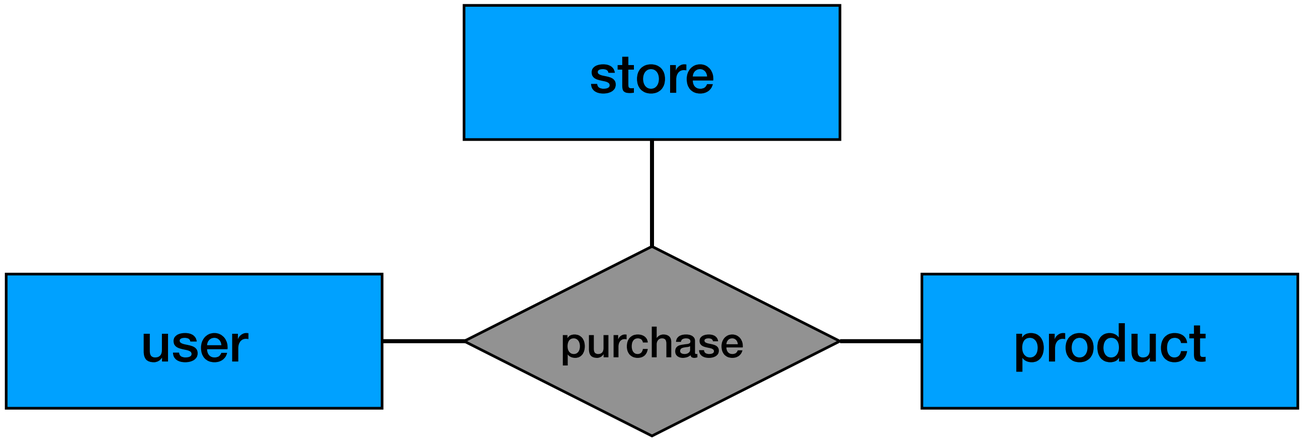


Each country has one capital city, and each capital city belongs to one country

Multi way relations

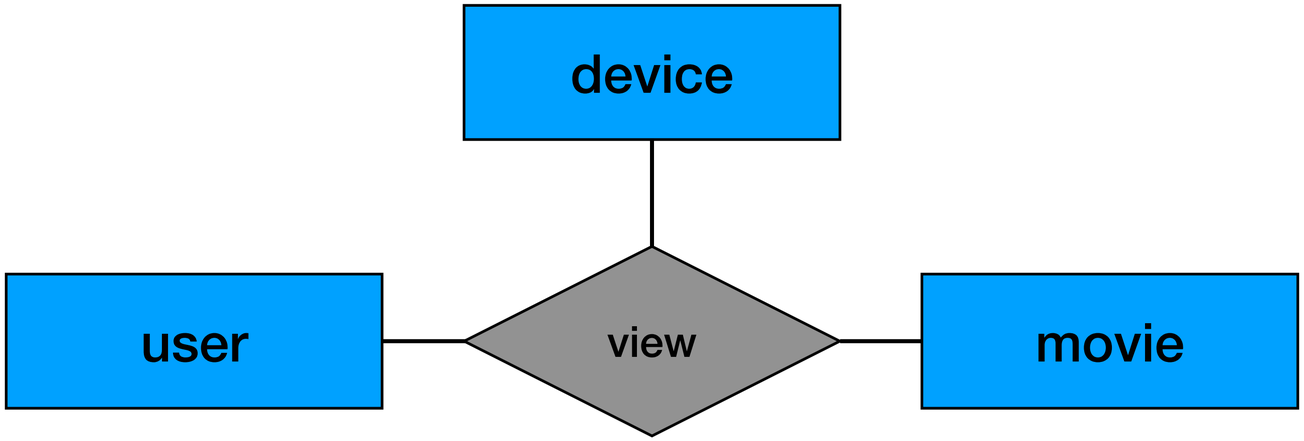


Multi way relations

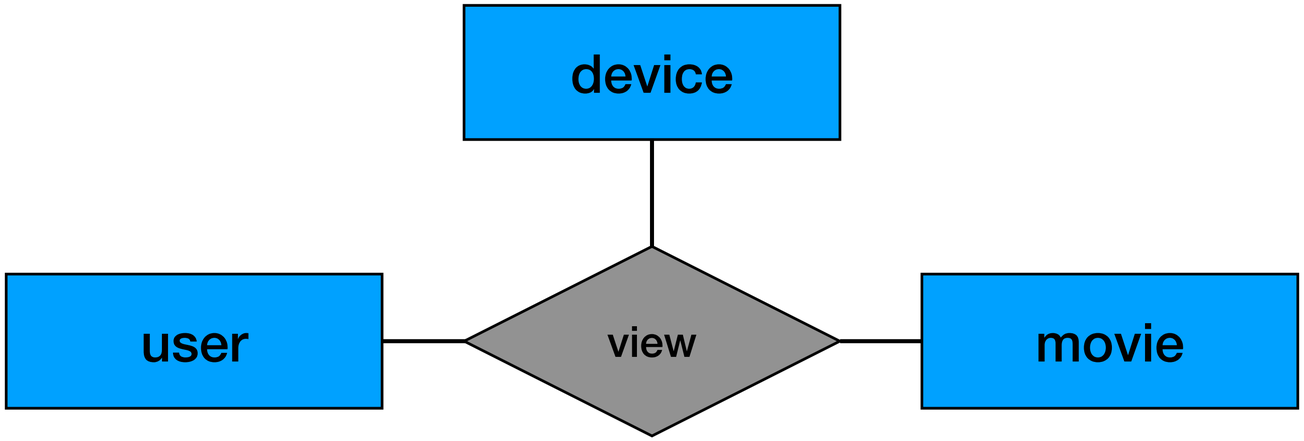


Each user can buy many products in different stores (but user-store-product combination only once)

Multi way relations (another example)

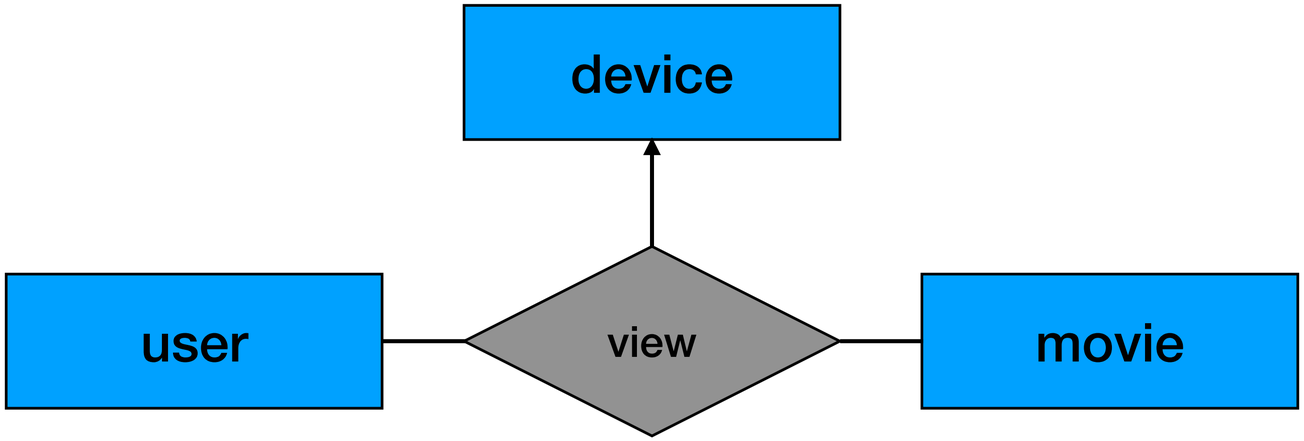


Multi way relations (another example)

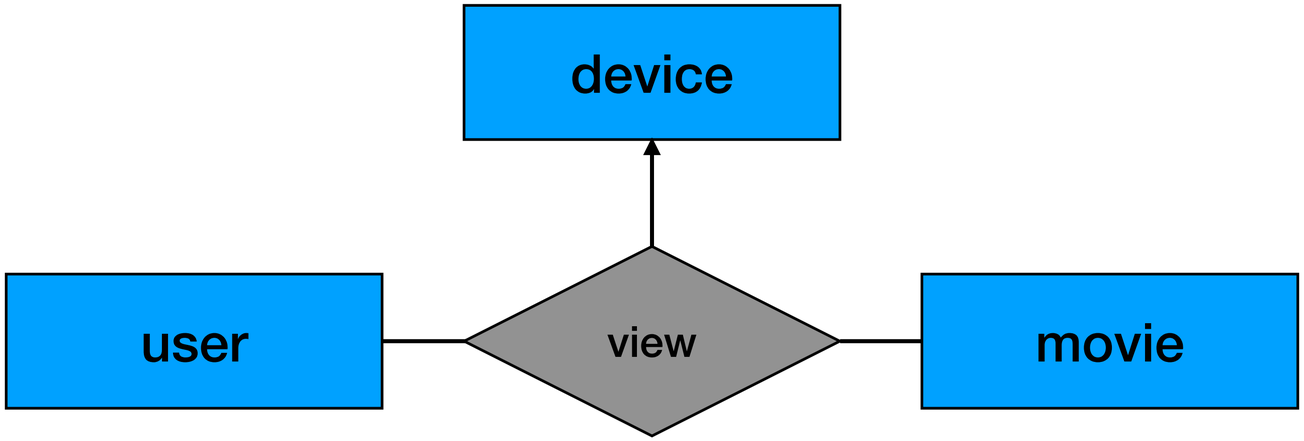


Each user can view many movies on different devices (but user-movie-device combination only once)

Multi way relations + cardinality

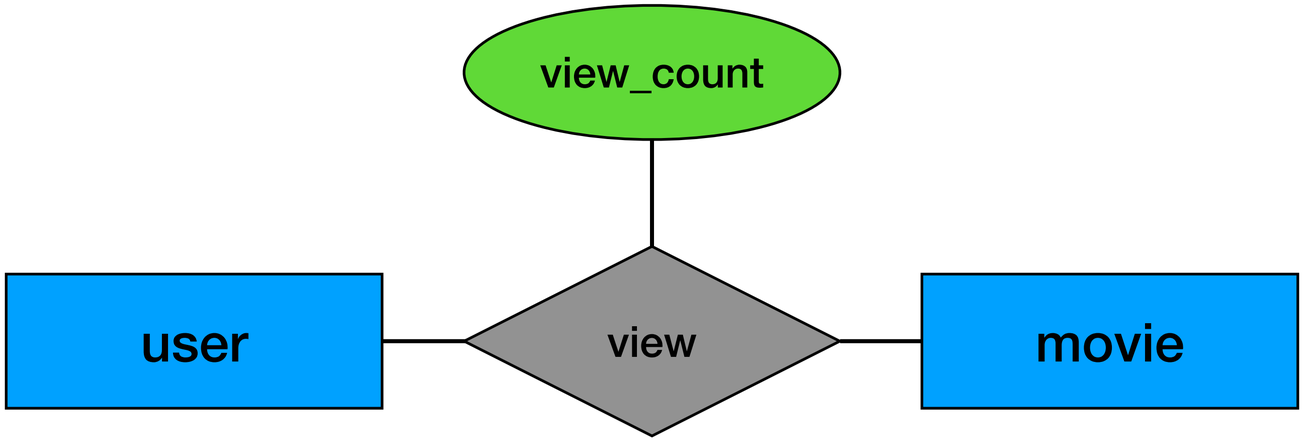


Multi way relations + cardinality

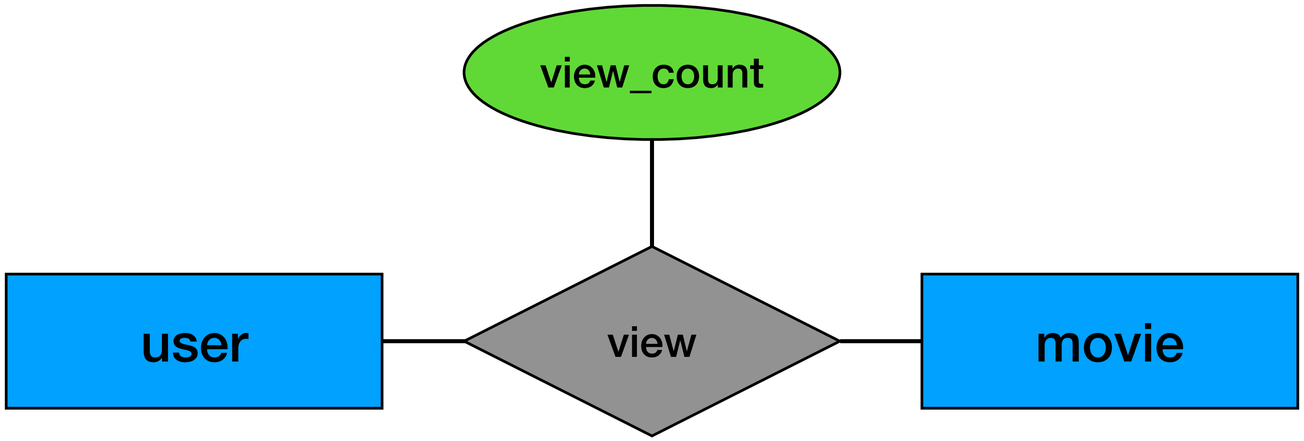


Each user can view many movies.
If we know the user and the movie, we know the device

Attributes for relations

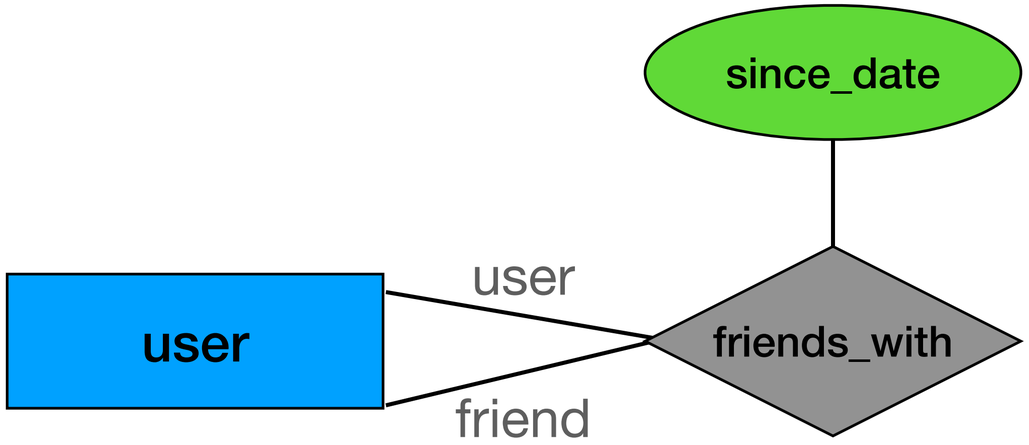


Attributes for relations

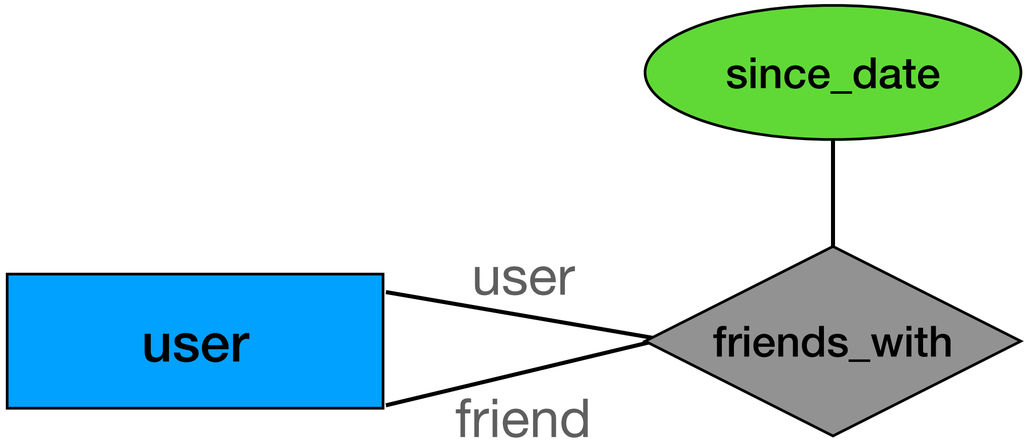


Each user can view many movies.
For each “view” we also save the view_count

Roles in relations



Roles in relations



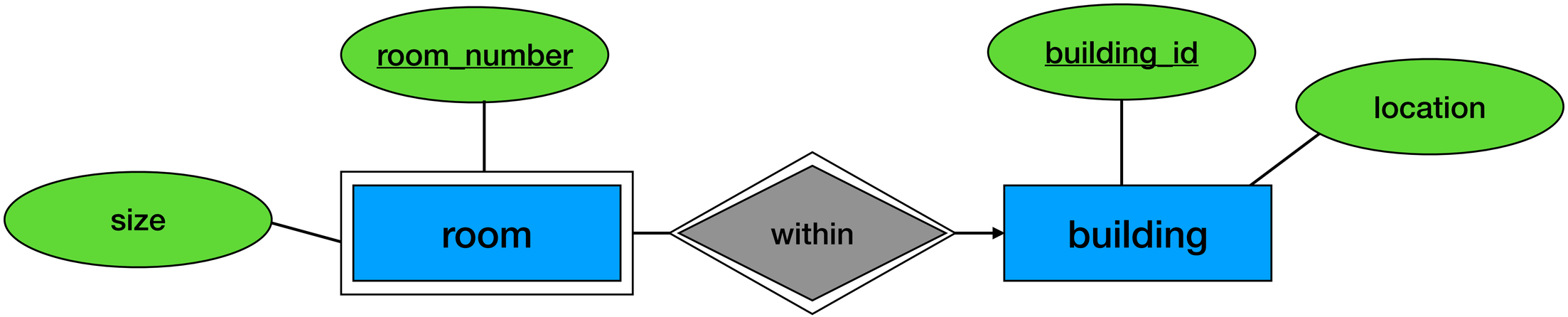
A user can be friends a different user

From previous class:

```
friends(user_id, friend_user_id, since_date)
```

Weak Entity

- When some of their keys comes from other entities



Weak Entity

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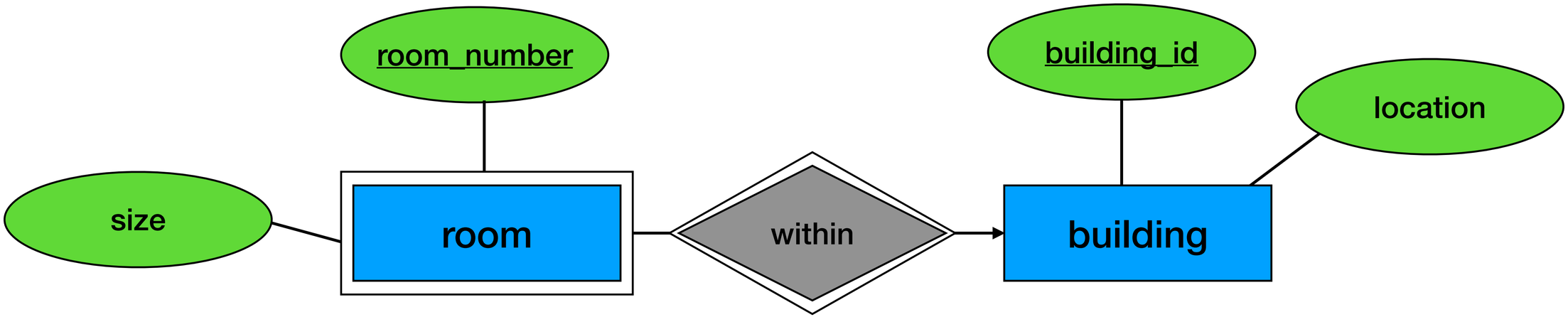


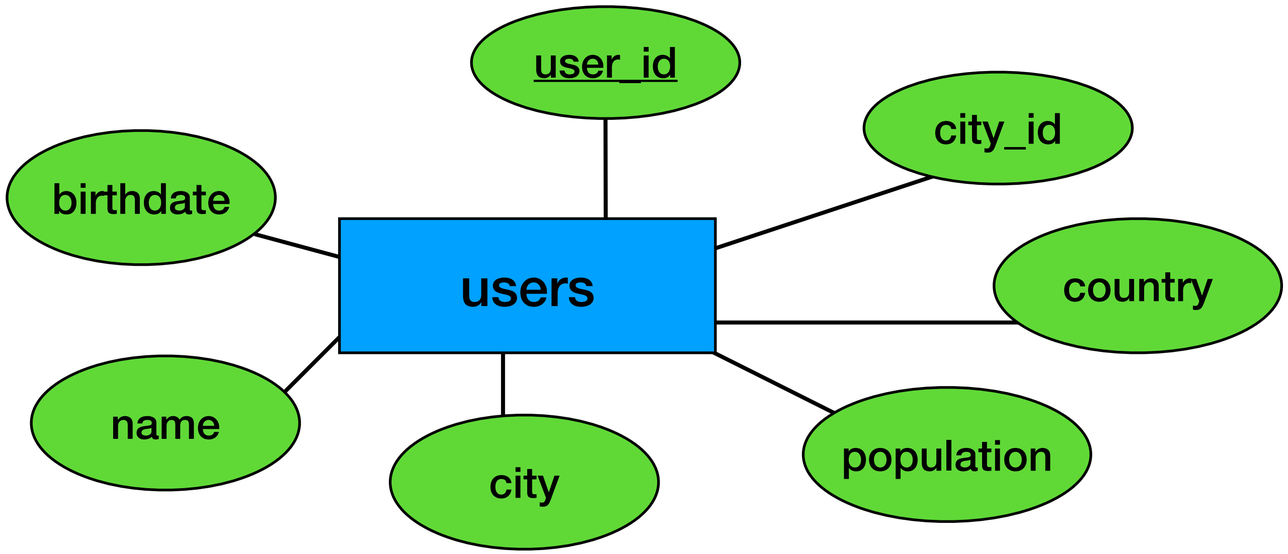
In this example, the key for room is building_id and room_number

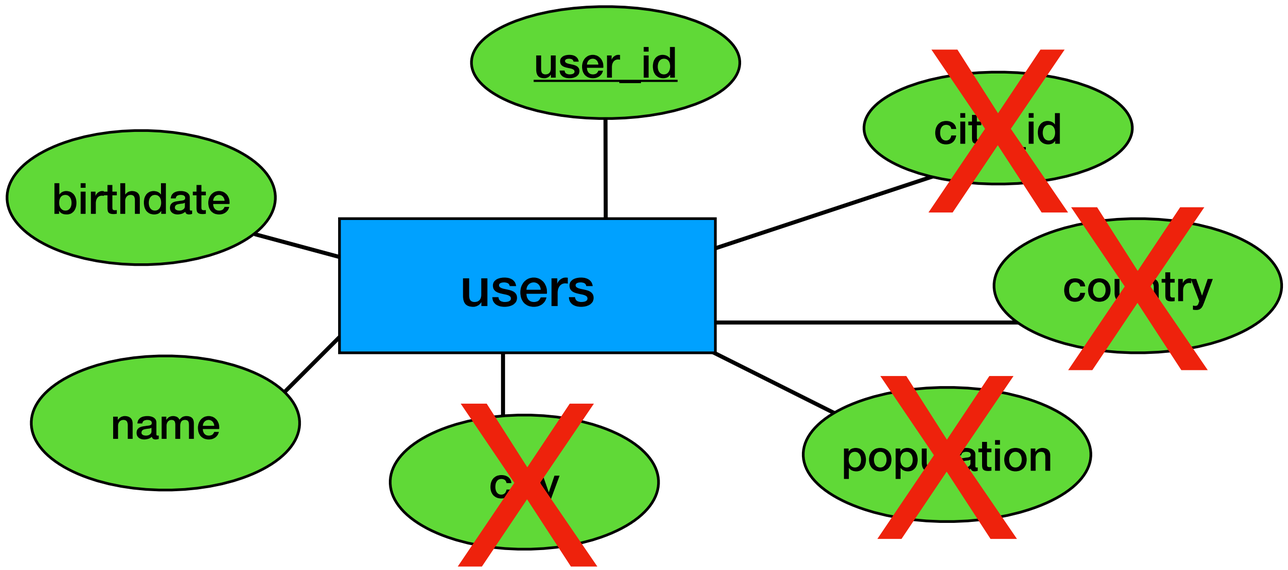
Example

Story time

Design an ER diagram for a video platform:

- A user is defined by user_id. We also save her name, birthdate and city. For each city we save the city_id, name, population and country
- A video is defined by a video_id and we store its genre, release date and title
- For each video we keep the actors that appears in it along with their character name.
- The actors are defined by an actor_id along with their name
- For analytics, if a user views a video we save the most recent viewing timestamp


user_id
city_id
birthdate
users
country
name
city
population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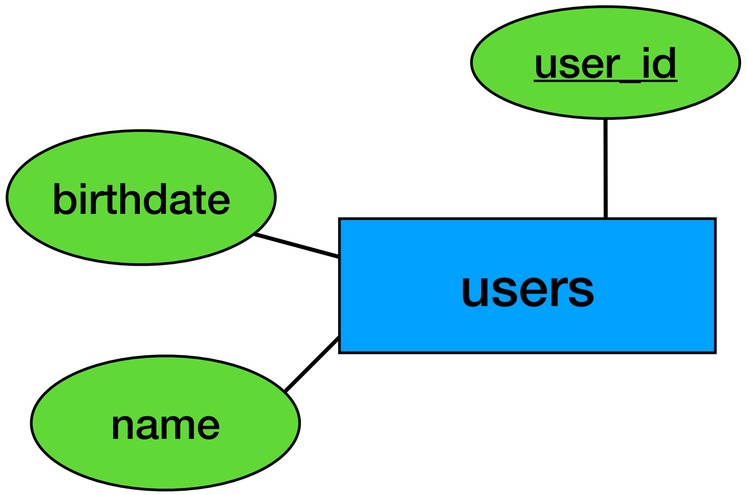
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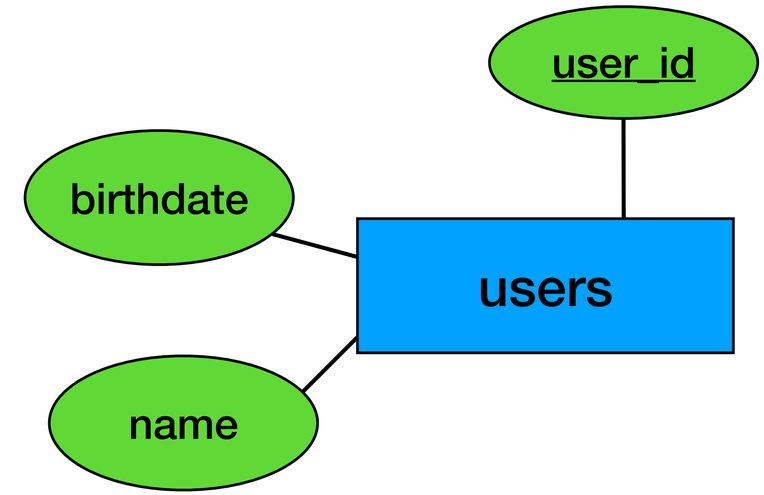
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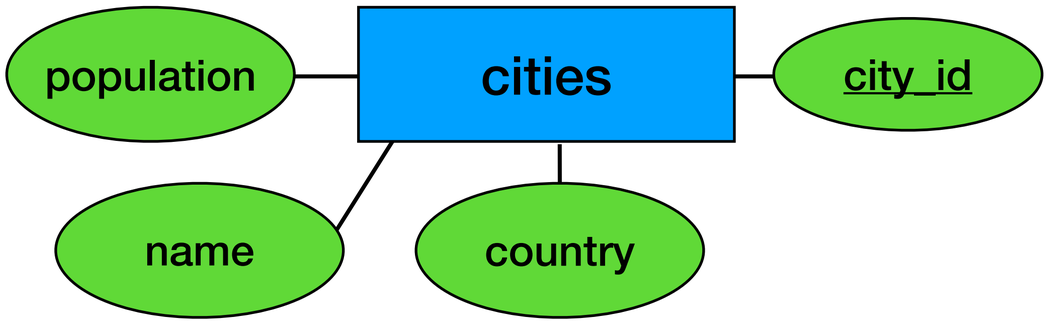
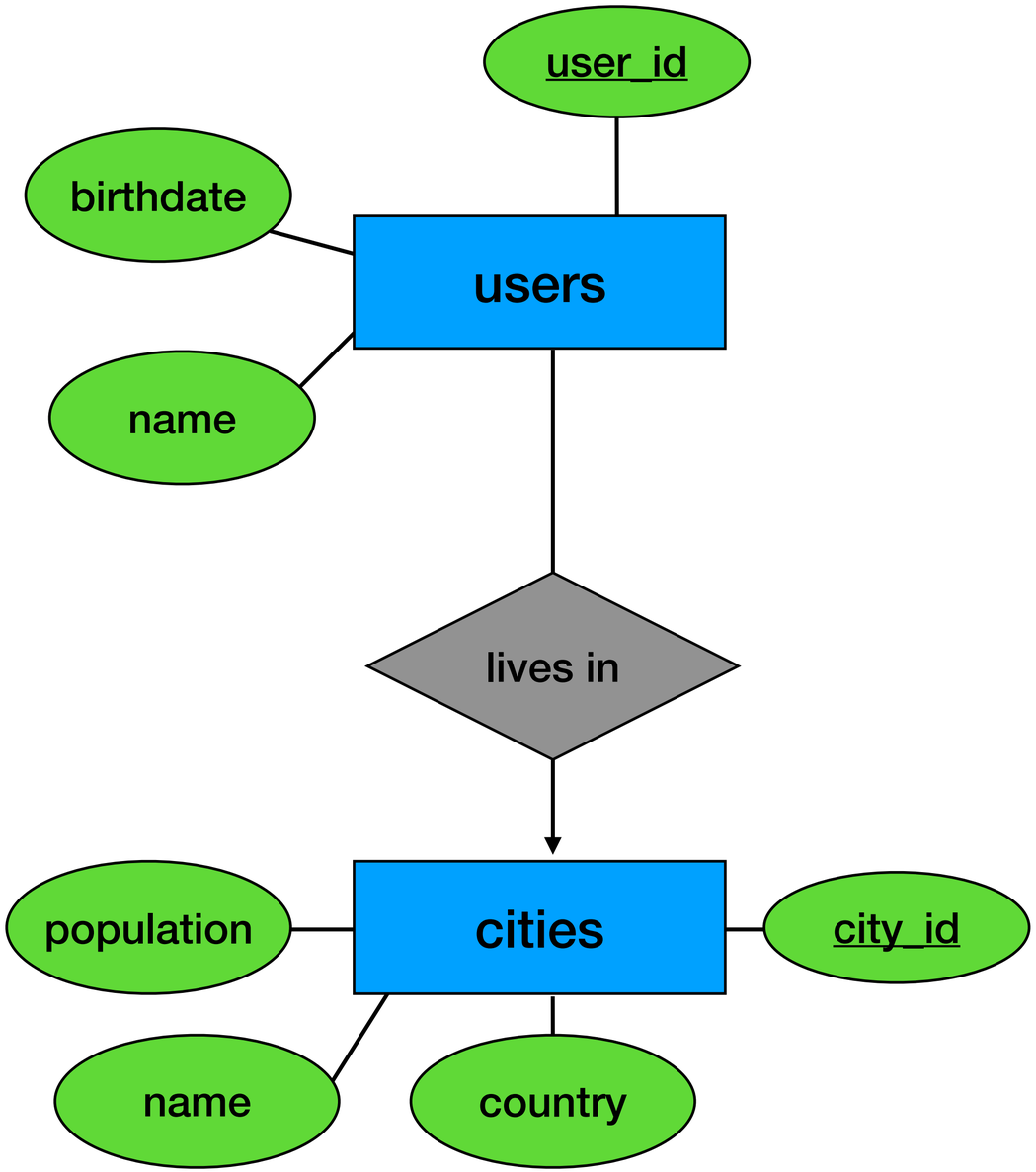

population
cities
city_id
name
country


user_id
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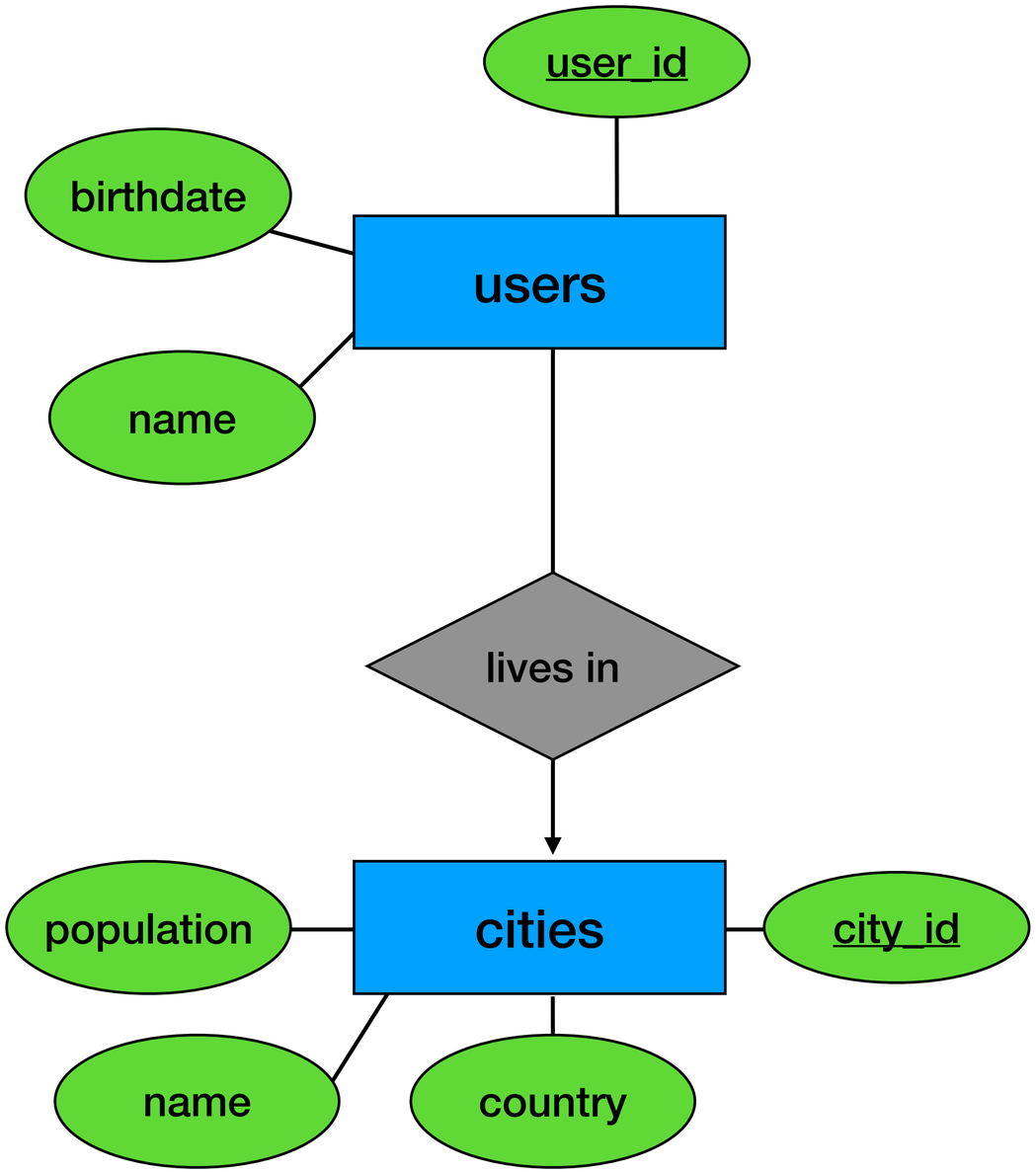
users
name
lives in
population
cities
city_id
name
country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city_id
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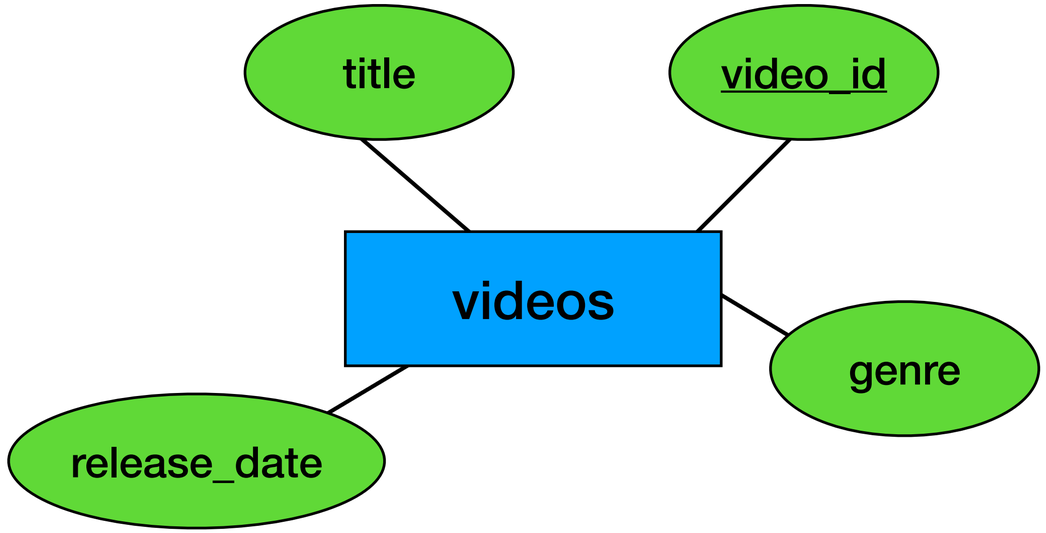
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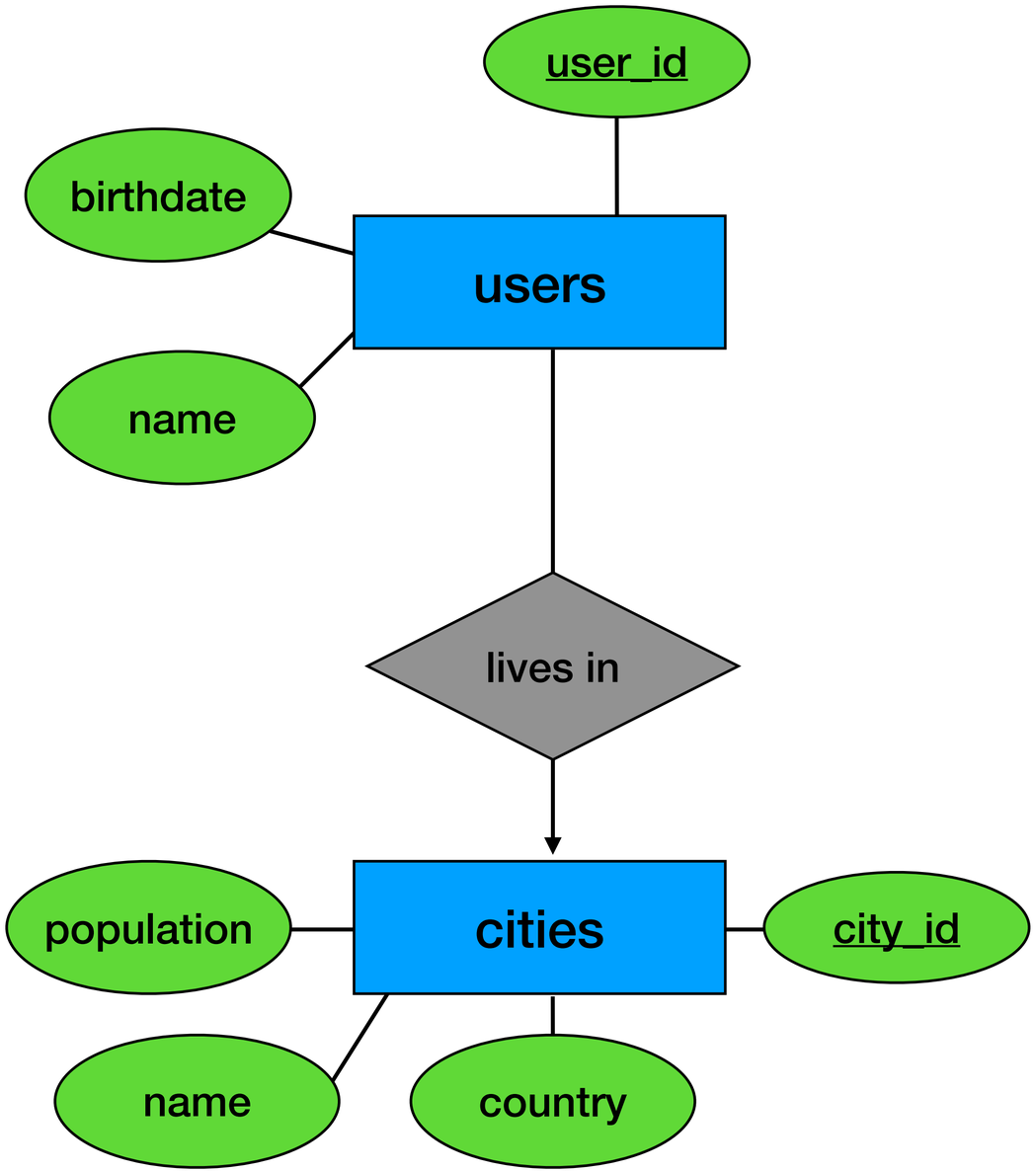
videos
genre
release_date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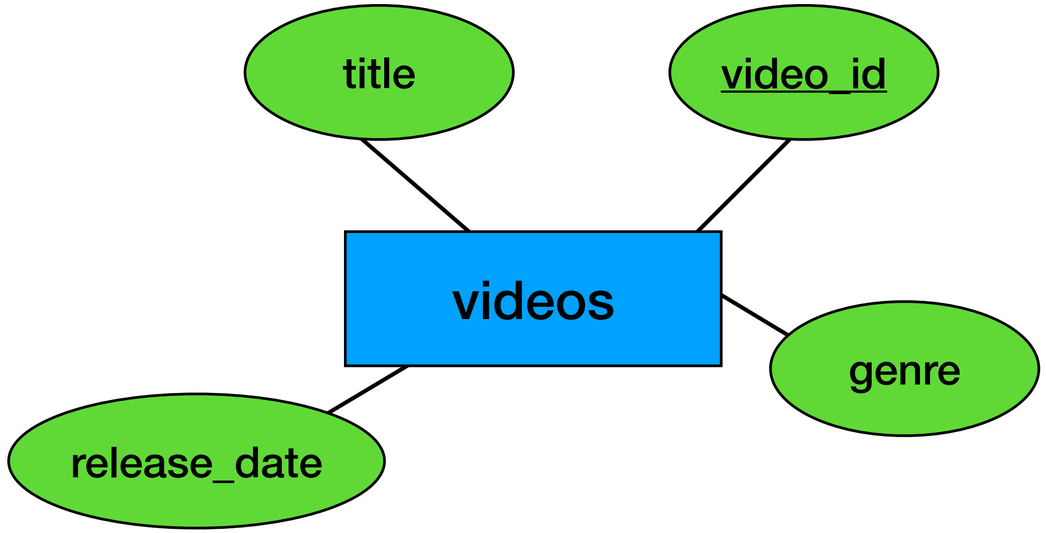
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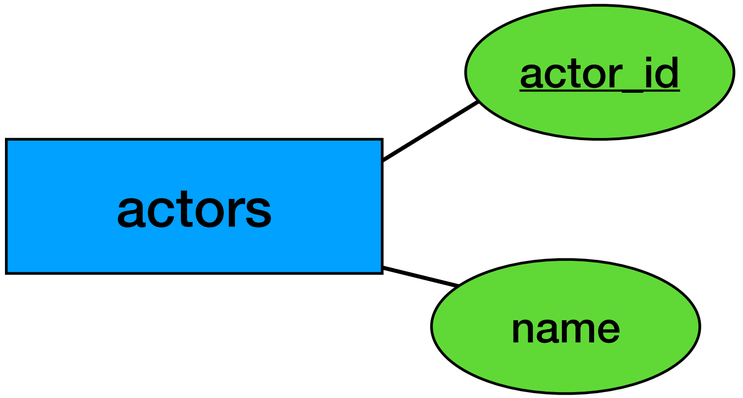
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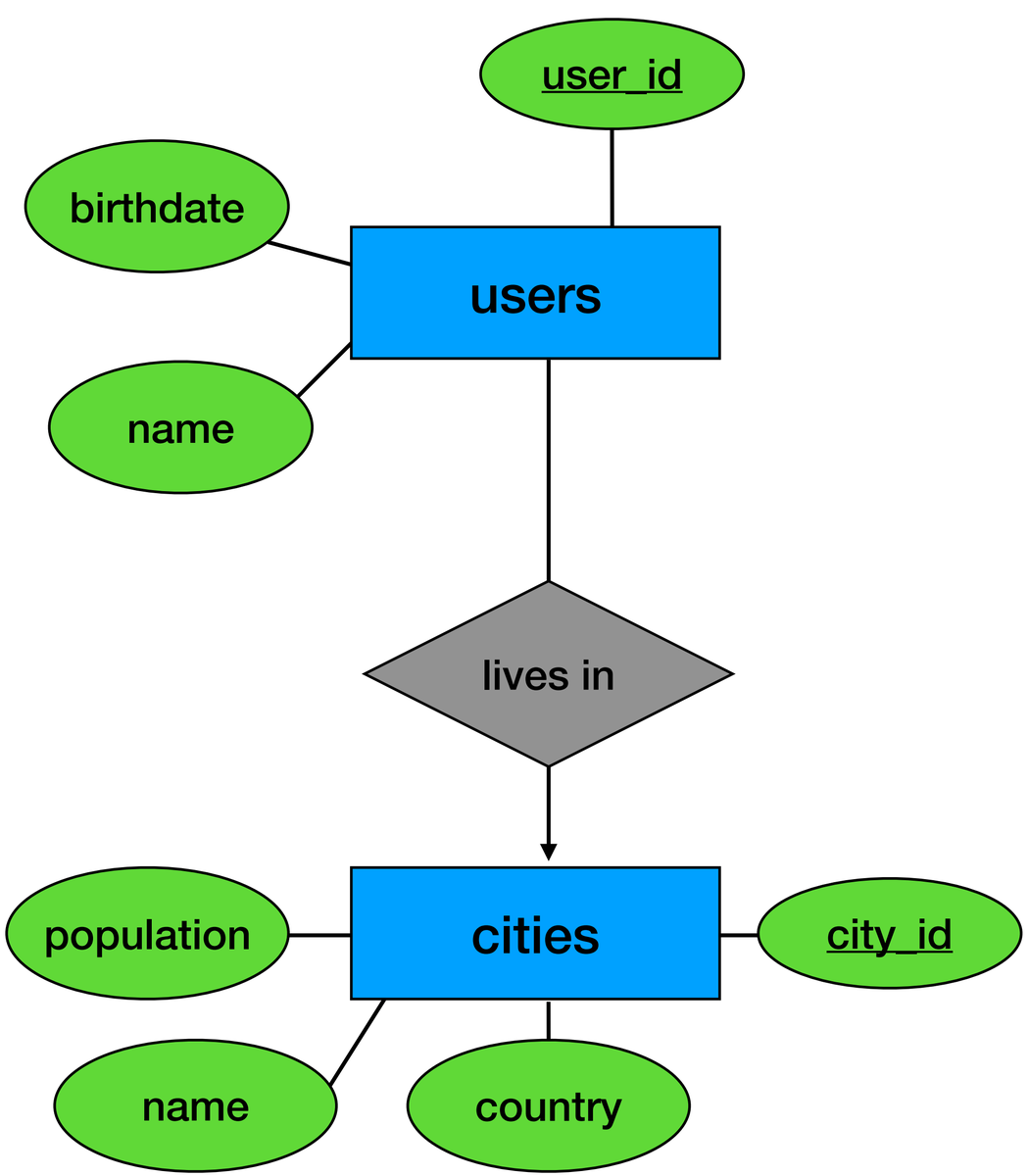
actors
name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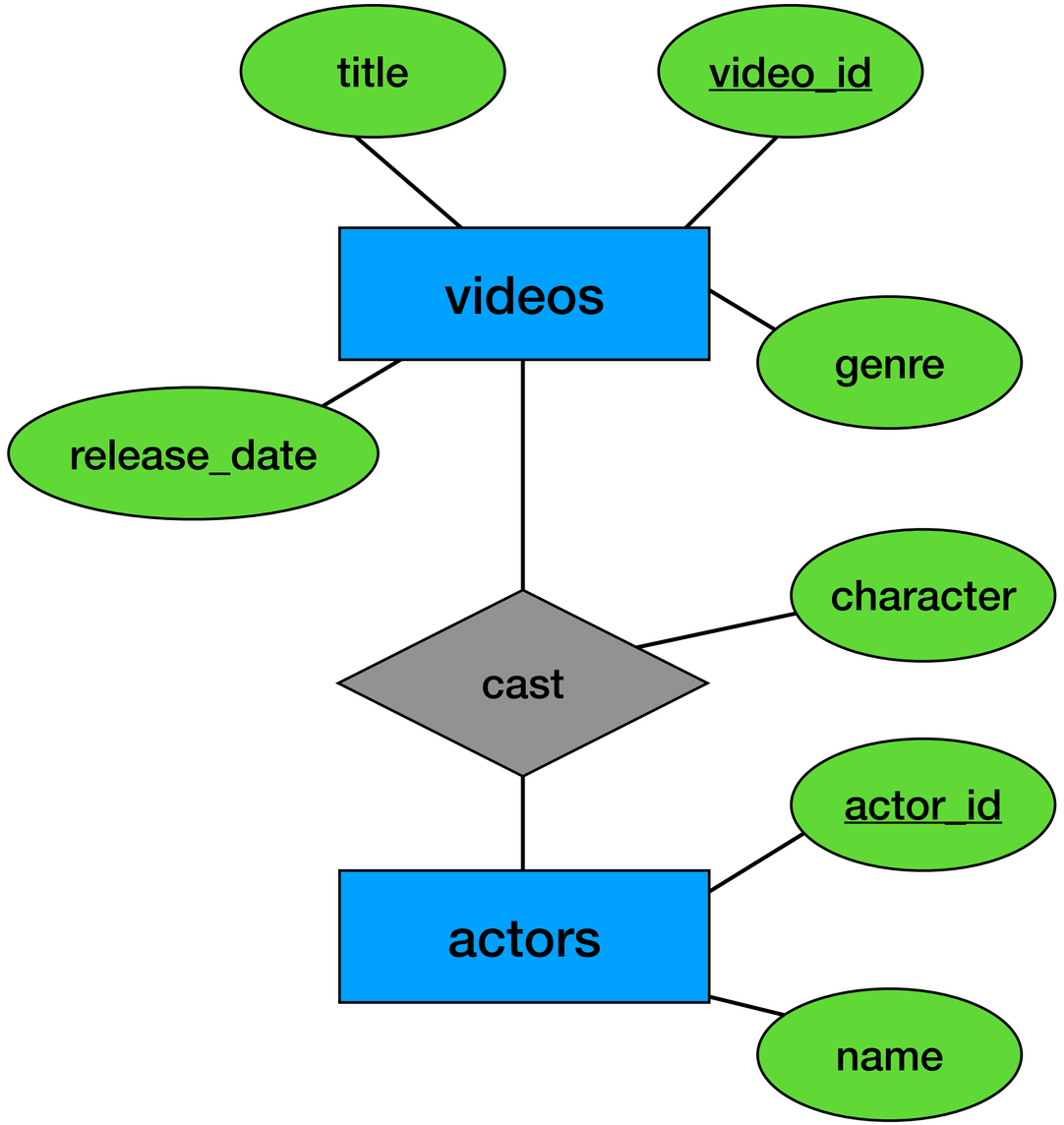
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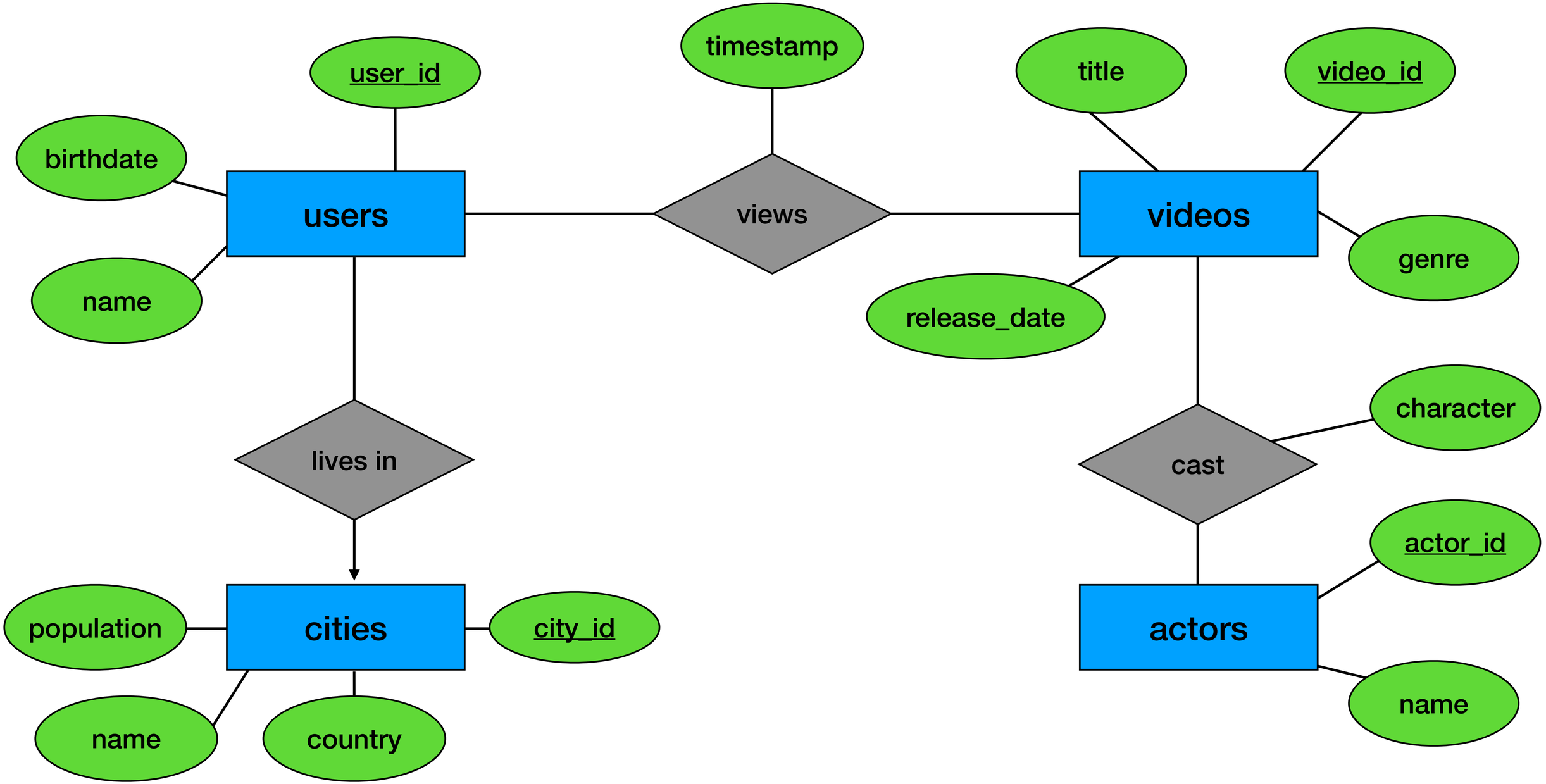
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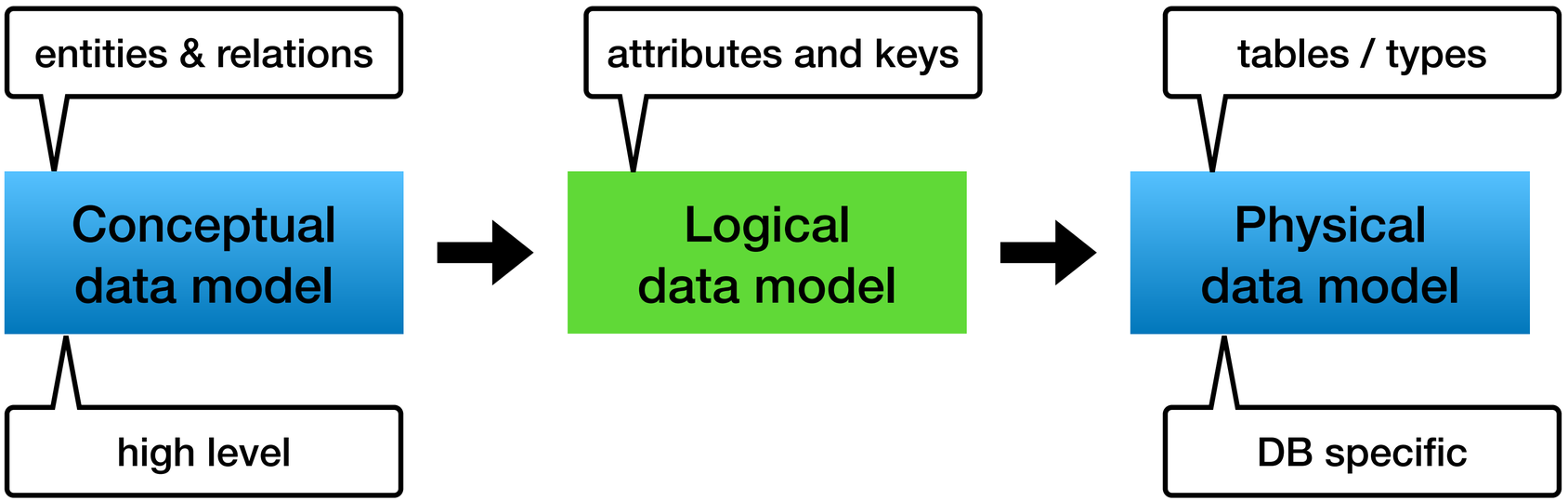
name
country

Relational Modeling - 10,000 foot view

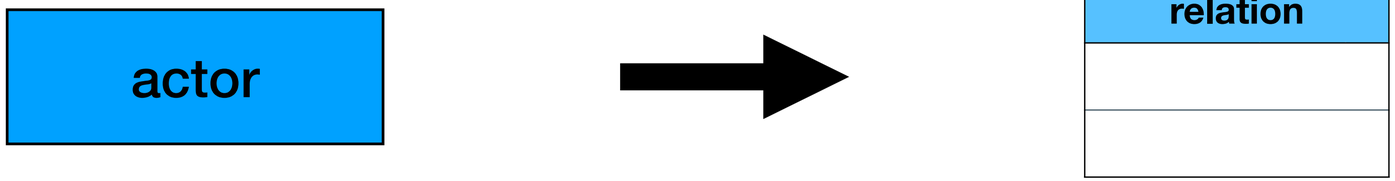


Logical data model

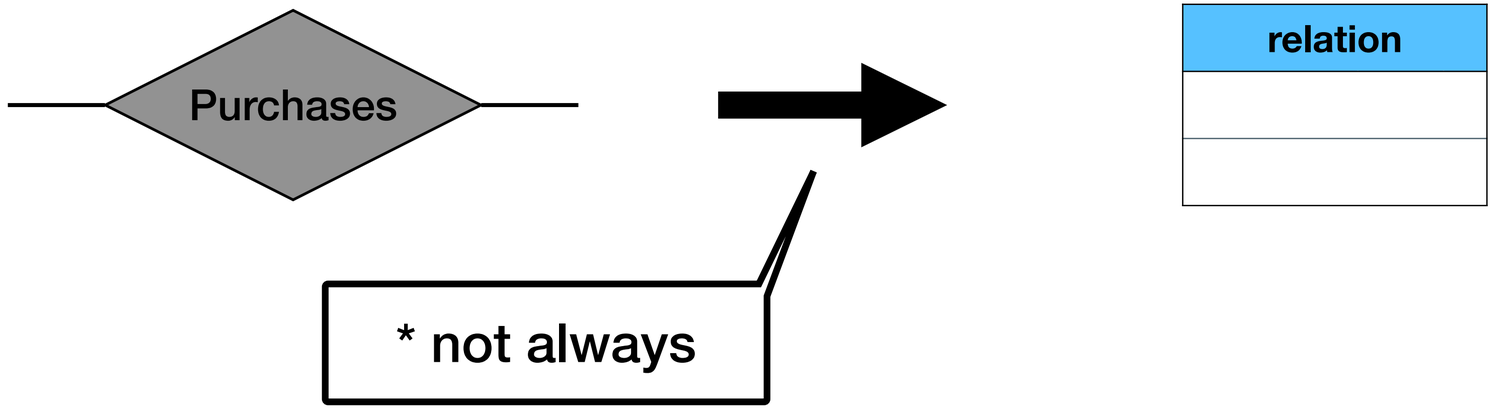
- From concept the “schema”
- Keys, foreign keys
- Data types are not yet defined

ER to Relational schema

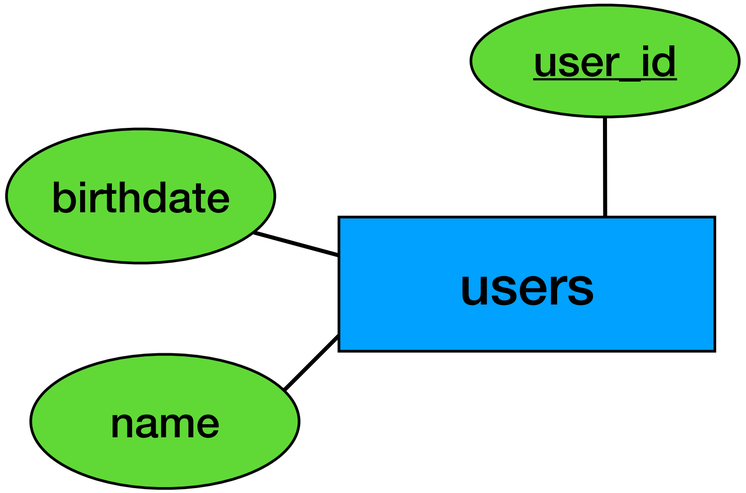
- Entities



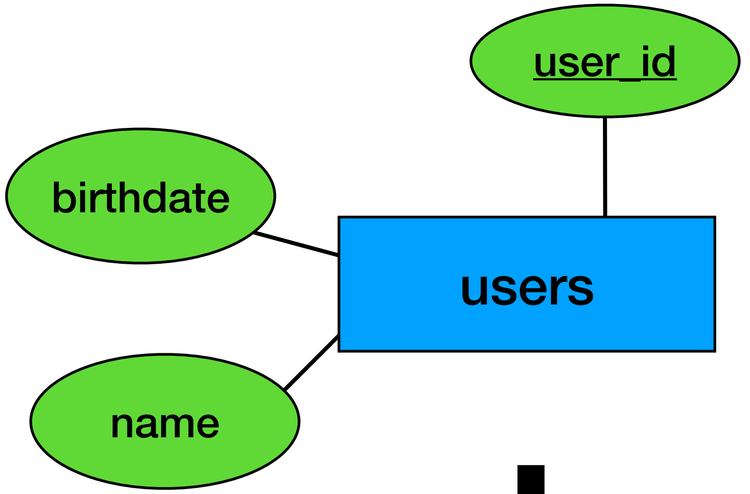
- Relations

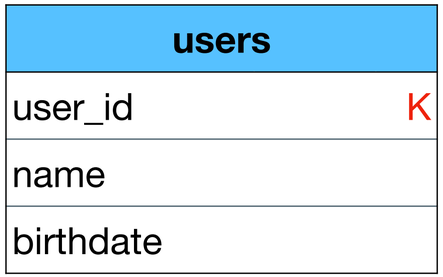


Entity to Relation

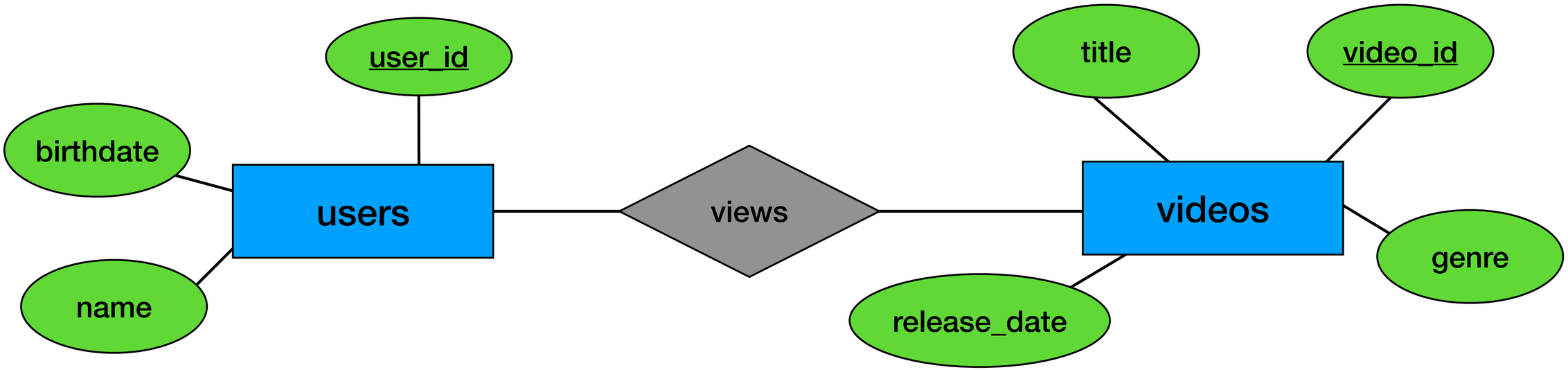


Entity to Relation

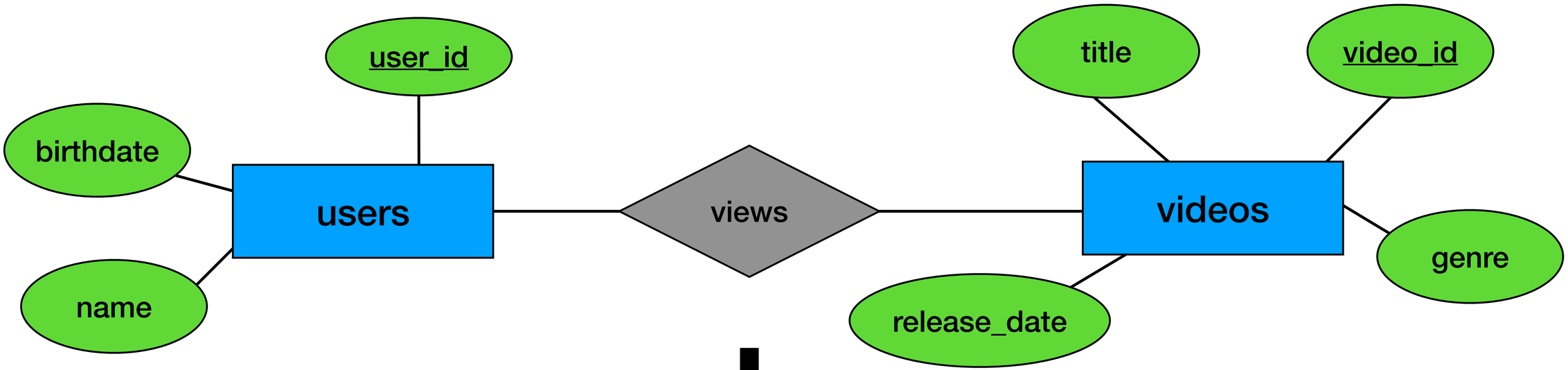




Relation to Relation (many-to-many)



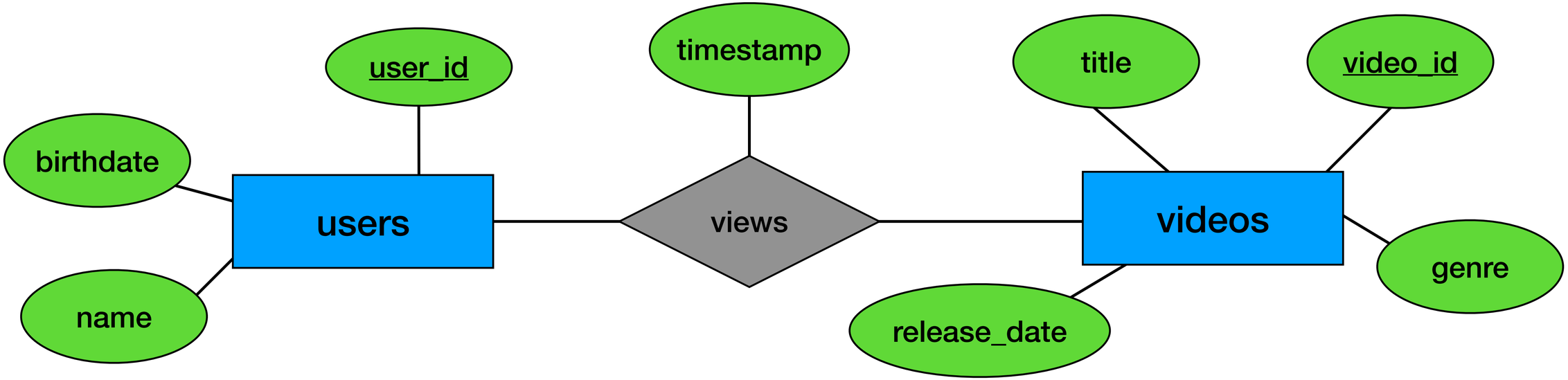
Relation to Relation (many-to-many)



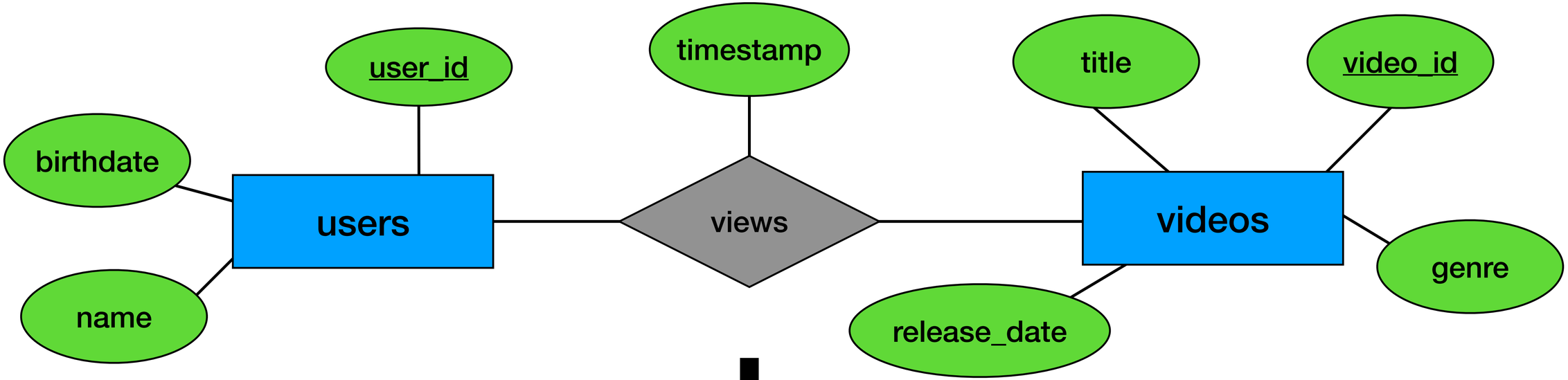
views	
user_id	K
video_id	K

Keys are derived from entities

Relation to Relation (+attributes)



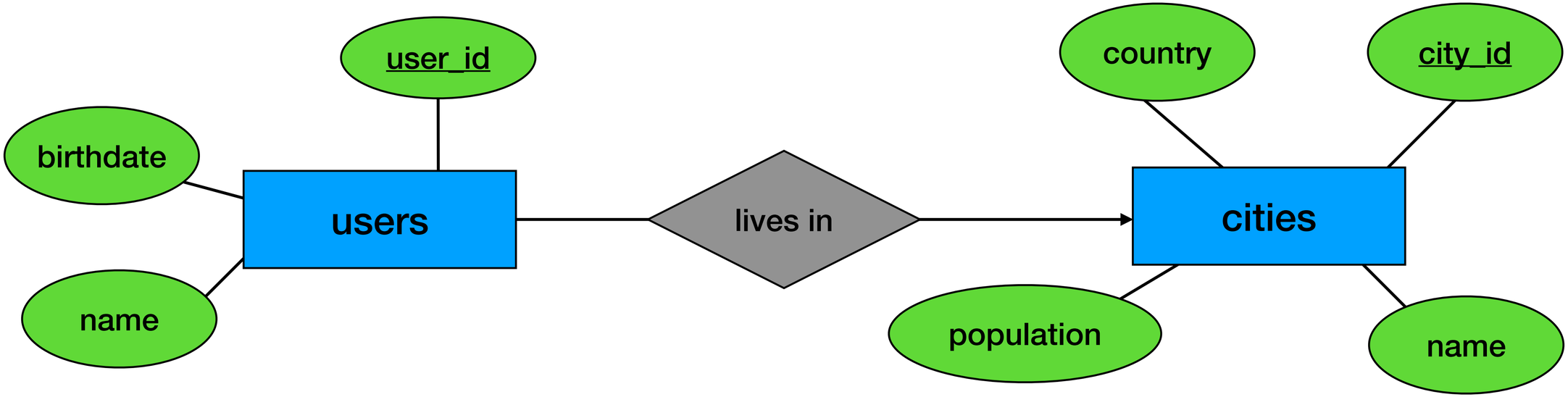
Relation to Relation (+attributes)



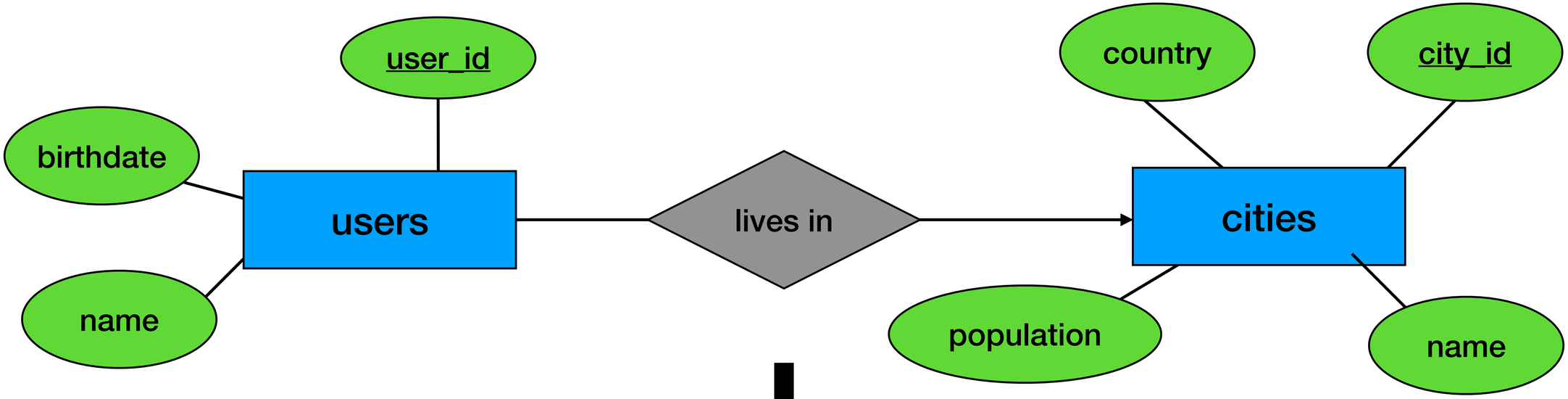
Additional attributes

views	
user_id	K
video_id	K
timestamp	

Relation to Relation (many-to-one)



Relation to Relation (many-to-one)

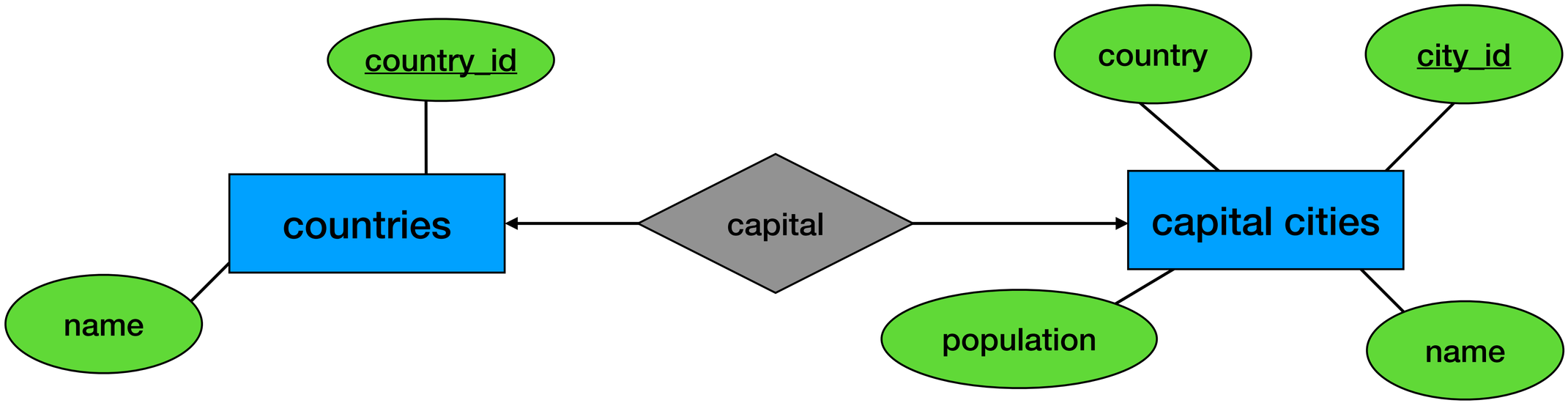


No additional table is required. We add to users the key(s) of cities

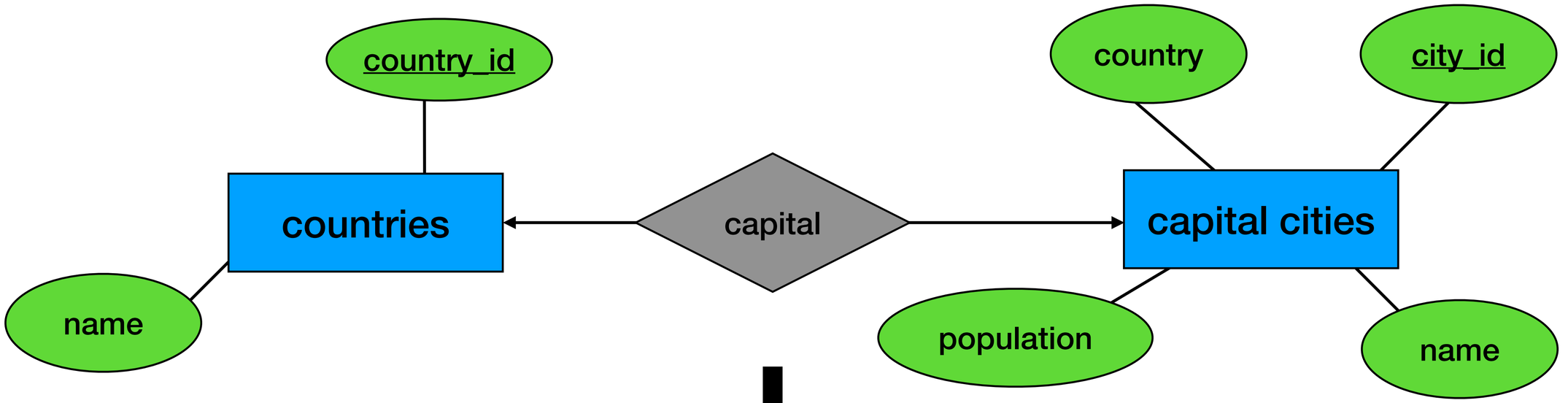
users	
user_id	K
name	
birthdate	
city_id	FK

Sometimes FKs are omitted and will be represented by arrows (see next slides)

Relation to Relation (one-to-one)



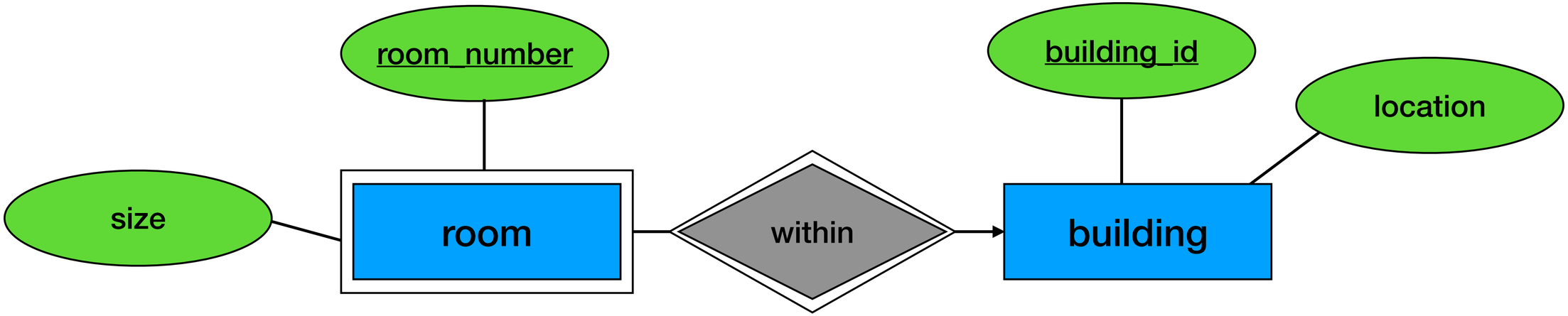
Relation to Relation (one-to-one)



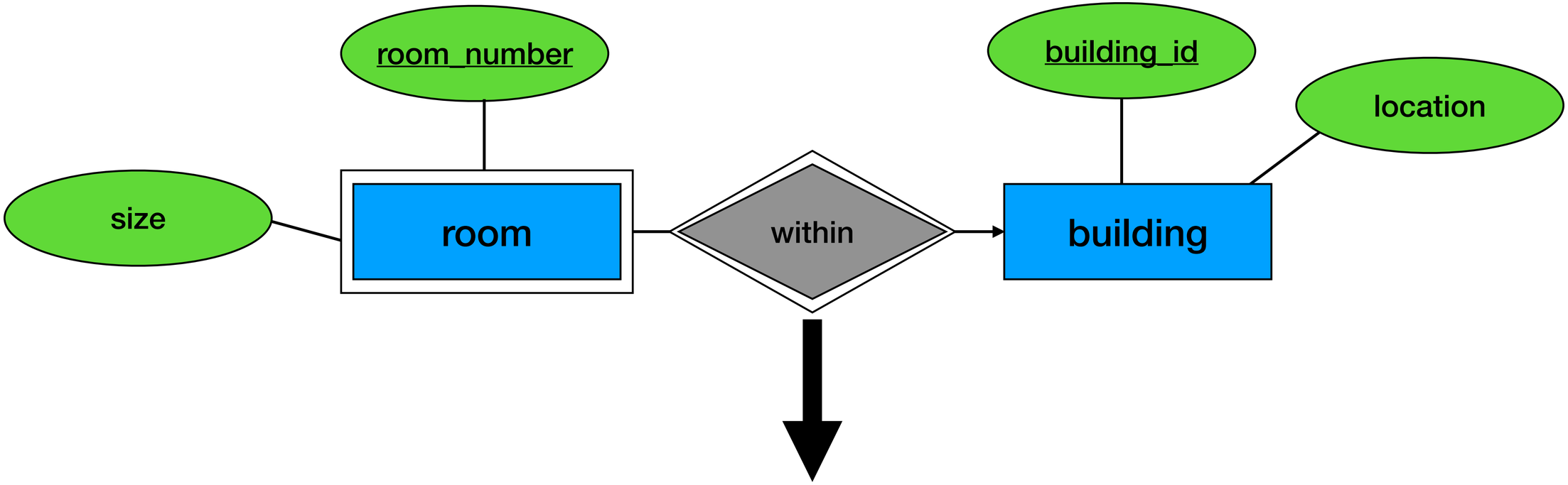
countries	
country_id	K
name	
city_id	FK, U

FK + Unique index

Weak Entity

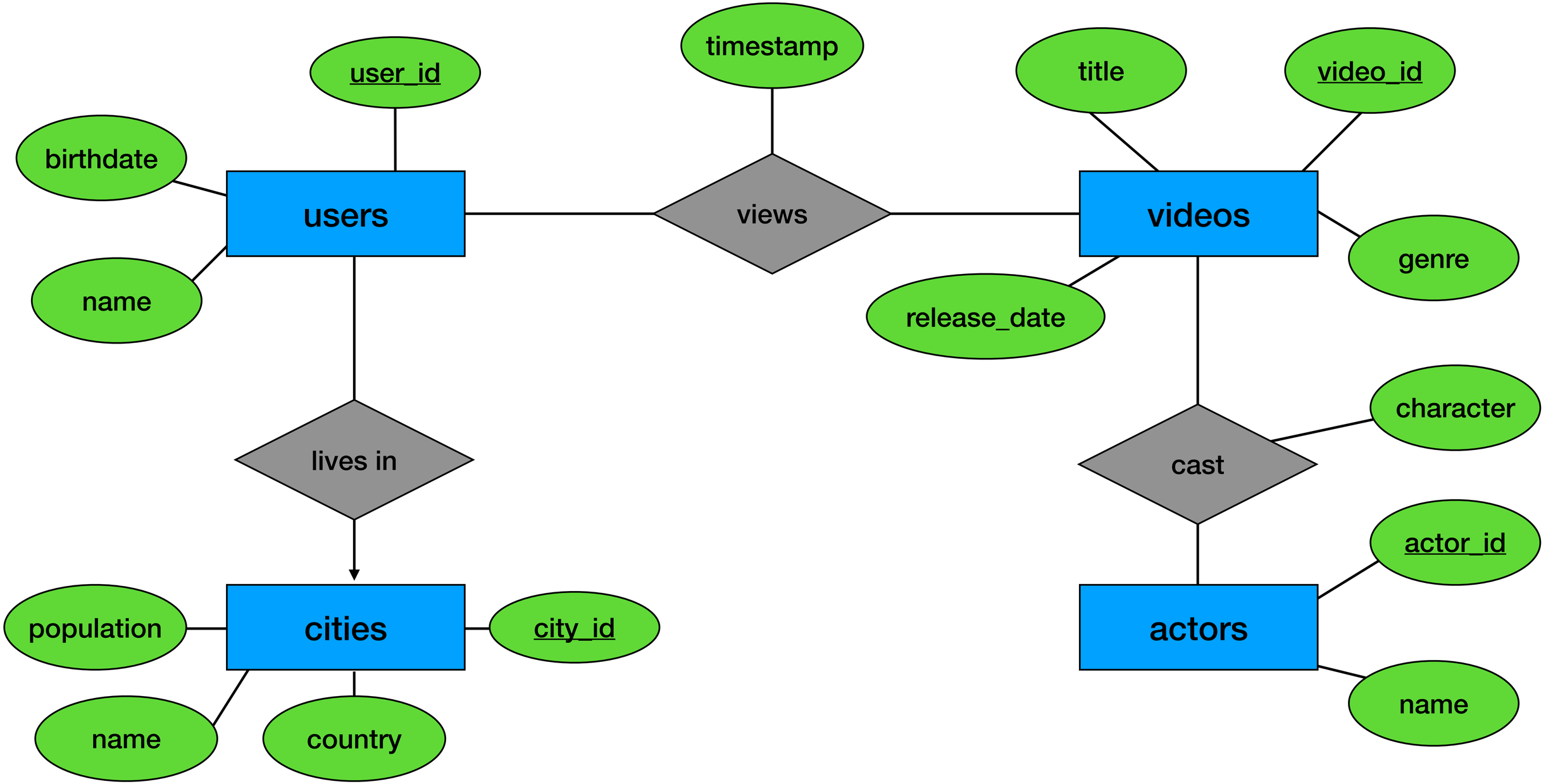

room_number
building_id
location
size
room
within
building

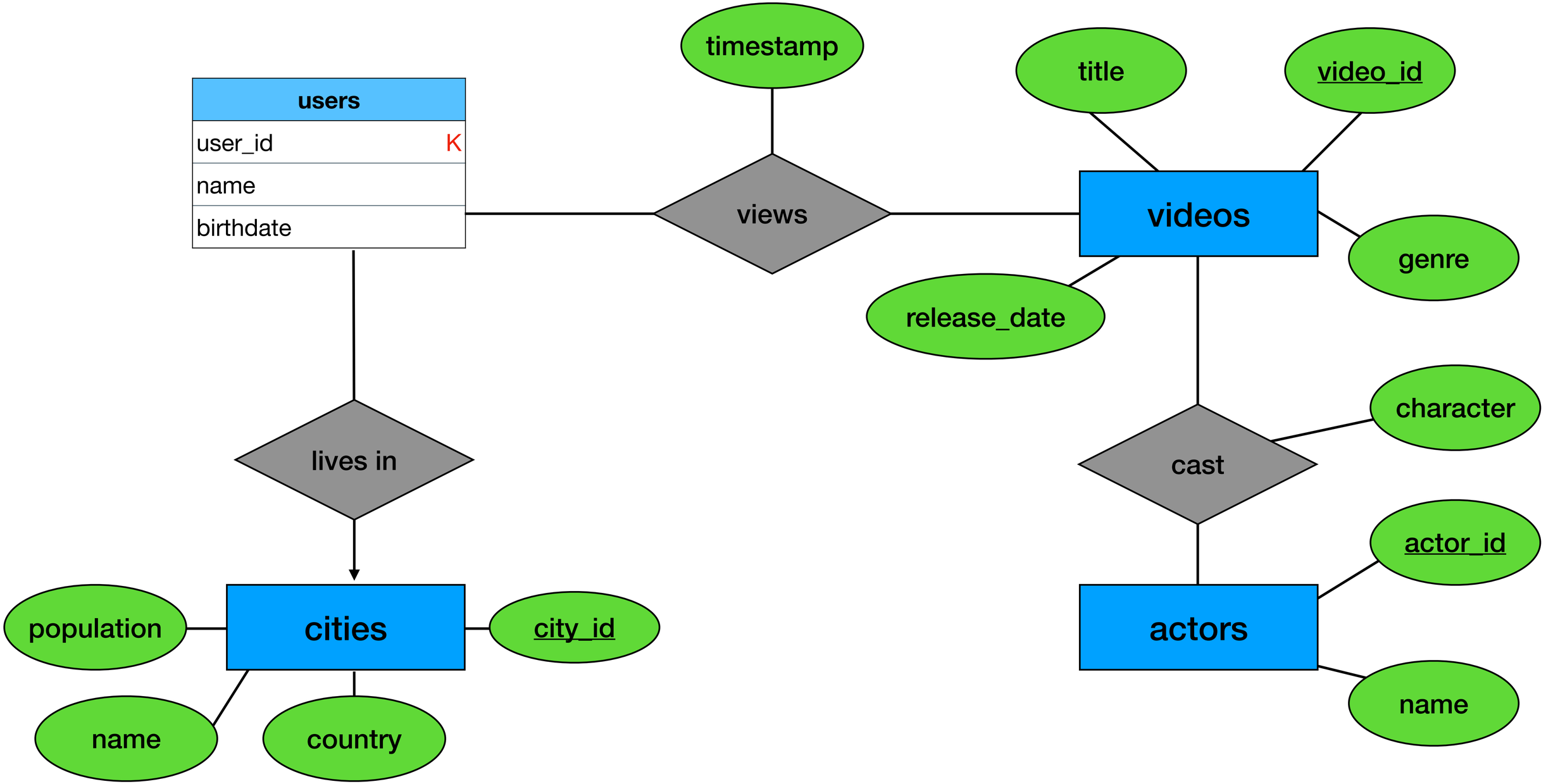
Weak Entity



room	
building_id	K
room_number	K
size	

Example


user_id
timestamp
title
video_id
birthdate
users
views
videos
genre
name
release_date
lives in
character
cast
actor_id
population
cities
city_id
actors
name
name
country


users
user_id
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name
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lives in
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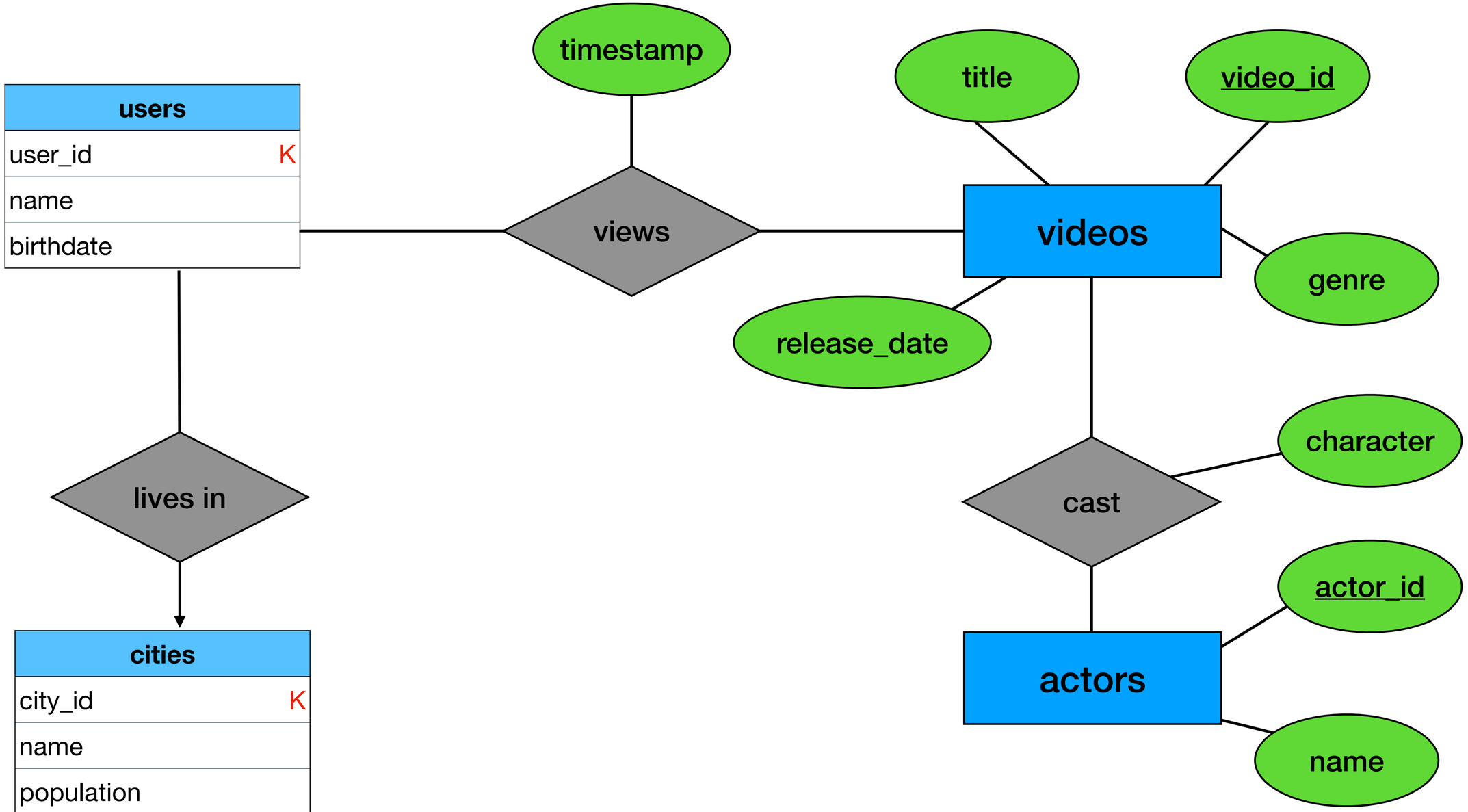
population
city_id
name
country
actors
actor_id
name


users
user_id
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name
birthdate
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title
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cities
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population
country
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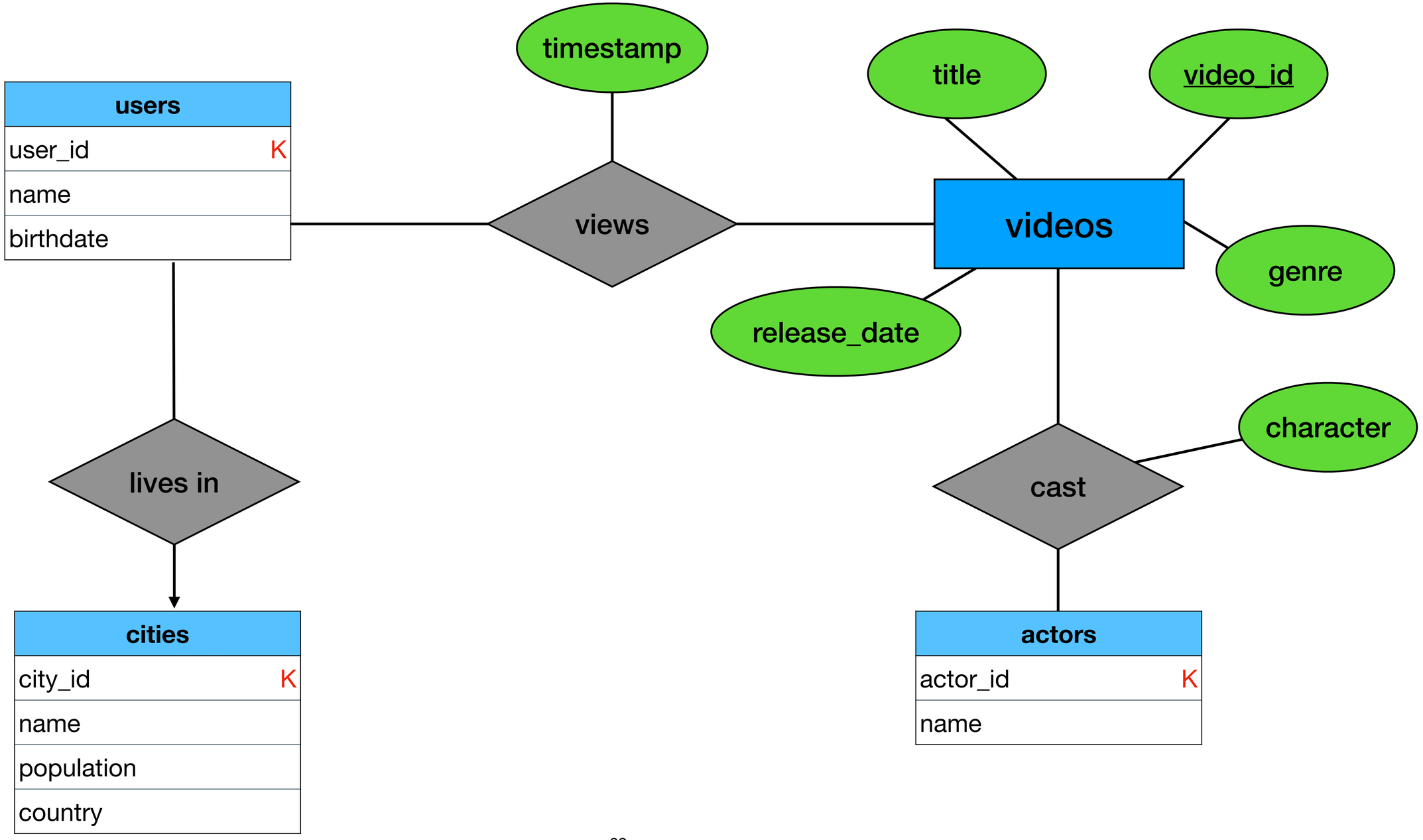
actor_id
actors
name


timestamp
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birthdate
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genre
release_date
character
lives in
cast
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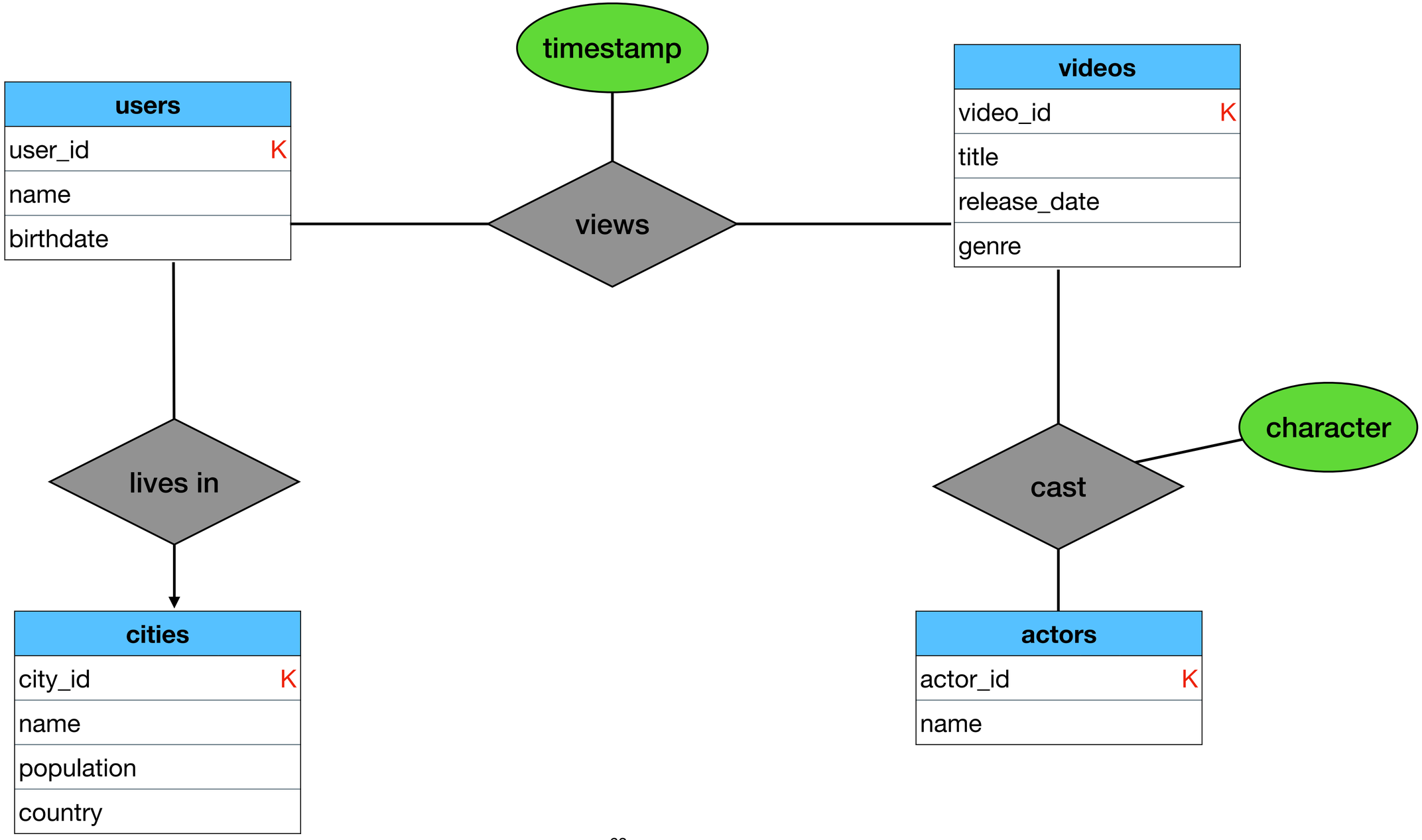
city_id
K
name
population
country
actors
actor_id
K
name


timestamp
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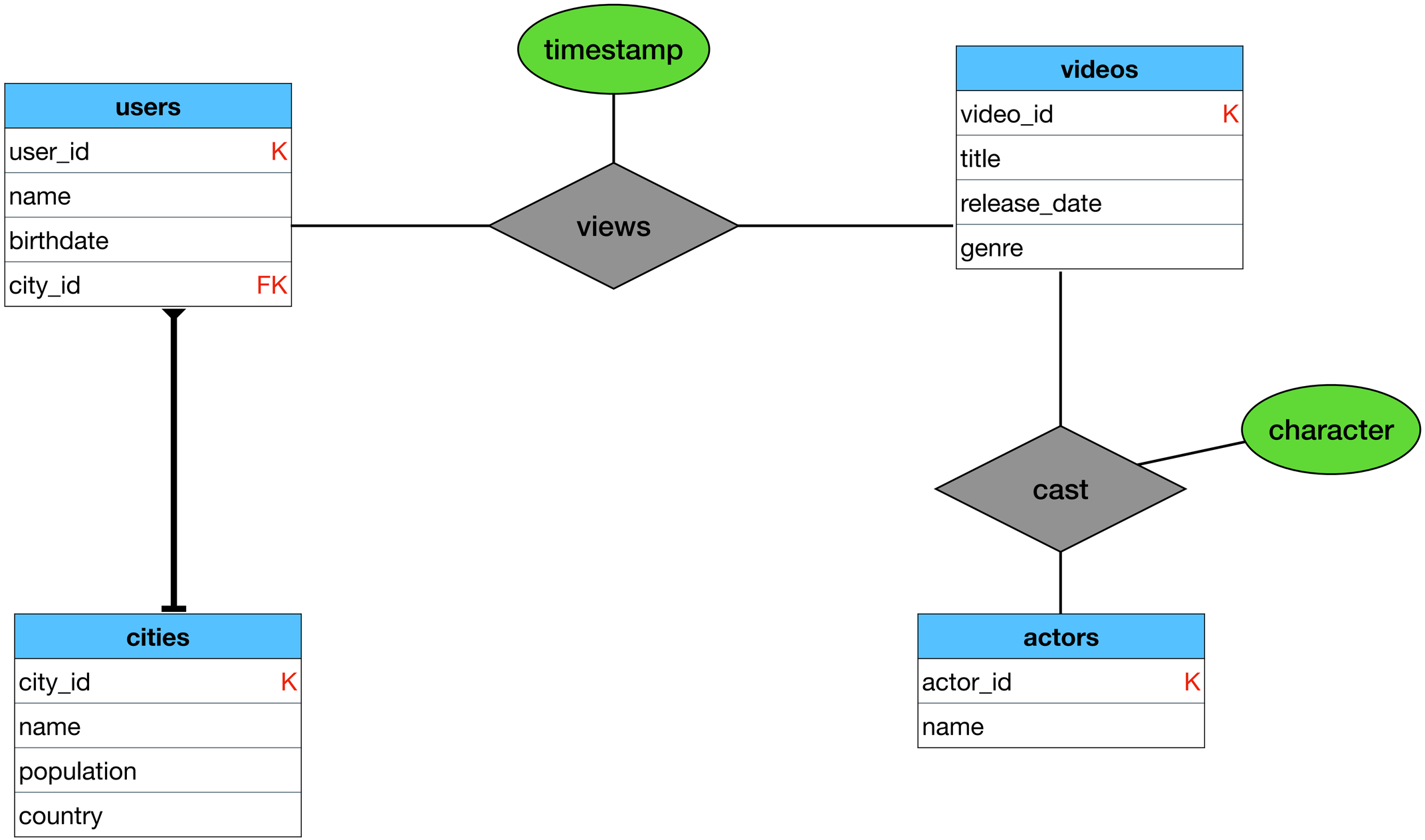
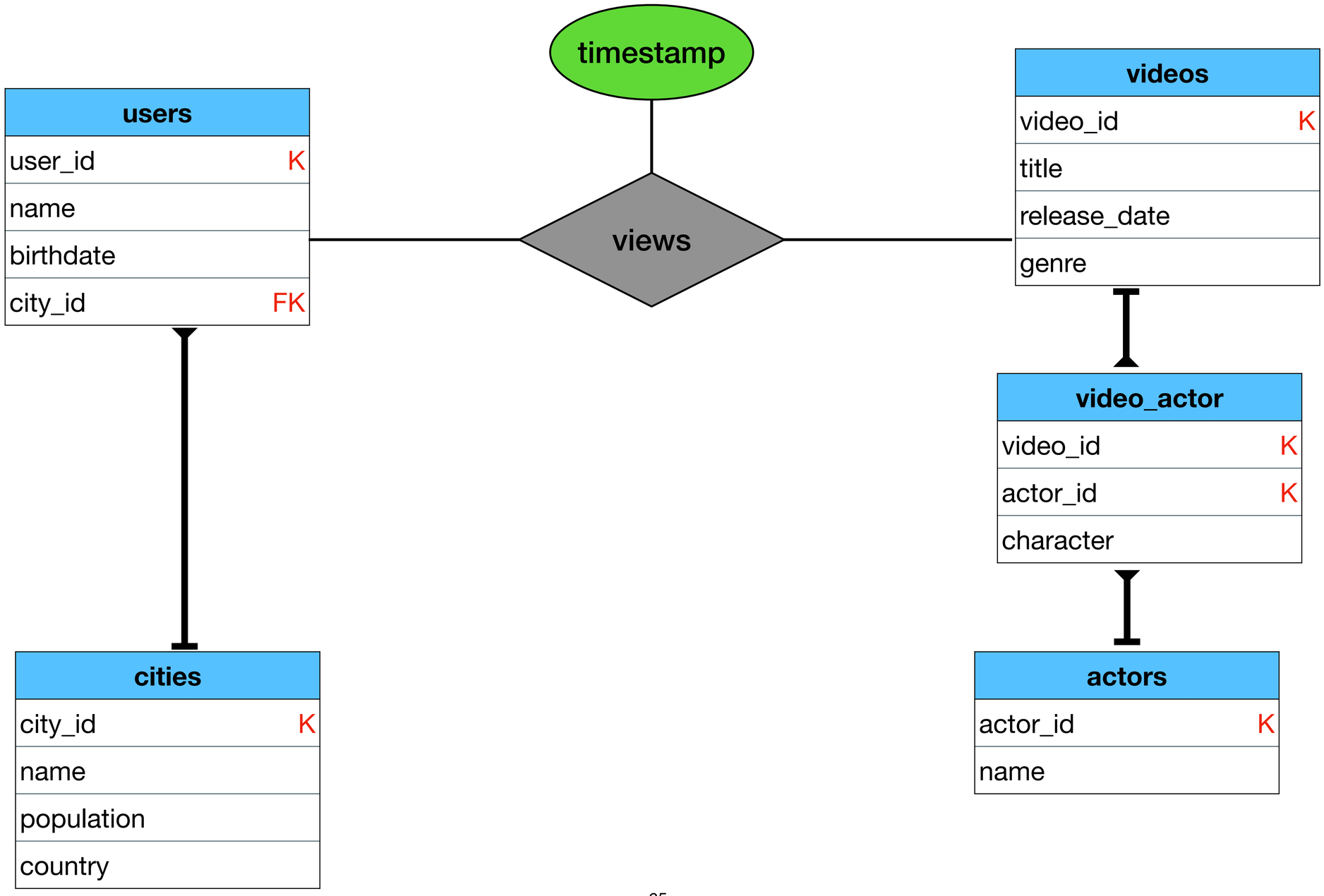
user_id K
name
birthdate
views
videos
video_id K
title
release_date
genre
lives in
character
cast
cities
city_id K
name
population
country
actors
actor_id K
name


timestamp
users
user_id K
name
birthdate
city_id FK
views
videos
video_id K
title
release_date
genre
character
cast
cities
city_id K
name
population
country
actors
actor_id K
name


timestamp
users
user_id K
name
birthdate
city_id FK
views
videos
video_id K
title
release_date
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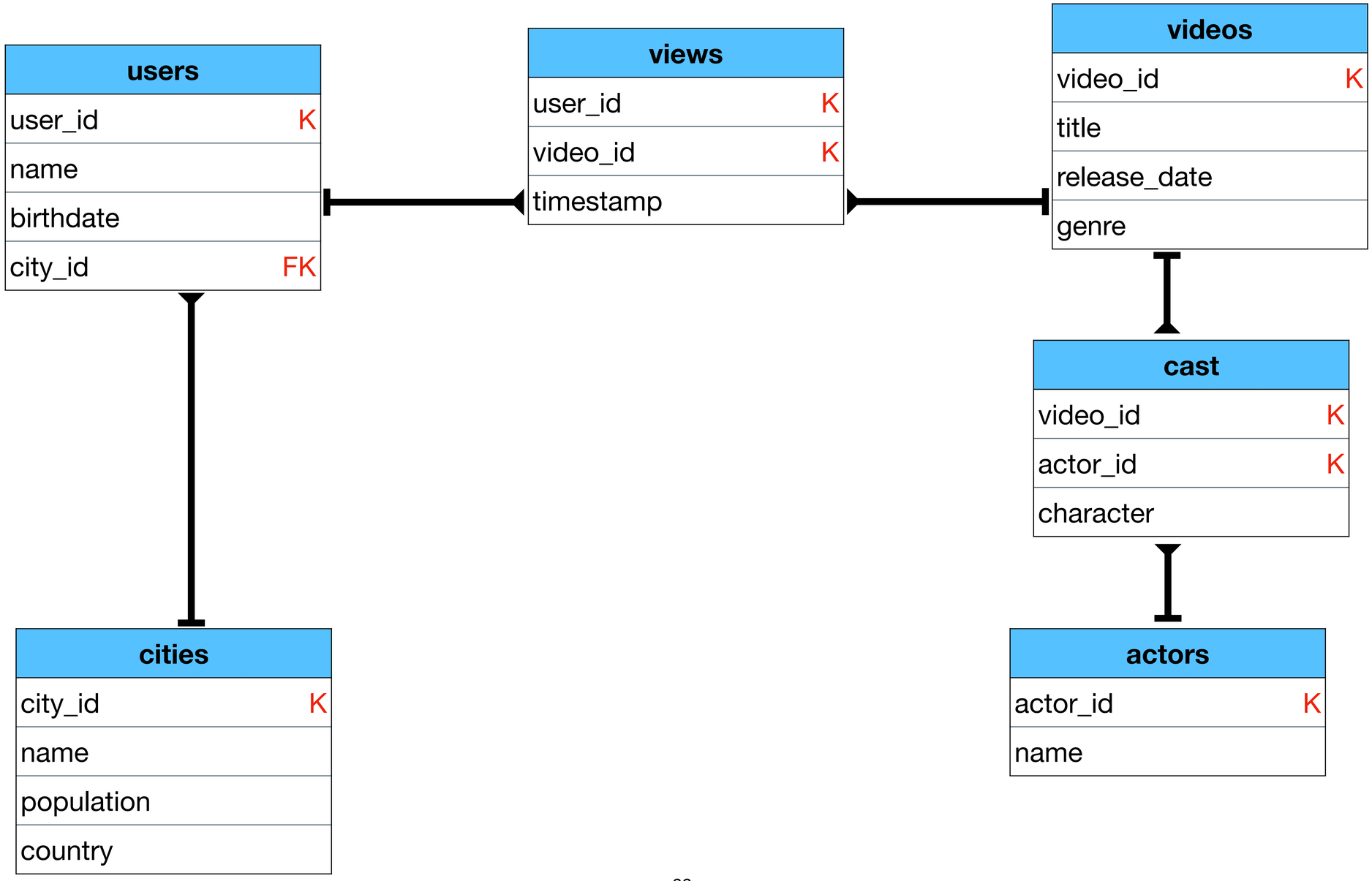
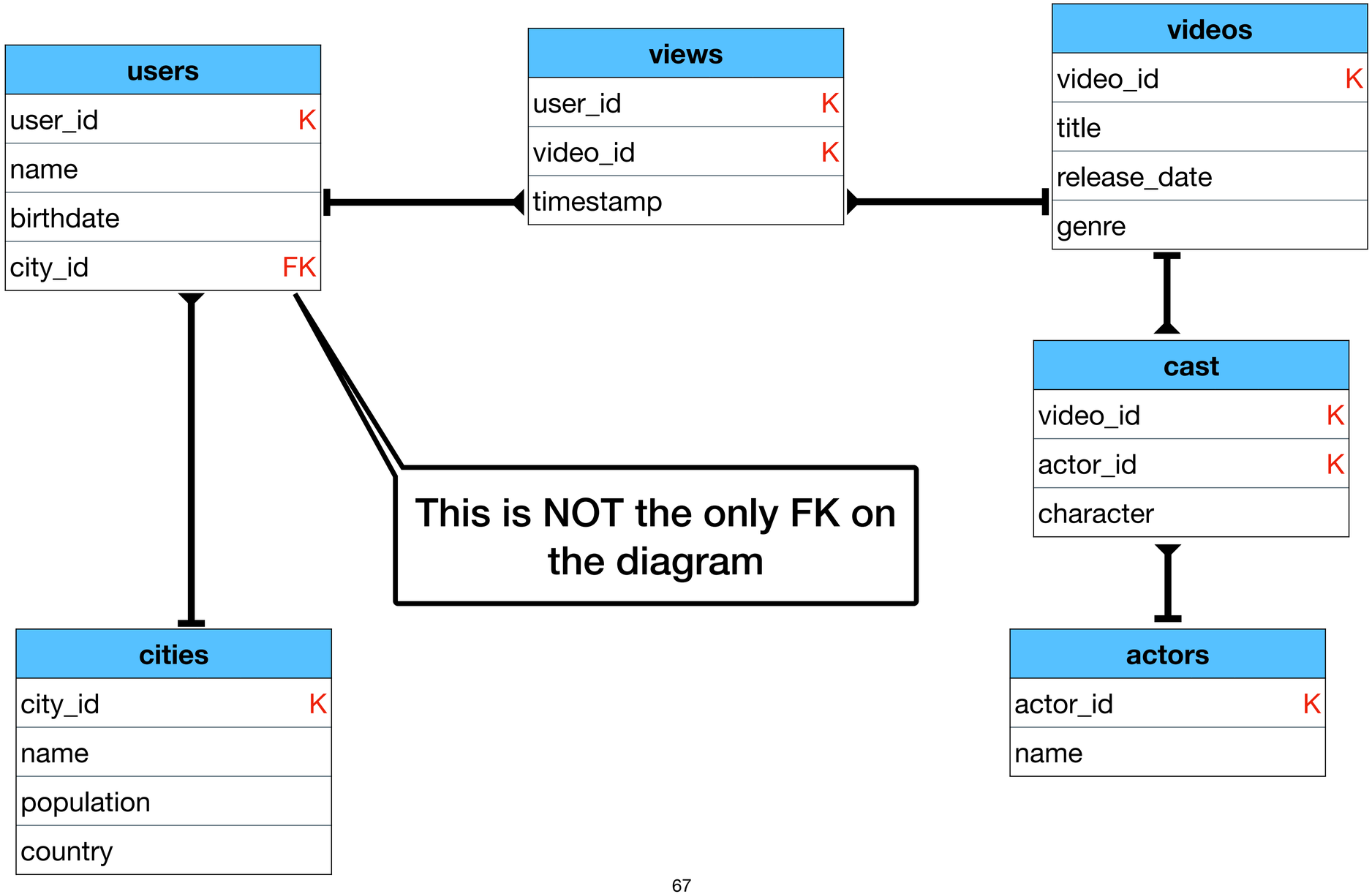
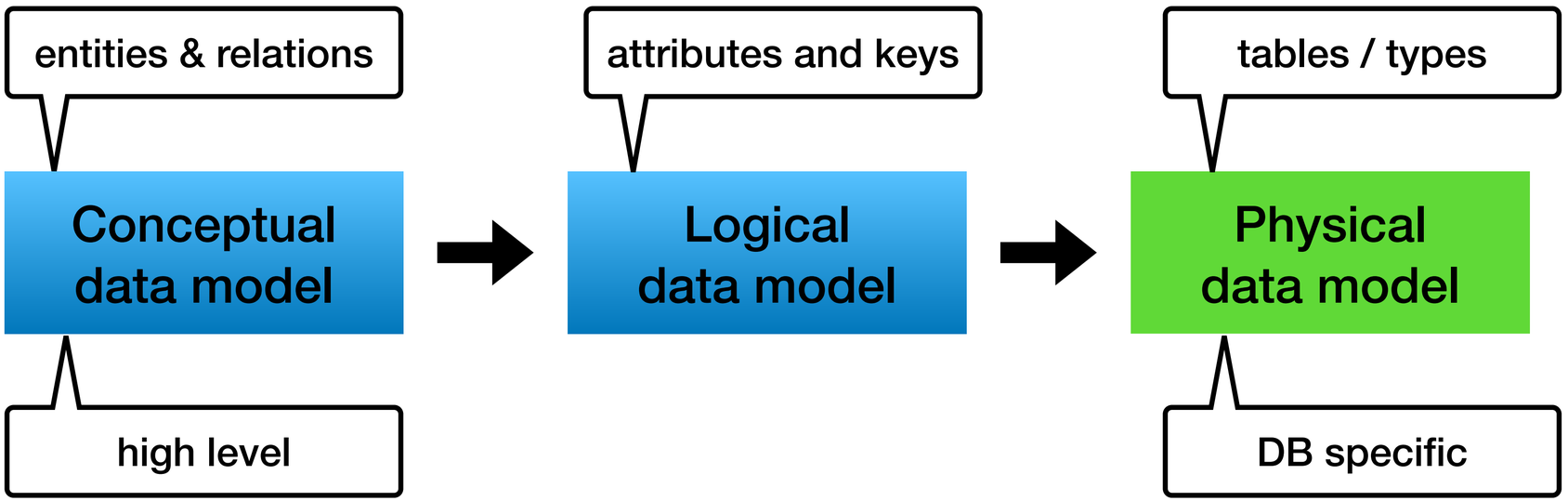
video_actor
video_id K
actor_id K
character
cities
city_id K
name
population
country
actors
actor_id K
name


users
user_id K
name
birthdate
city_id FK
views
user_id K
video_id K
timestamp
videos
video_id K
title
release_date
genre
cast
video_id K
actor_id K
character
cities
city_id K
name
population
country
actors
actor_id K
name


users
user_id K
name
birthdate
city_id FK
views
user_id K
video_id K
timestamp
videos
video_id K
title
release_date
genre
cast
video_id K
actor_id K
character
actors
actor_id K
name
cities
city_id K
name
population
country
This is NOT the only FK on the diagram

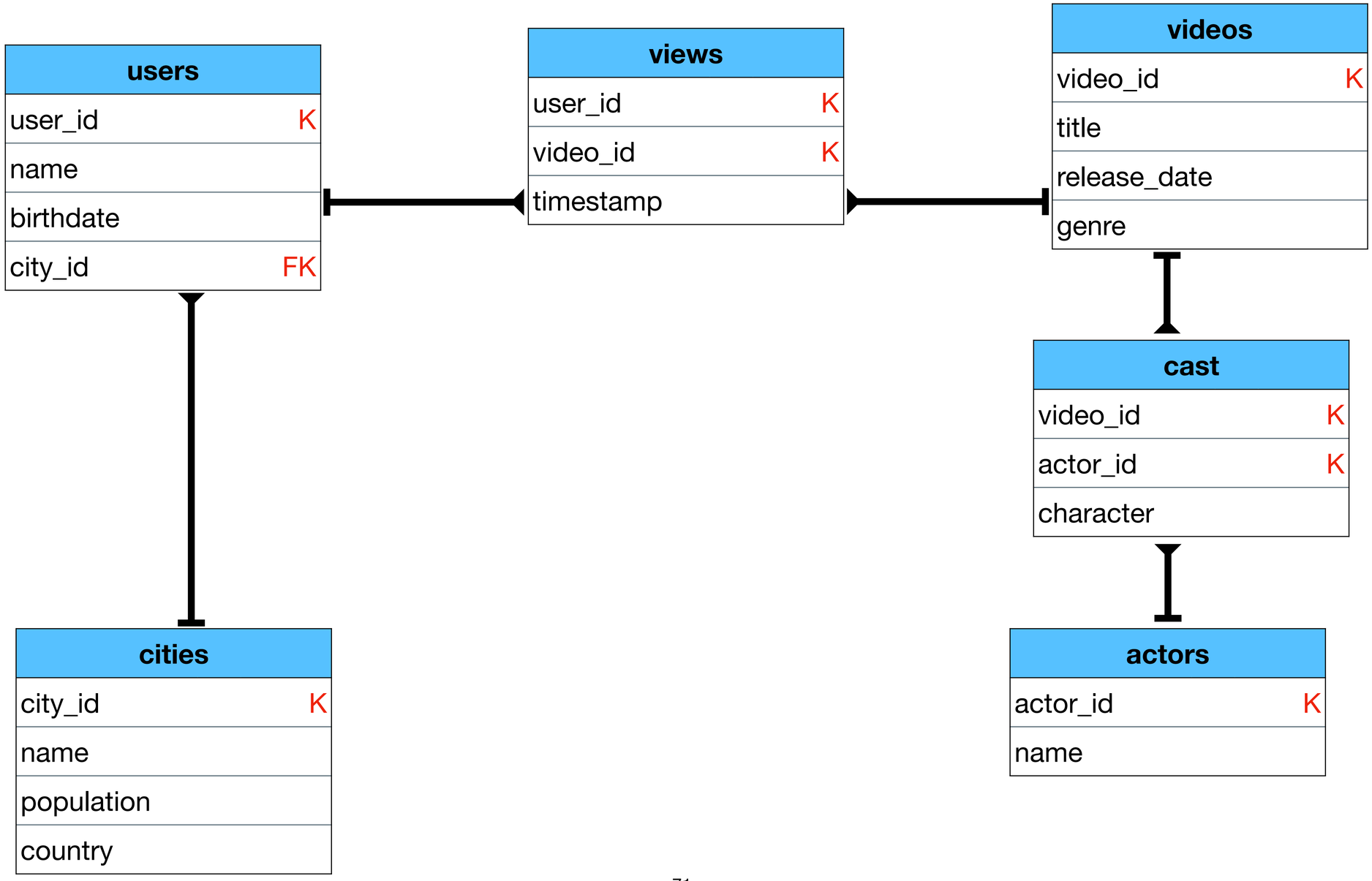
Relational Modeling - 10,000 foot view

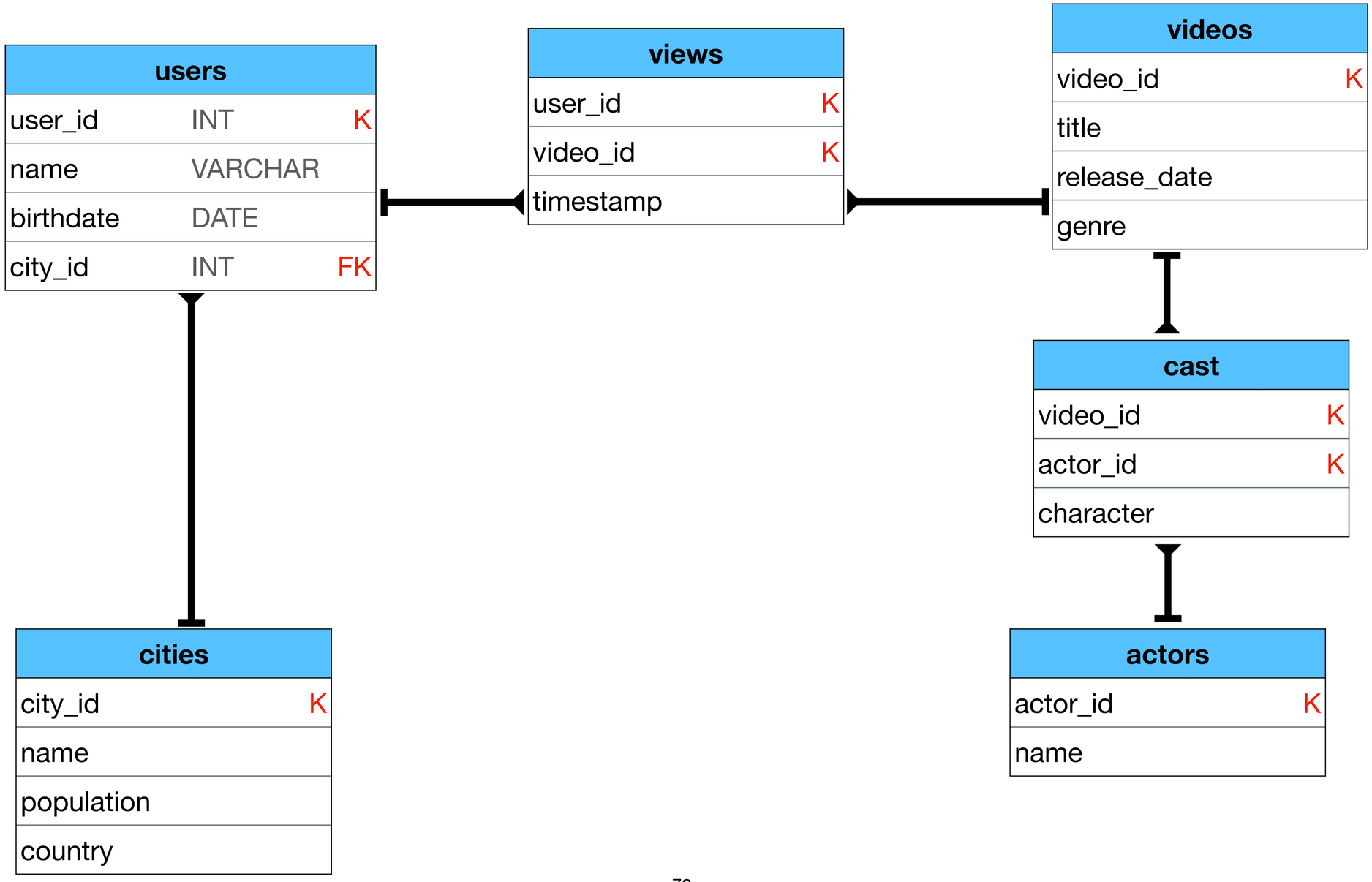


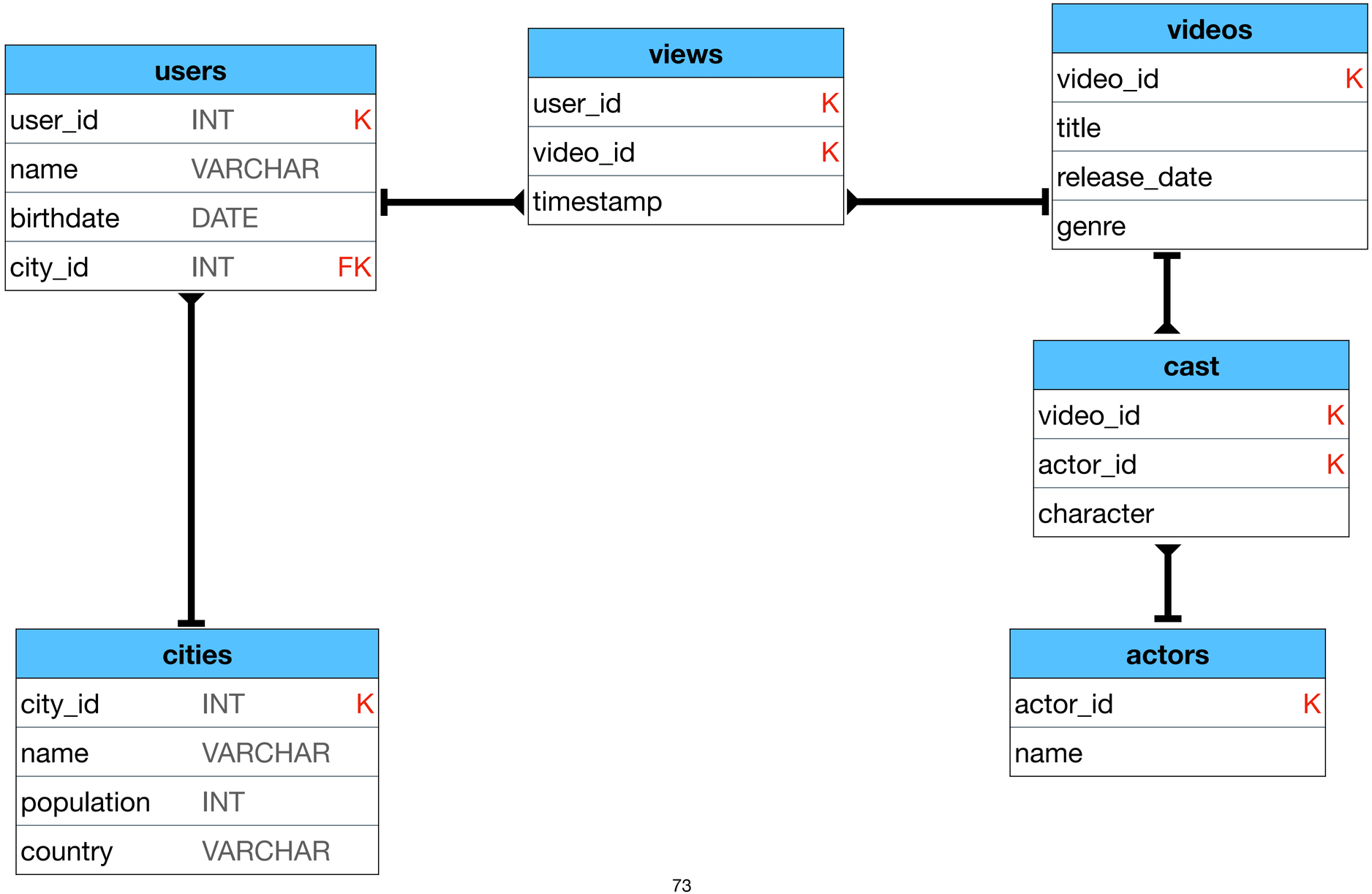
Physical data model

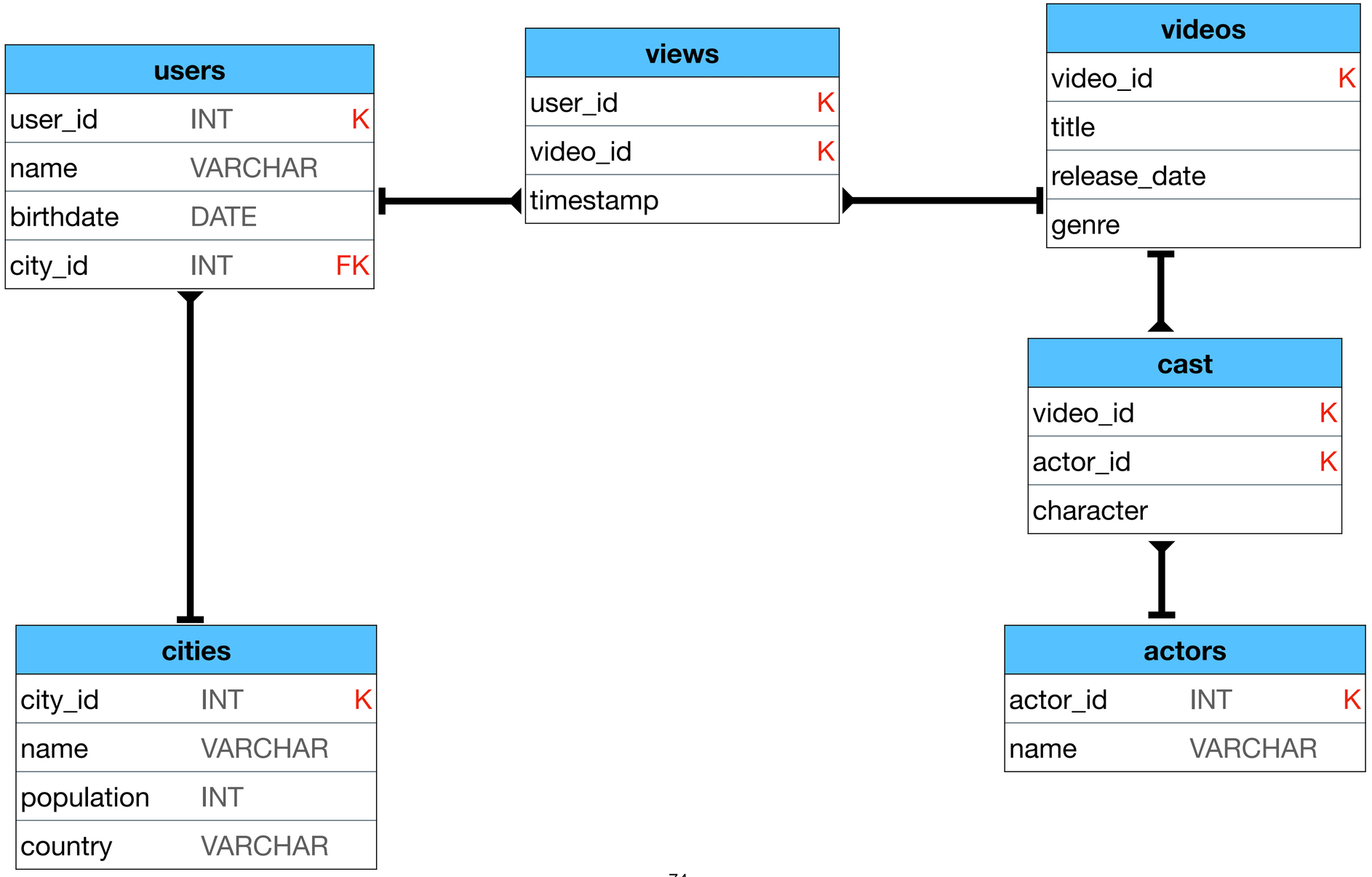
- Finalize the schema
- Add types
- Generate create table statements

Example


users
user_id K
name
birthdate
city_id FK
views
user_id K
video_id K
timestamp
videos
video_id K
title
release_date
genre
cast
video_id K
actor_id K
character
cities
city_id K
name
population
country
actors
actor_id K
name


users
user_id INT K
name VARCHAR
birthdate DATE
city_id INT FK
views
user_id K
video_id K
timestamp
videos
video_id K
title
release_date
genre
cast
video_id K
actor_id K
character
cities
city_id K
name
population
country
actors
actor_id K
name


users
user_id INT K
name VARCHAR
birthdate DATE
city_id INT FK
views
user_id K
video_id K
timestamp
videos
video_id K
title
release_date
genre
cast
video_id K
actor_id K
character
cities
city_id INT K
name VARCHAR
population INT
country VARCHAR
actors
actor_id K
name


users
user_id INT K
name VARCHAR
birthdate DATE
city_id INT FK
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user_id K
video_id K
timestamp
videos
video_id K
title
release_date
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cast
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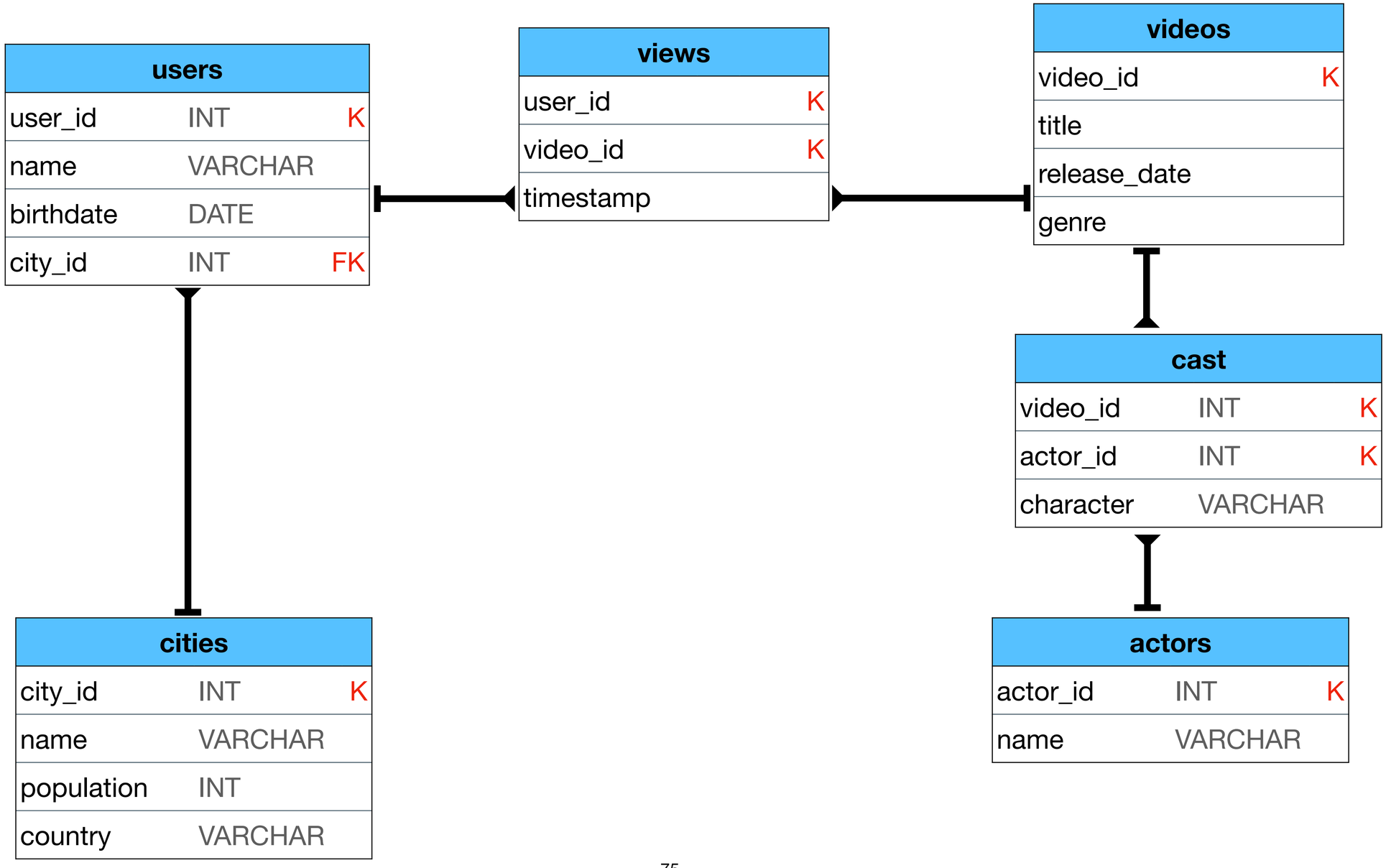
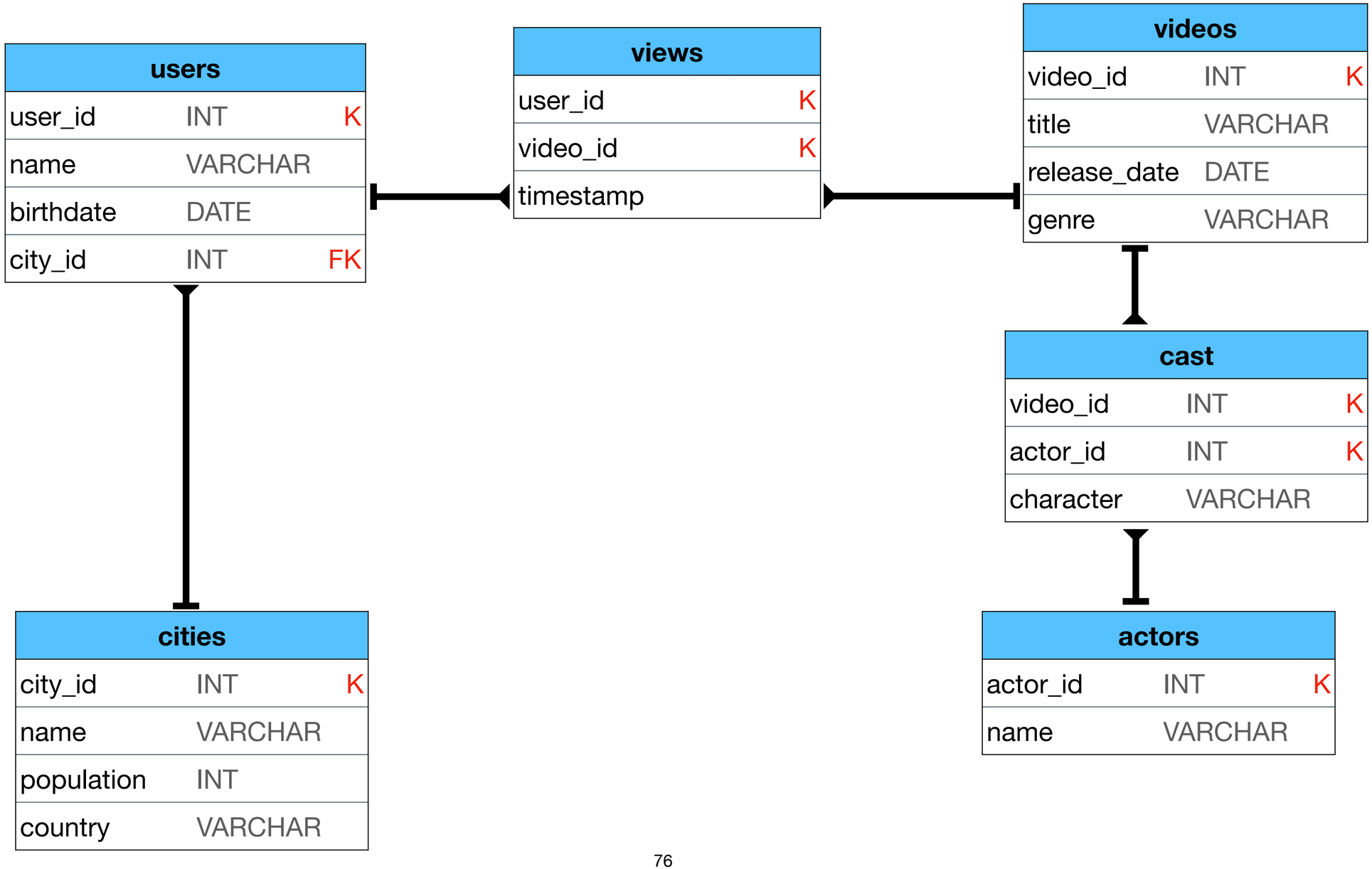
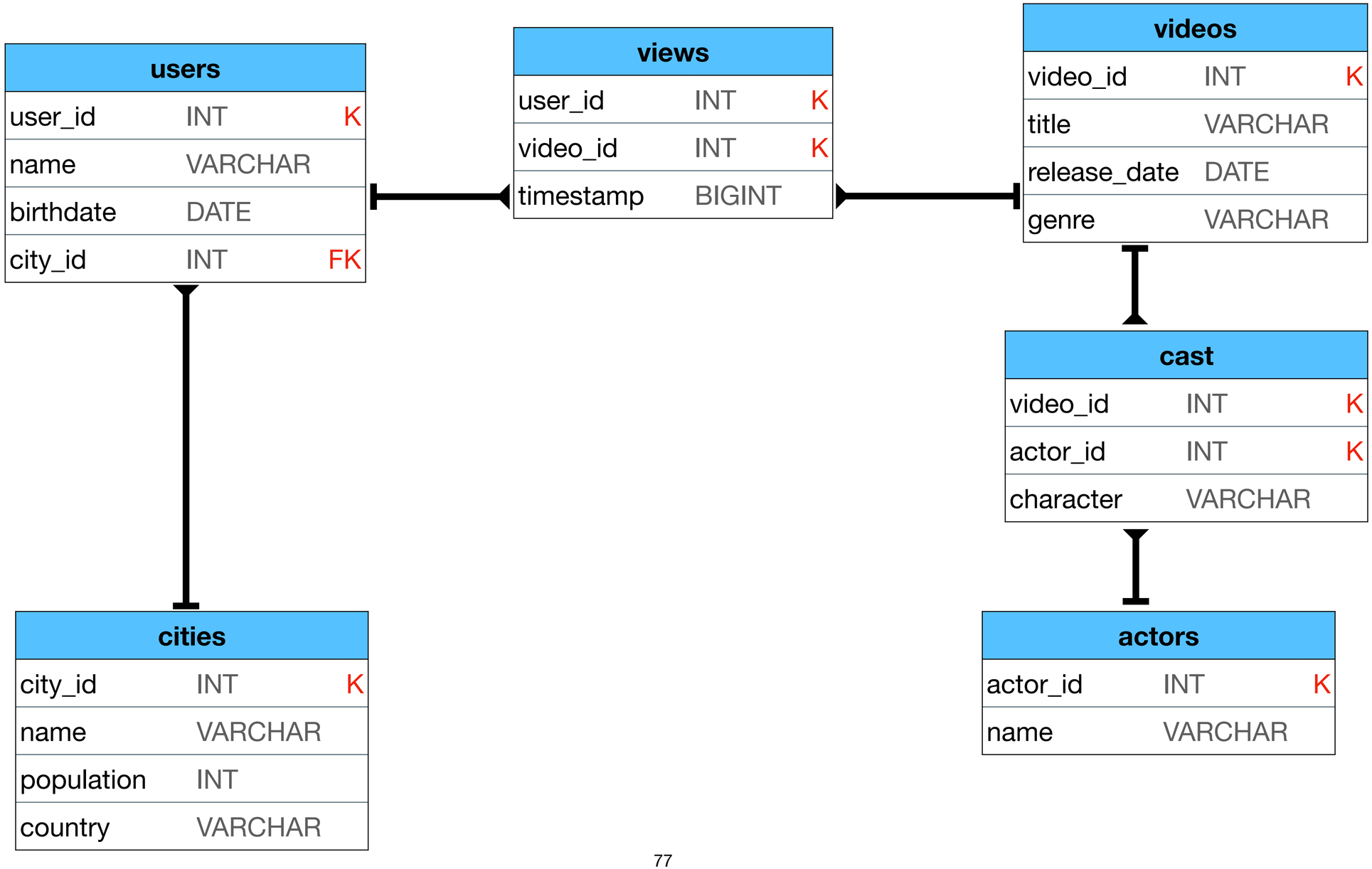
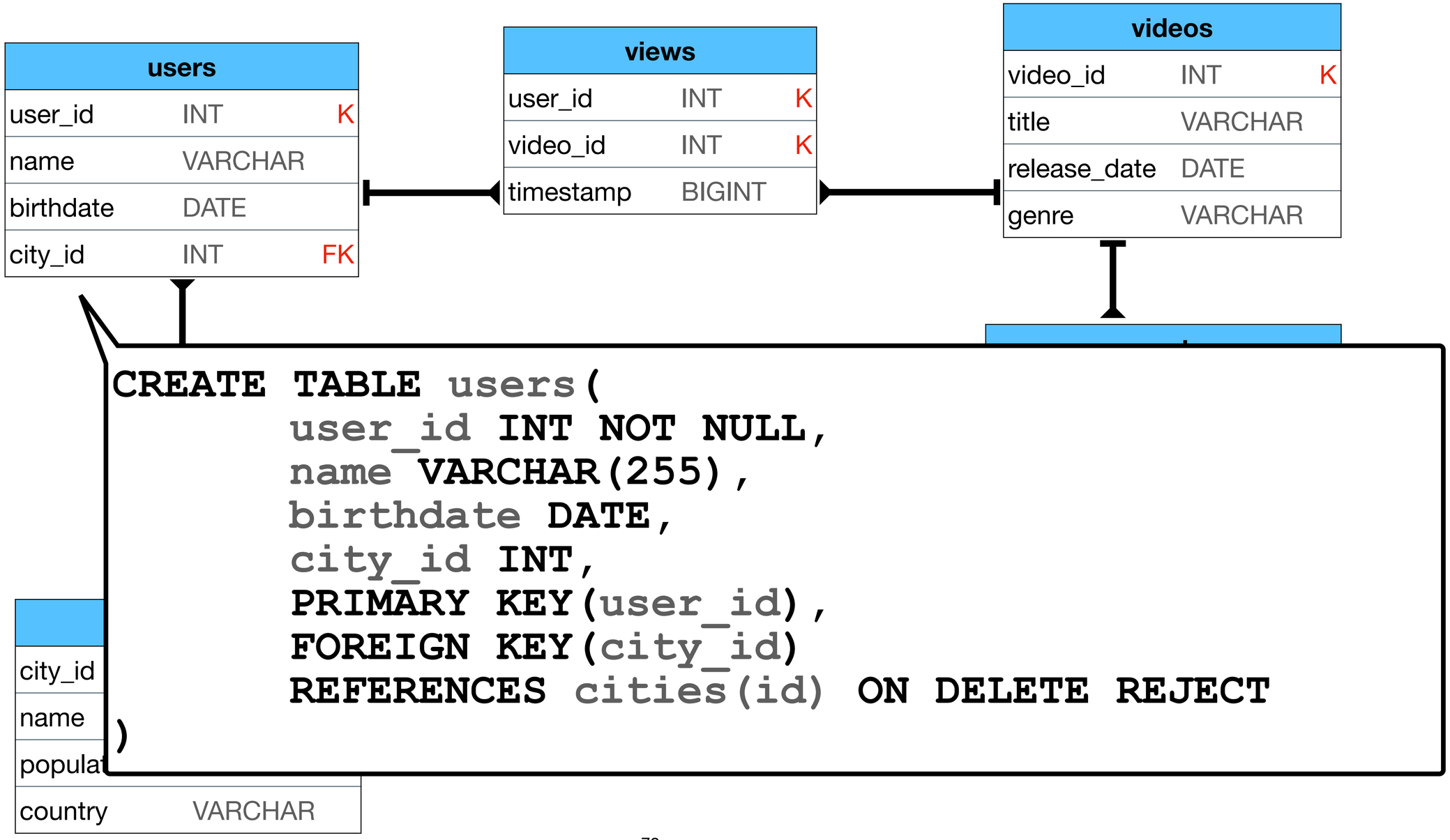
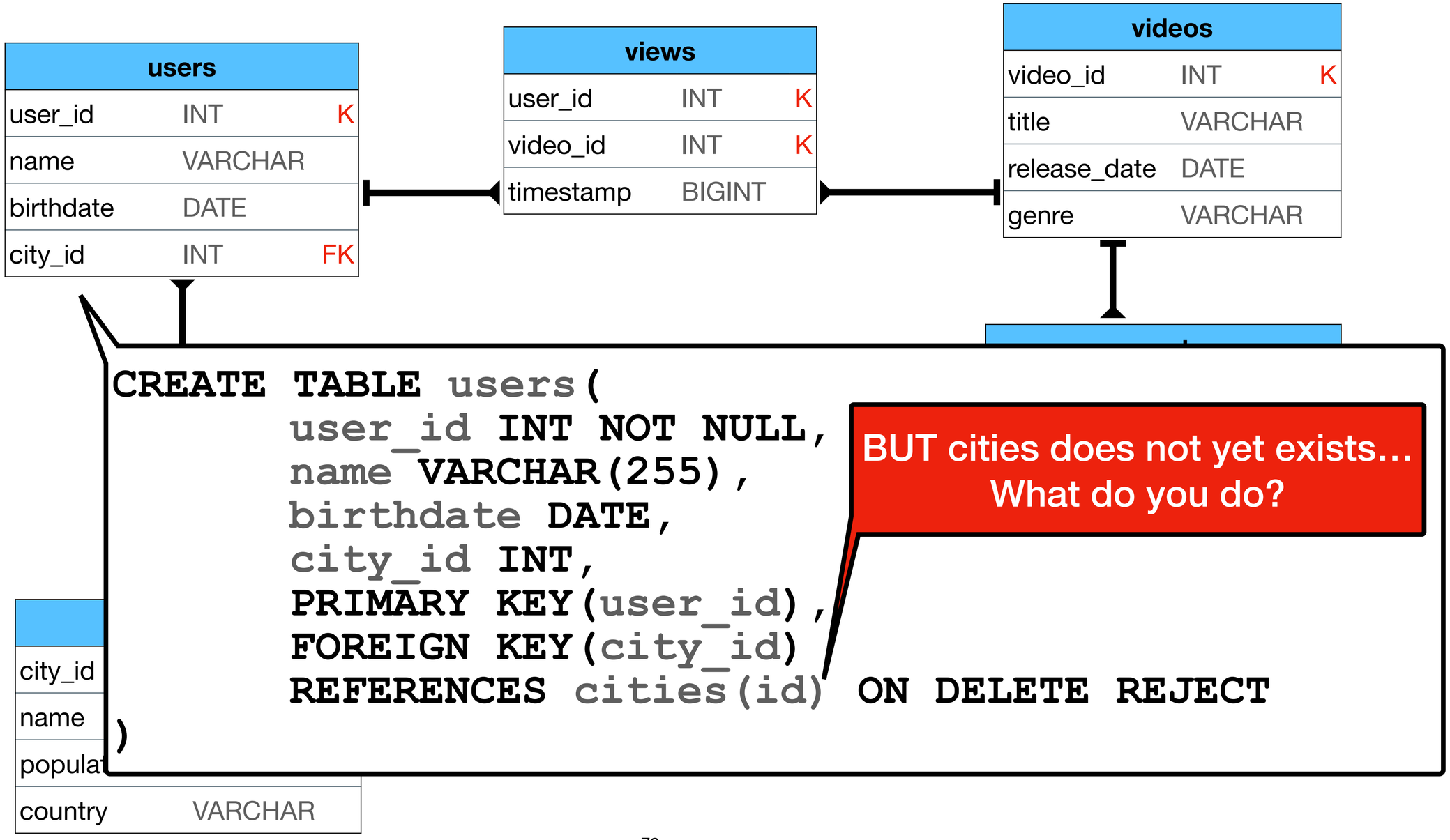
actor_id K
character
cities
city_id INT K
name VARCHAR
population INT
country VARCHAR
actors
actor_id INT K
name VARCHAR

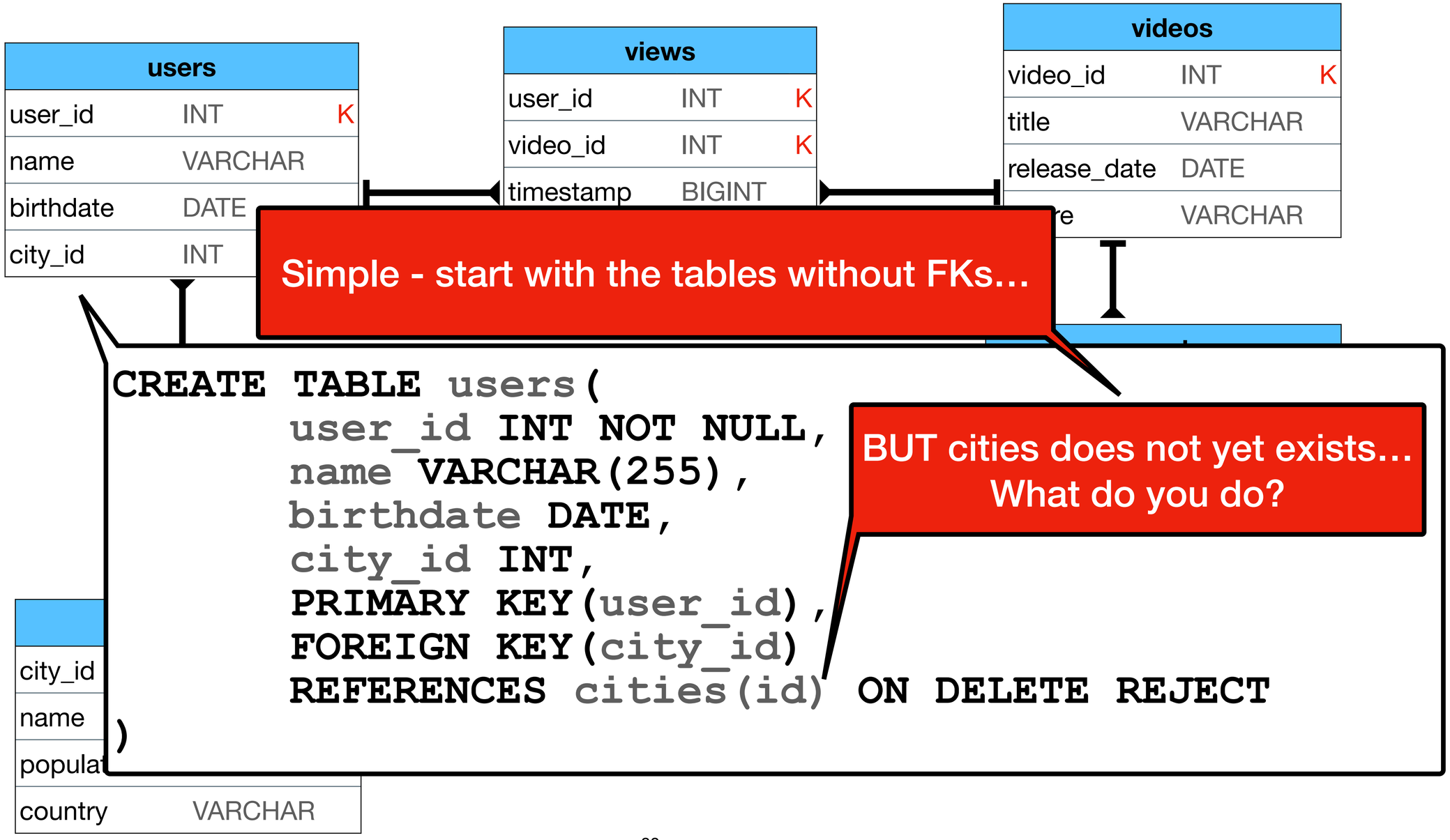

users
user_id INT K
name VARCHAR
birthdate DATE
city_id INT FK
views
user_id K
video_id K
timestamp
videos
video_id K
title
release_date
genre
cast
video_id INT K
actor_id INT K
character VARCHAR
cities
city_id INT K
name VARCHAR
population INT
country VARCHAR
actors
actor_id INT K
name VARCHAR


users
user_id INT K
name VARCHAR
birthdate DATE
city_id INT FK
views
user_id K
video_id K
timestamp
videos
video_id INT K
title VARCHAR
release_date DATE
genre VARCHAR
cast
video_id INT K
actor_id INT K
character VARCHAR
cities
city_id INT K
name VARCHAR
population INT
country VARCHAR
actors
actor_id INT K
name VARCHAR


users
user_id INT K
name VARCHAR
birthdate DATE
city_id INT FK
views
user_id INT K
video_id INT K
timestamp BIGINT
videos
video_id INT K
title VARCHAR
release_date DATE
genre VARCHAR
cast
video_id INT K
actor_id INT K
character VARCHAR
cities
city_id INT K
name VARCHAR
population INT
country VARCHAR
actors
actor_id INT K
name VARCHAR


users
user_id INT K
name VARCHAR
birthdate DATE
city_id INT FK
views
user_id INT K
video_id INT K
timestamp BIGINT
videos
video_id INT K
title VARCHAR
release_date DATE
genre VARCHAR
city_id
name
popula
country VARCHAR
CREATE TABLE users(
user_id INT NOT NULL,
name VARCHAR(255),
birthdate DATE,
city_id INT,
PRIMARY KEY(user_id),
FOREIGN KEY(city_id)
REFERENCES cities(id) ON DELETE REJECT
)


users
user_id INT K
name VARCHAR
birthdate DATE
city_id INT FK
views
user_id INT K
video_id INT K
timestamp BIGINT
videos
video_id INT K
title VARCHAR
release_date DATE
genre VARCHAR
CREATE TABLE users(
user_id INT NOT NULL,
name VARCHAR(255),
birthdate DATE,
city_id INT,
PRIMARY KEY(user_id),
FOREIGN KEY(city_id)
REFERENCES cities(id) ON DELETE REJECT
)
BUT cities does not yet exists…
What do you do?
city_id
name
country VARCHAR

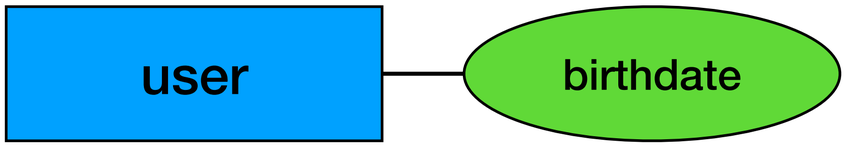

users
user_id INT K
name VARCHAR
birthdate DATE
city_id INT
views
user_id INT K
video_id INT K
timestamp BIGINT
videos
video_id INT K
title VARCHAR
release_date DATE
VARCHAR
city_id
name
country VARCHAR
Simple - start with the tables without FKs…
BUT cities does not yet exists…
What do you do?
CREATE TABLE users(
user_id INT NOT NULL,
name VARCHAR(255),
birthdate DATE,
city_id INT,
PRIMARY KEY(user_id),
FOREIGN KEY(city_id)
REFERENCES cities(id) ON DELETE REJECT
)

Design examples

Example (1)

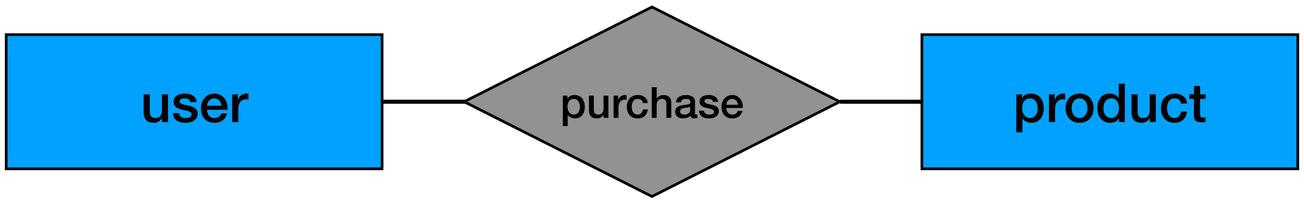
- What is the problem here? Solution?

Example (1)

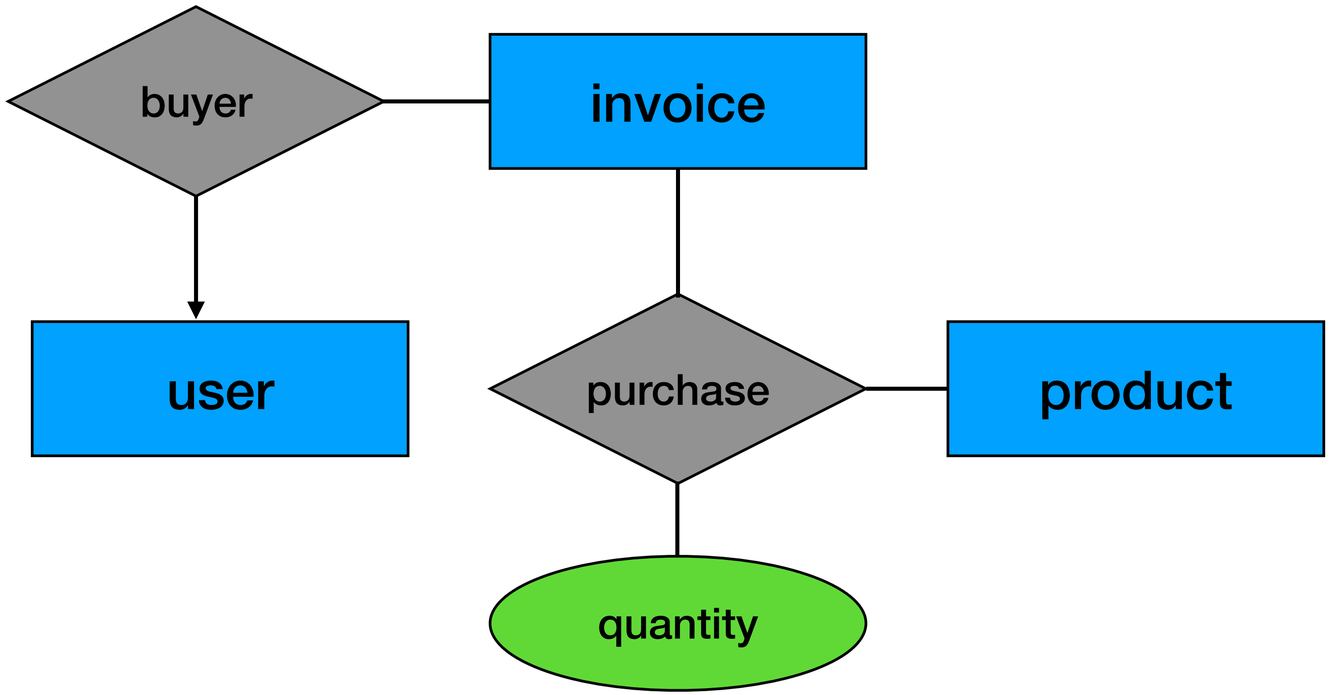


Example (2)

- What is the problem here? Solution?

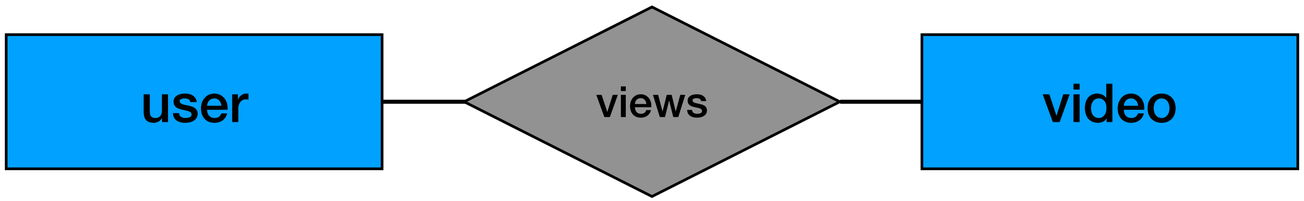


Example (2)



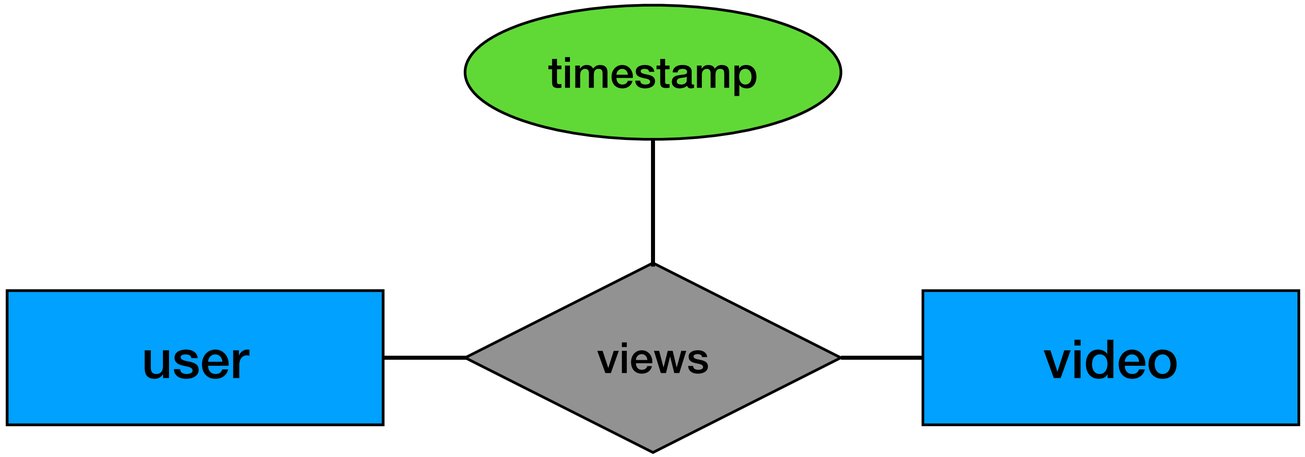
Example (3)

- What is the problem here? Solution?



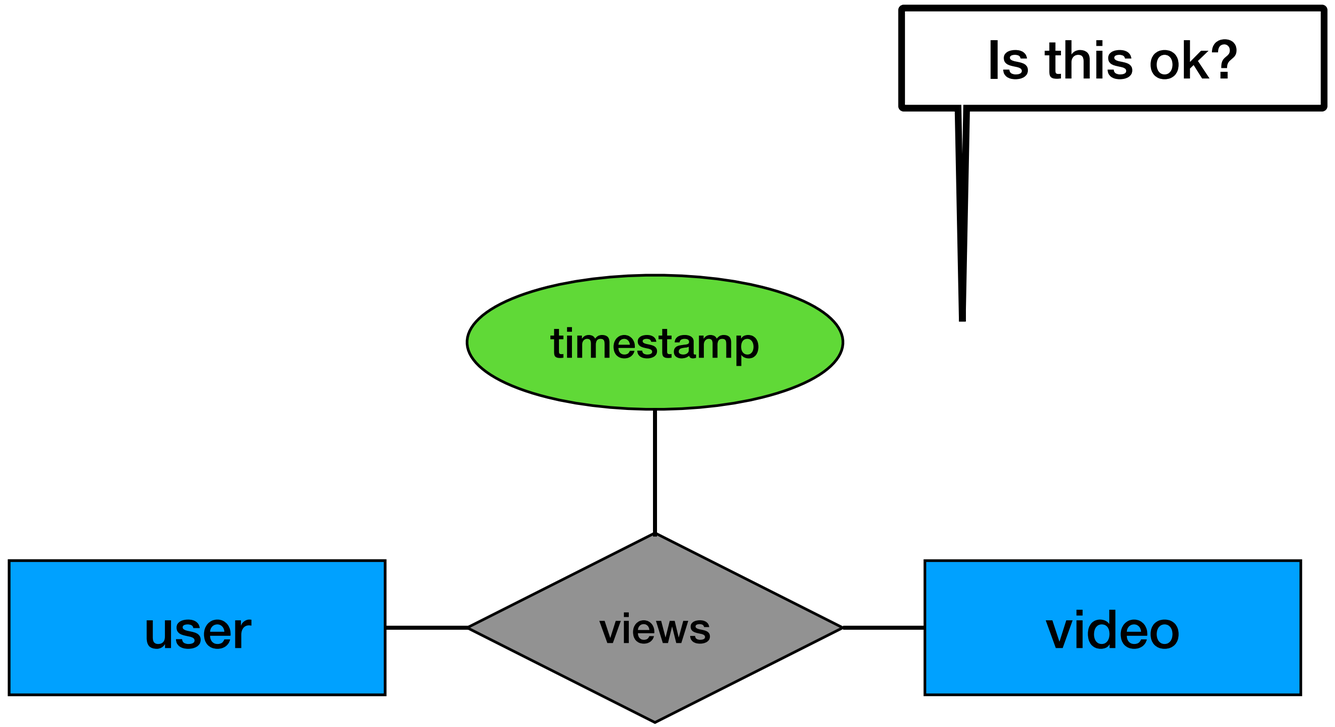
Example (3)

- Option 1



Example (3)

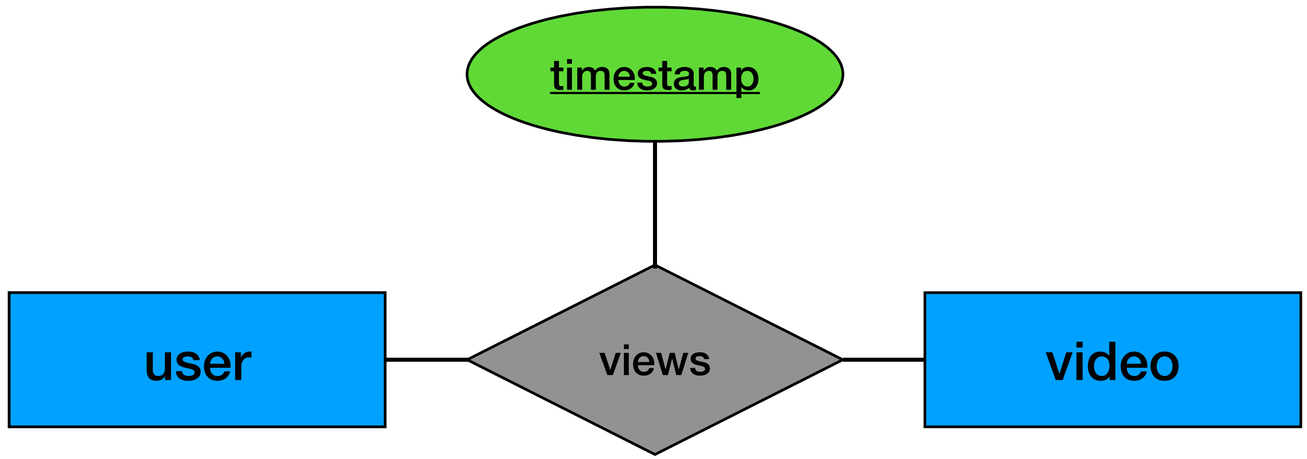
- Option 1



views_option_1		
user_id	INT	K
video_id	INT	K
timestamp	BIGINT	

Example (3)

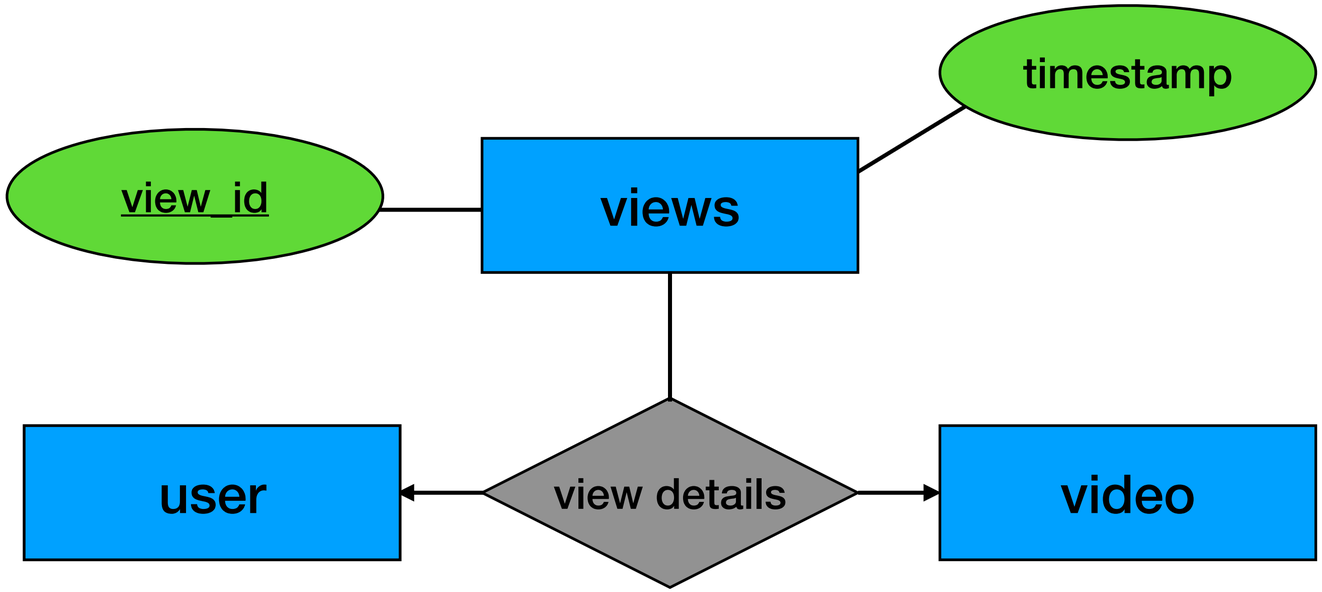
- Option 1



views_option_1		
user_id	INT	K
video_id	INT	K
timestamp	BIGINT	K

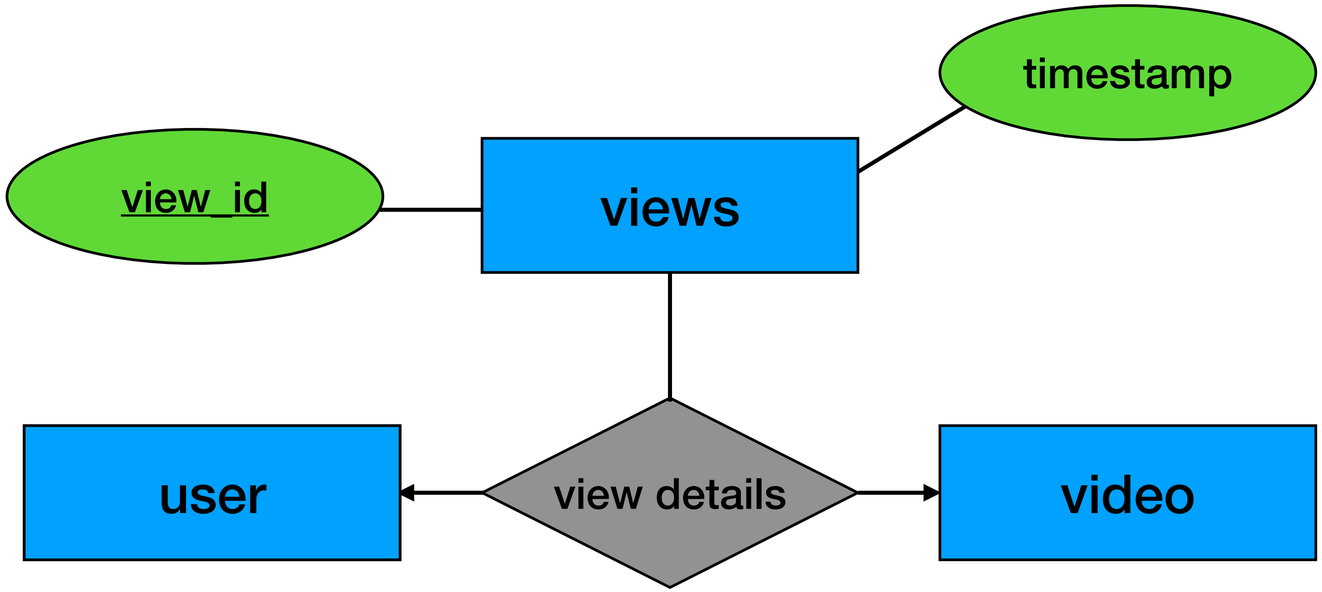
Example (3)

- Option 2



Example (3)

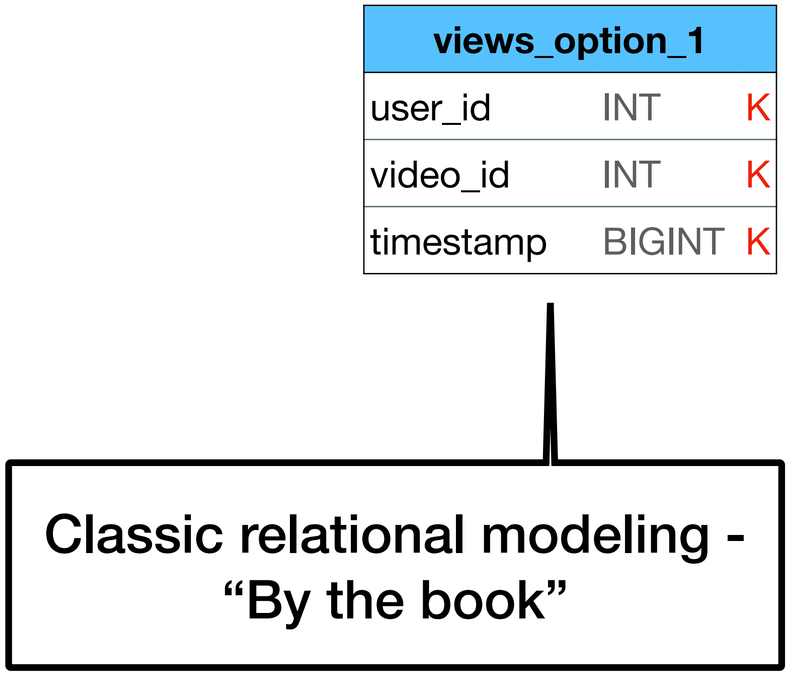
- Option 2

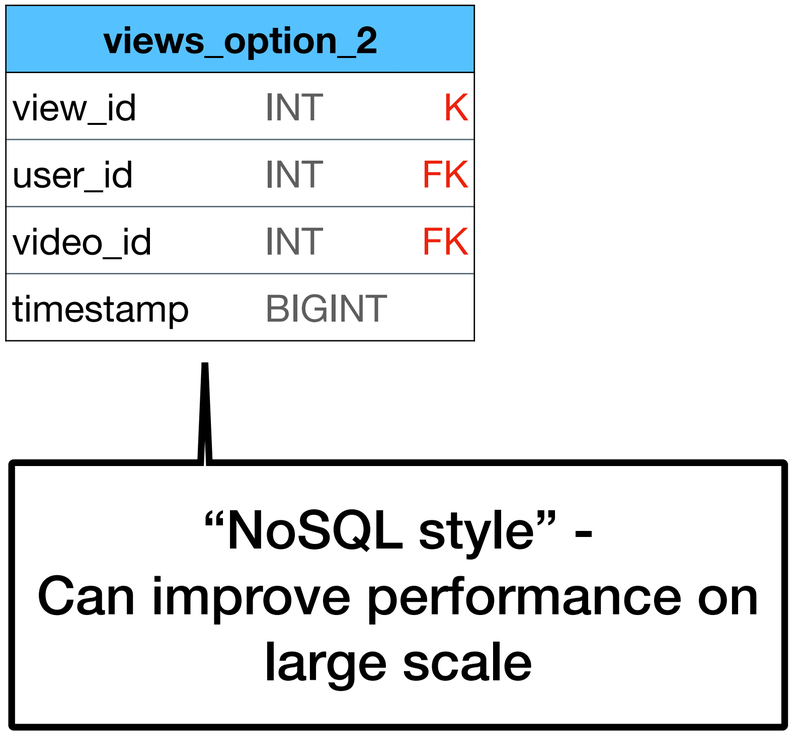


views_option_2		
view_id	INT	K
user_id	INT	FK
video_id	INT	FK
timestamp	BIGINT	

Example (3)

- Option 1 vs Option 2





Ex

- Op

Open discussion

Assume the data is **stored on disk** by the **order of the primary key**

Can you think of a query that would be “optimized” for each option?

views_option_1		
user_id	INT	K
video_id	INT	K
timestamp	BIGINT	K

Classic relational modeling - “By the book”

views_option_2		
view_id	INT	K
user_id	INT	FK
video_id	INT	FK
timestamp	BIGINT	

“NoSQL style” - Can improve performance on large scale

Ex

- Op

Open discussion

Assume the data is **stored on disk** by the **order of the primary key**

Can you think of a query that would be “optimized” for each option?

Return all videos viewed by a user

views_option_1		
user_id	INT	K
video_id	INT	K
timestamp	BIGINT	K

Classic relational modeling - “By the book”

views_option_2		
view_id	INT	K
user_id	INT	FK
video_id	INT	FK
timestamp	BIGINT	

Return all videos viewed last week

“NoSQL style” - Can improve performance on large scale

Ex

- Op

Open discussion

Assume the data is **stored on disk** by the **order of the primary key**

Can you think of a query that would be “optimized” for each option?

Return all videos viewed by a user

views_option_1		
user_id	INT	K
video_id	INT	K
timestamp	BIGINT	K

views_option_2		
view_id	INT	K
user_id	INT	FK
video_id	INT	FK
timestamp	BIGINT	

Return all videos viewed last week

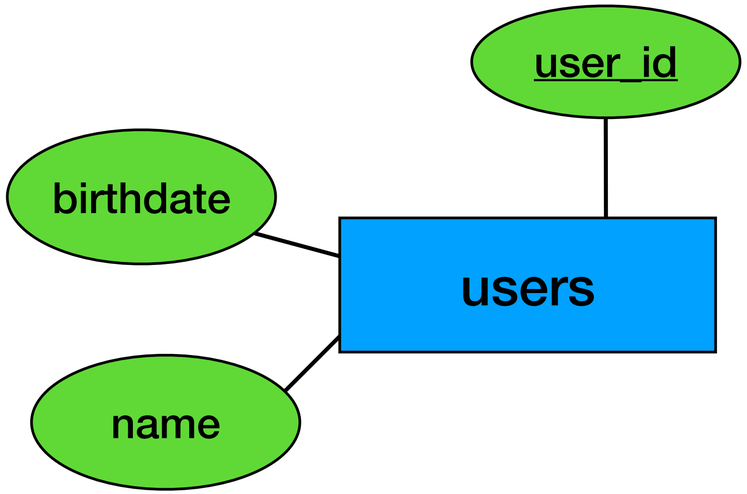
Modeling is an art…
There is not alway a clear right / wrong answer

Classic relational modeling - “By the book”

NoSQL style” - Can improve performance on large scale

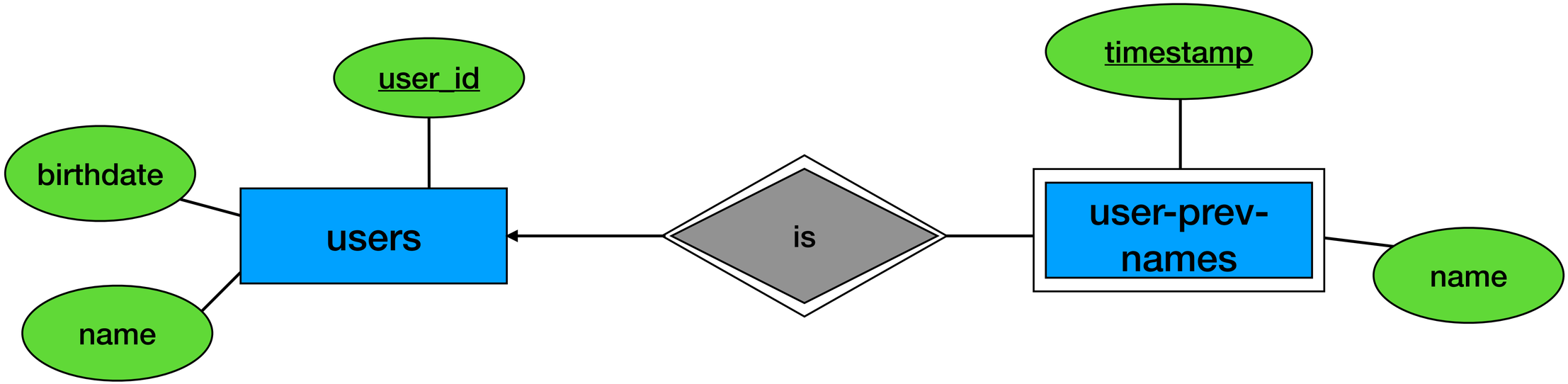
Example (4)

- Add the option to save previous changes to the name attribute



Example (4)

- Add the option to save previous changes to the name attribute



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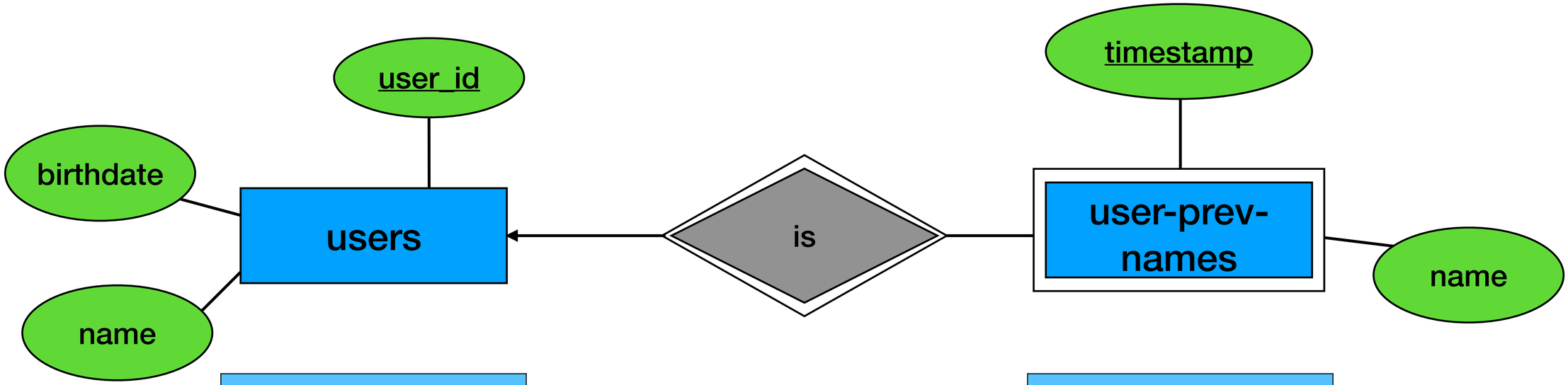
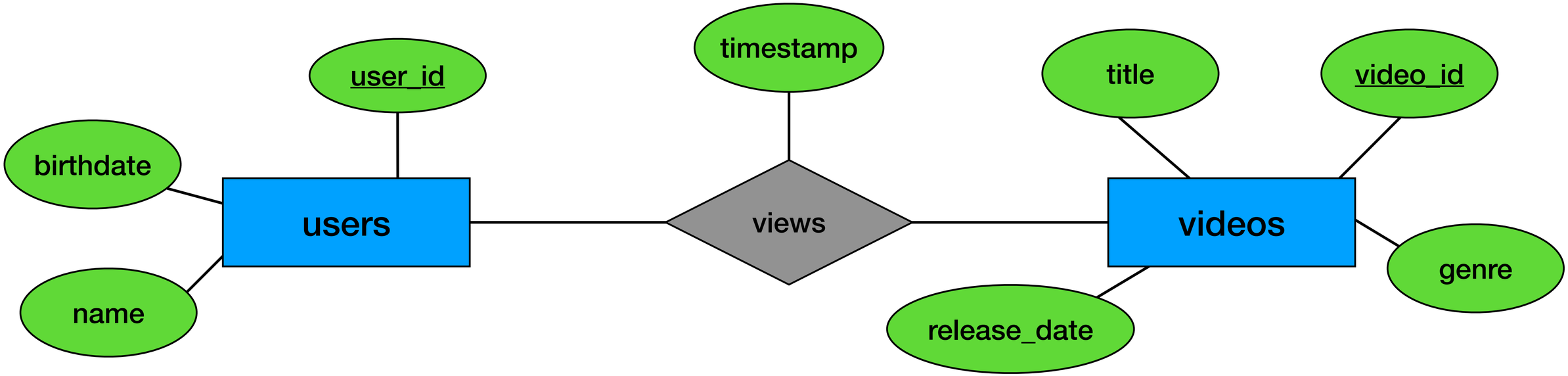


users	
user_id	K
name	
birthdate	

user_names	
user_id	K
timestamp	K
name	

Example (5)

- Add the option for a “premium” user



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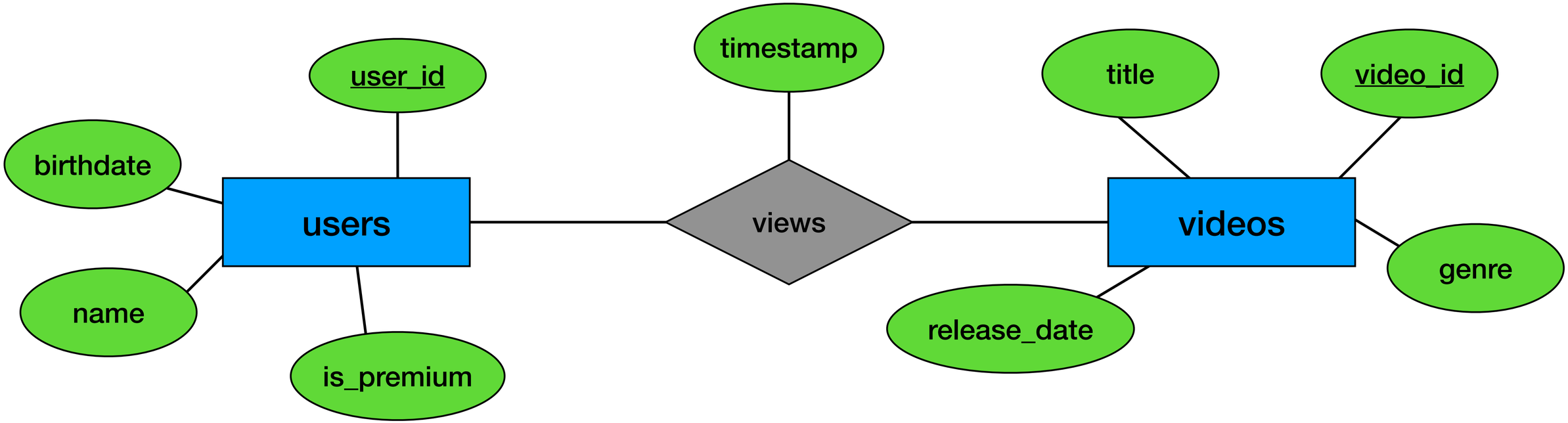
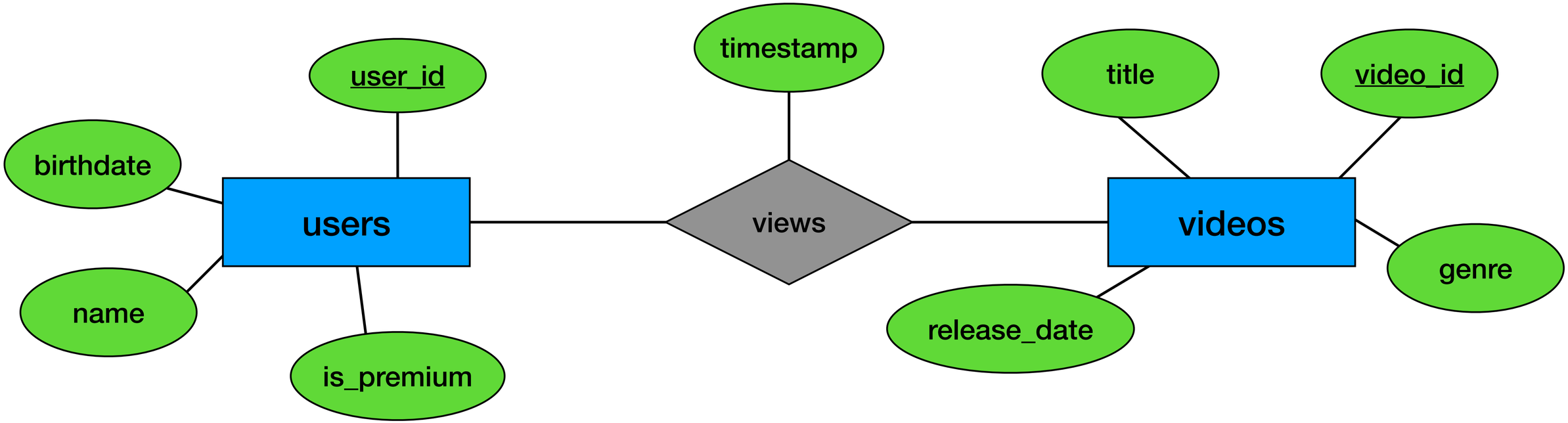


Example (5)

- Add the option for a “premium” user or “gold” user



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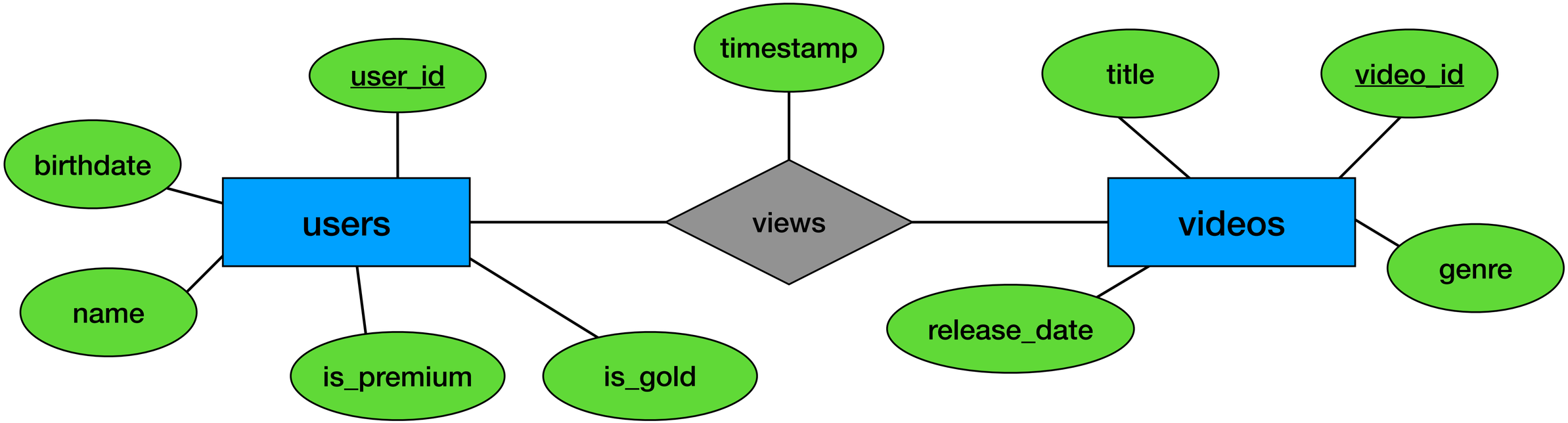

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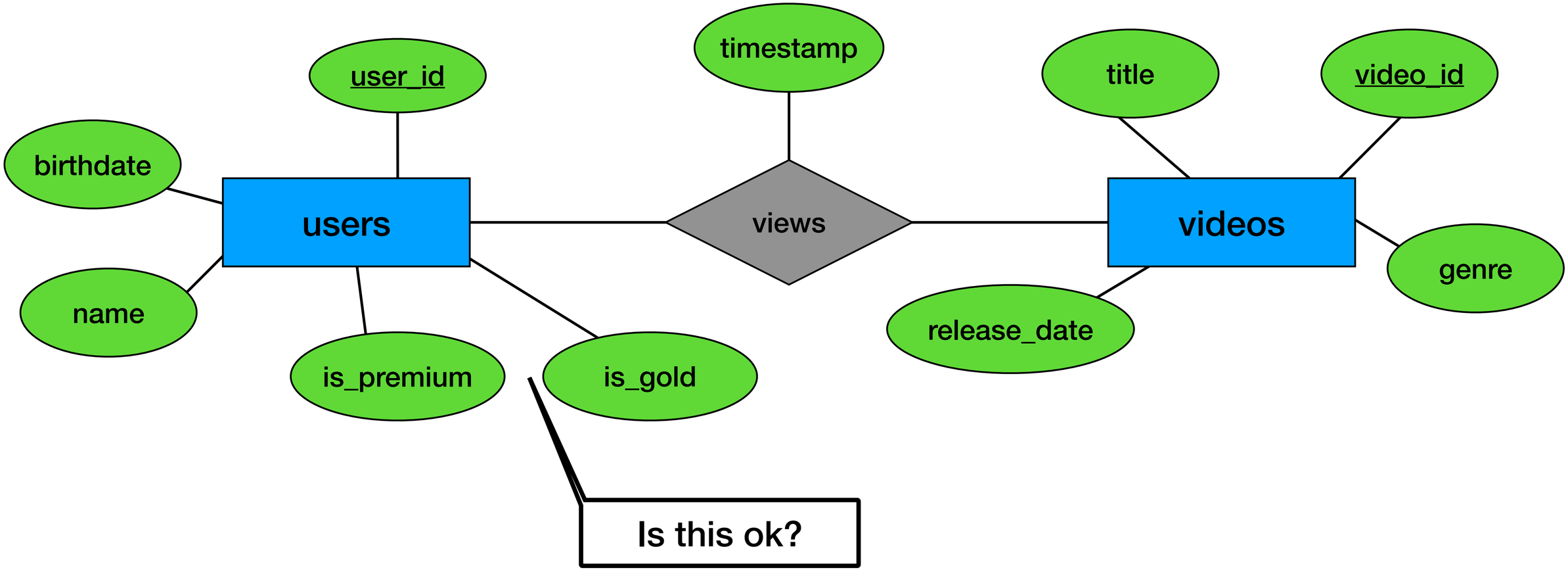

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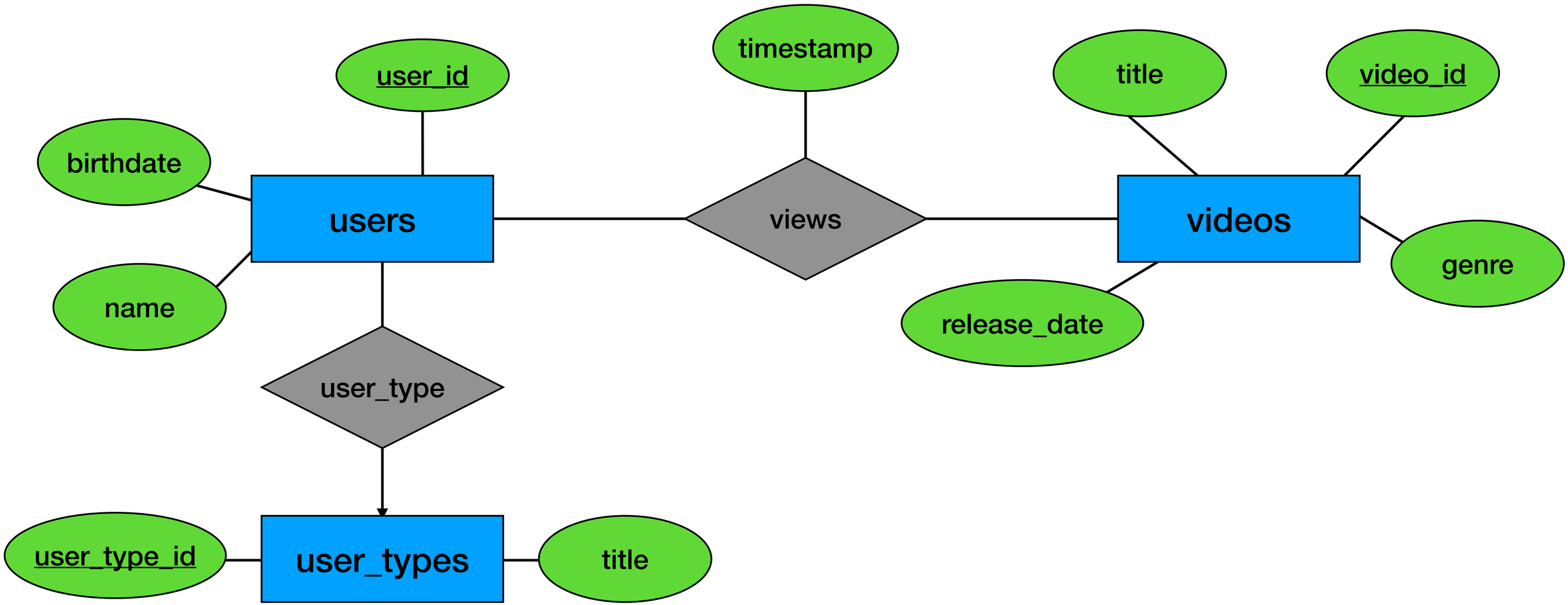
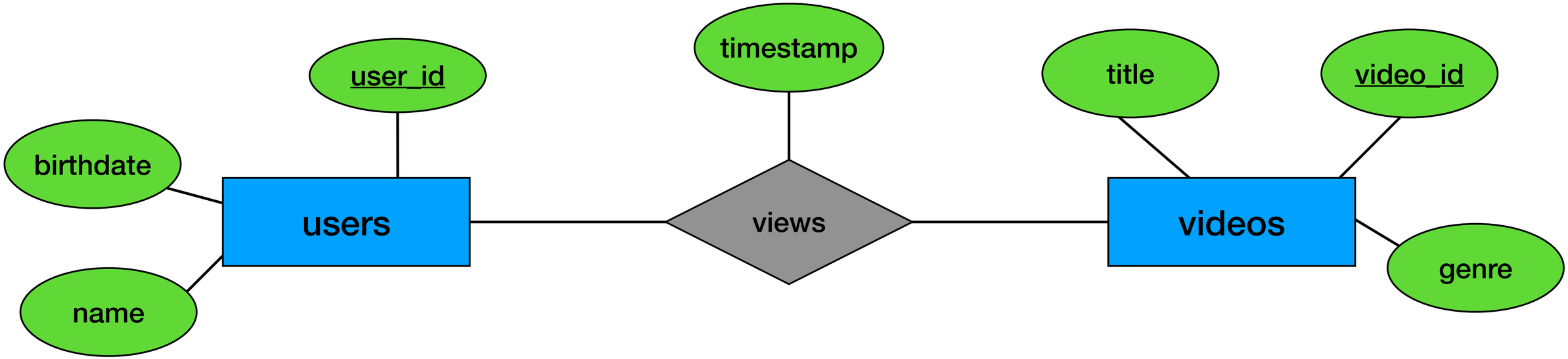


Example (6)

- Add the option to “download” videos



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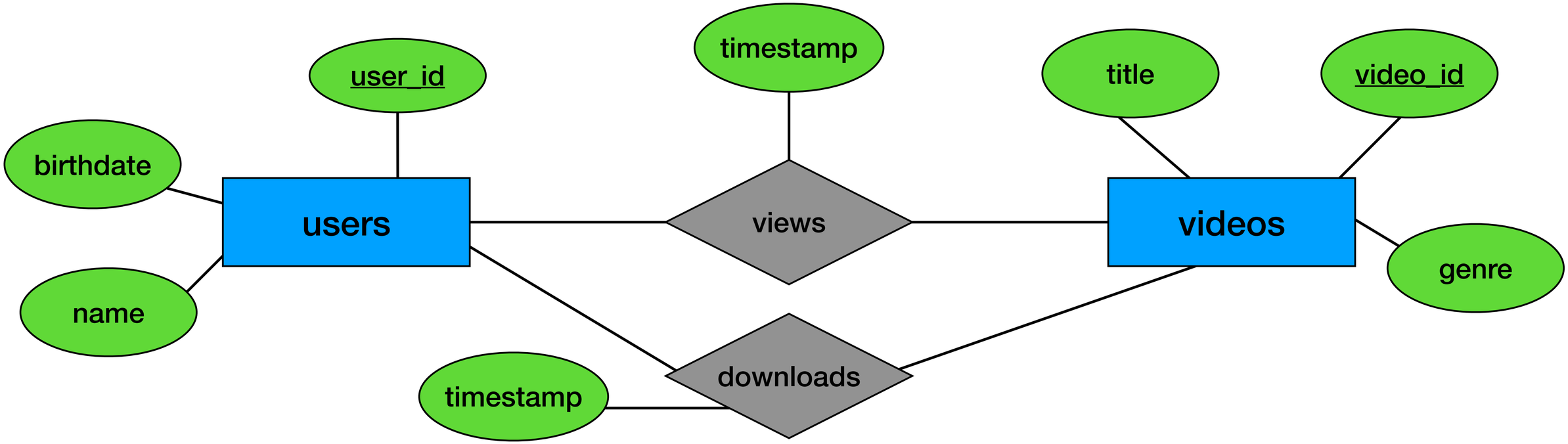
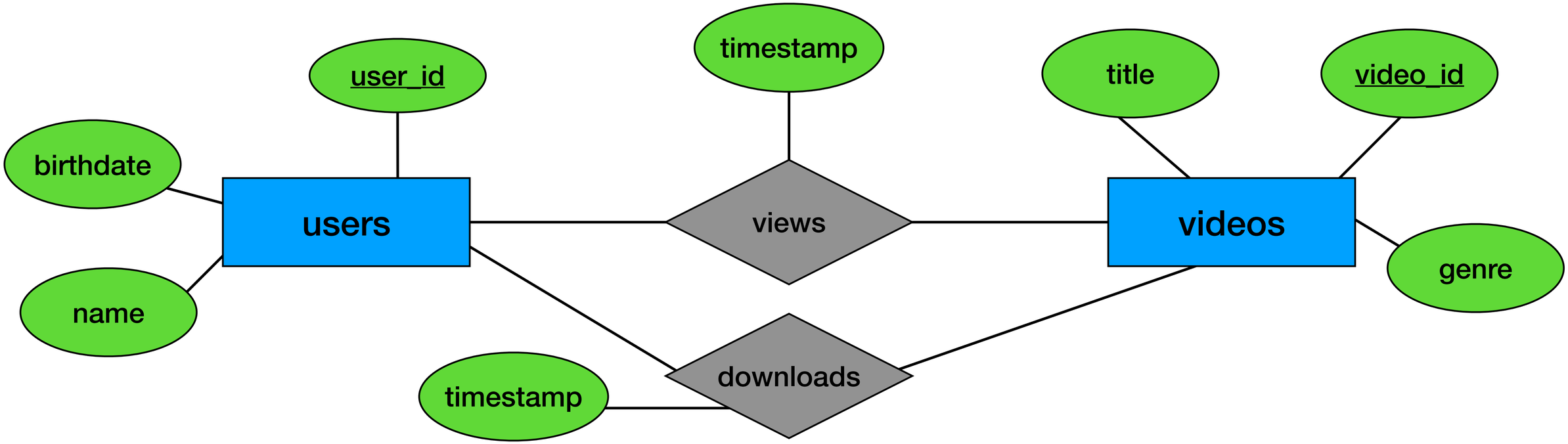


Example (6)

- Add also the option for “wish list”



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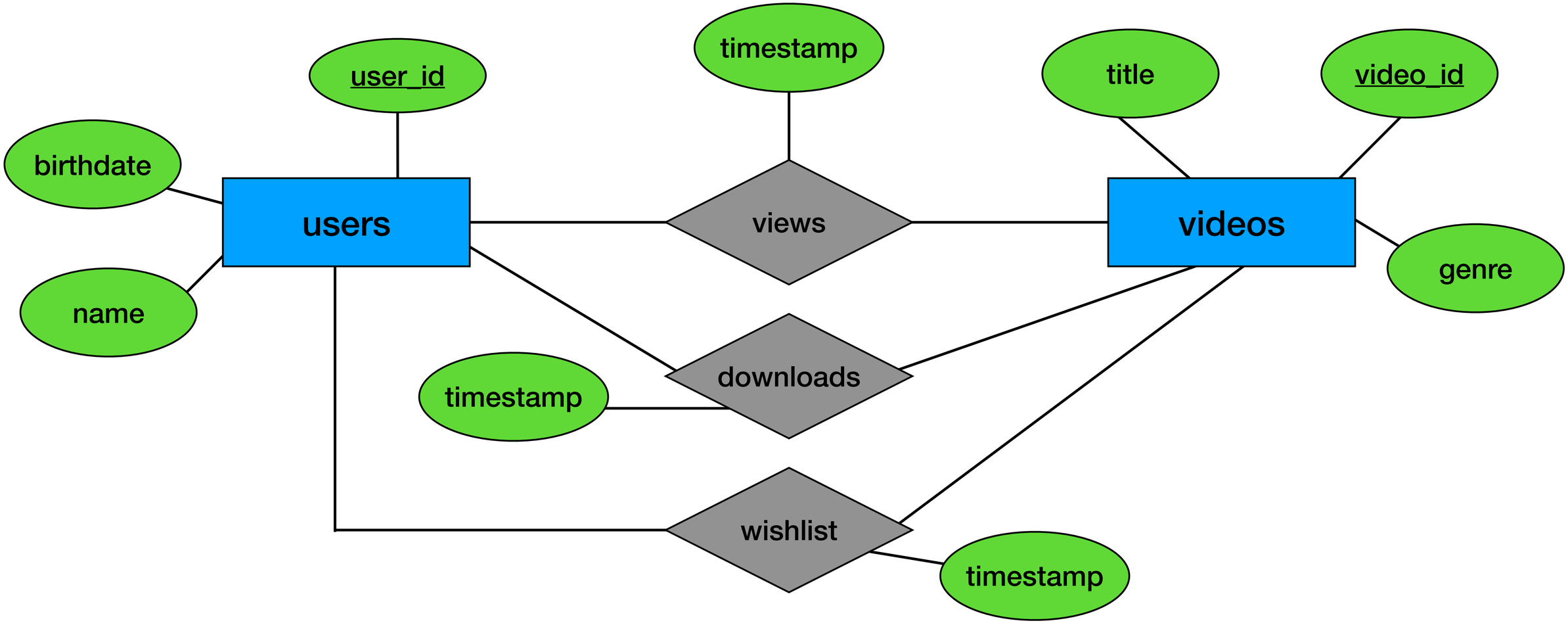

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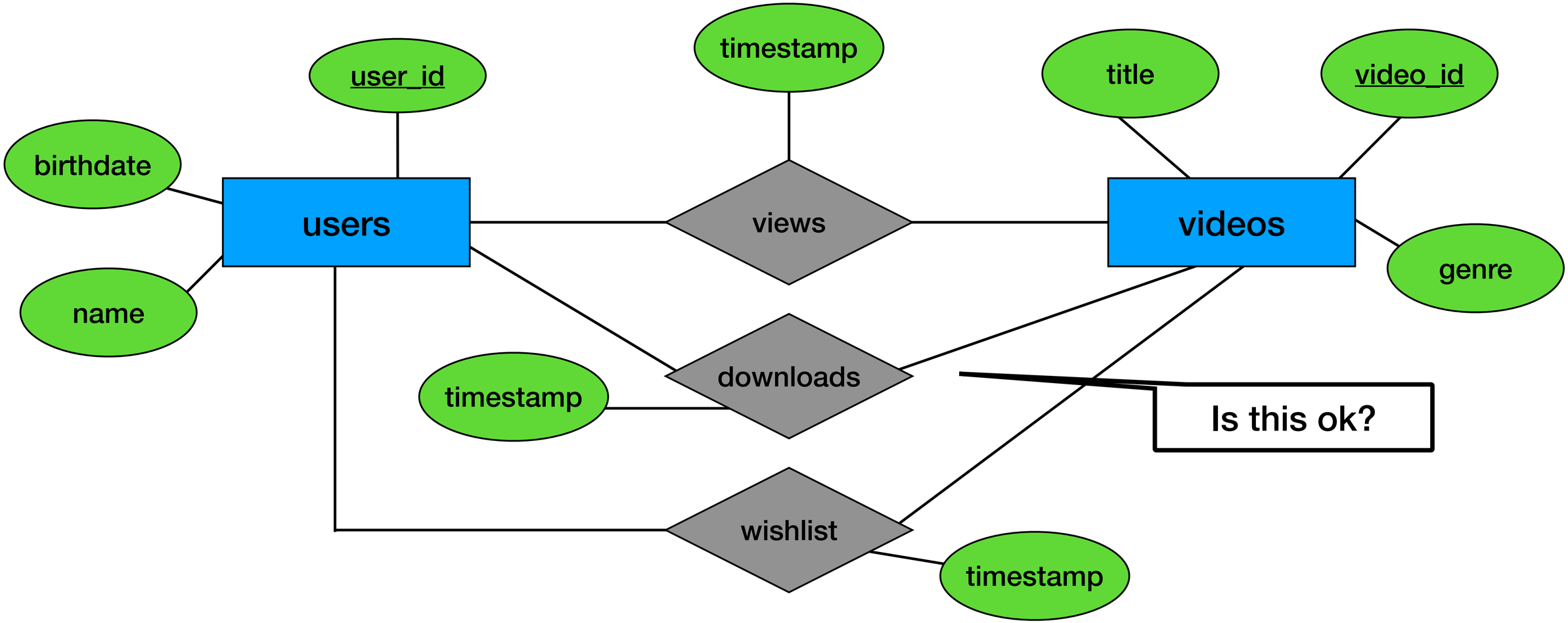

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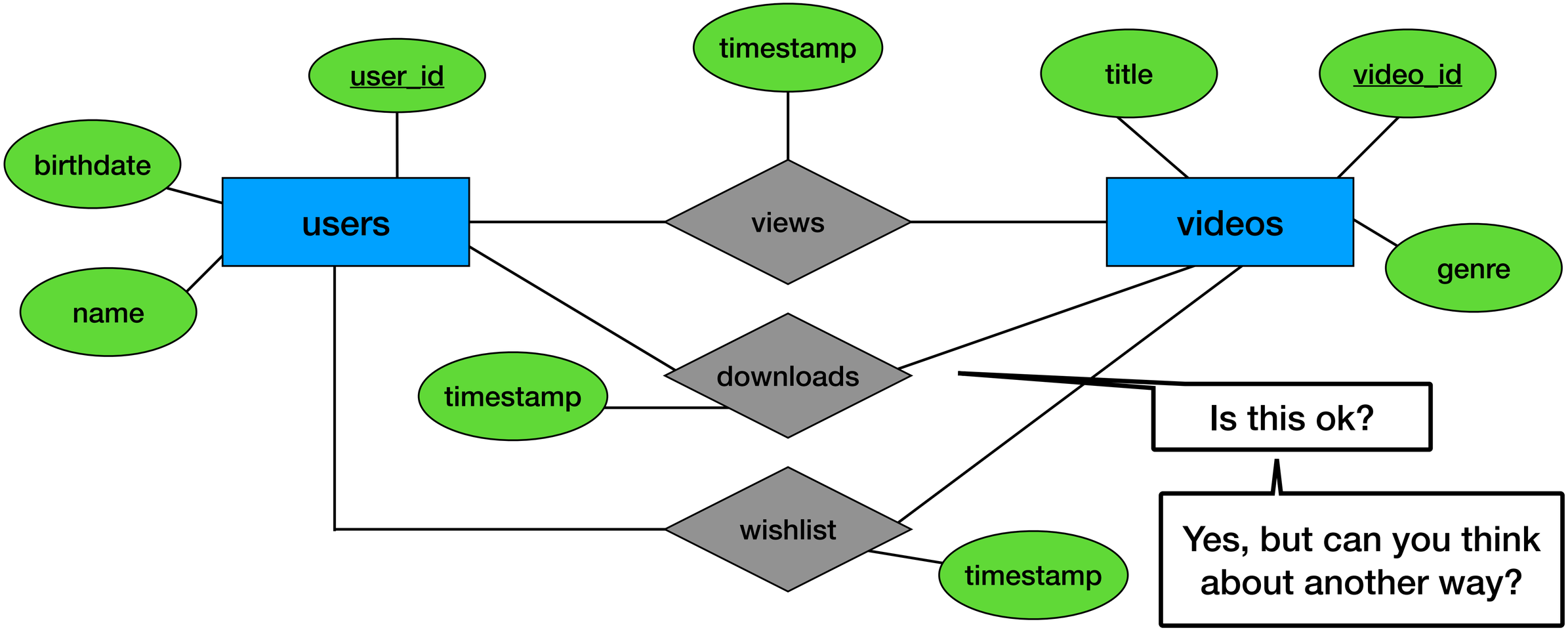
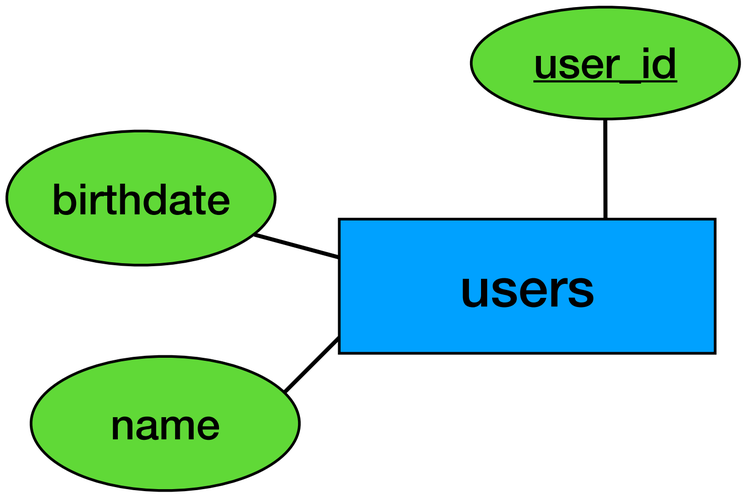
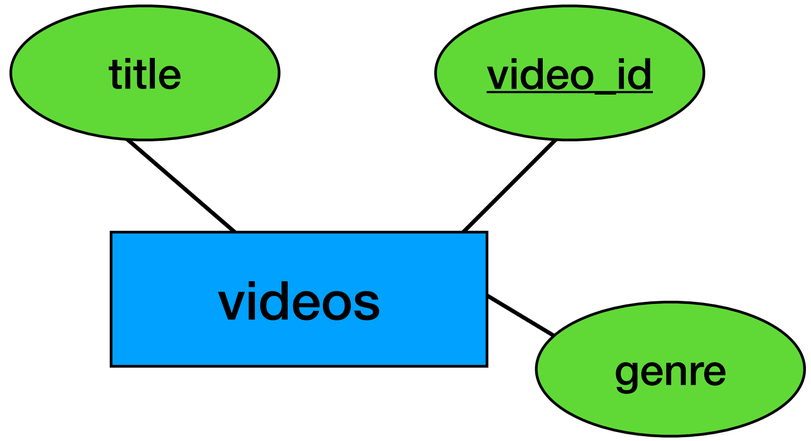


Example (6)

- Convert to “events"





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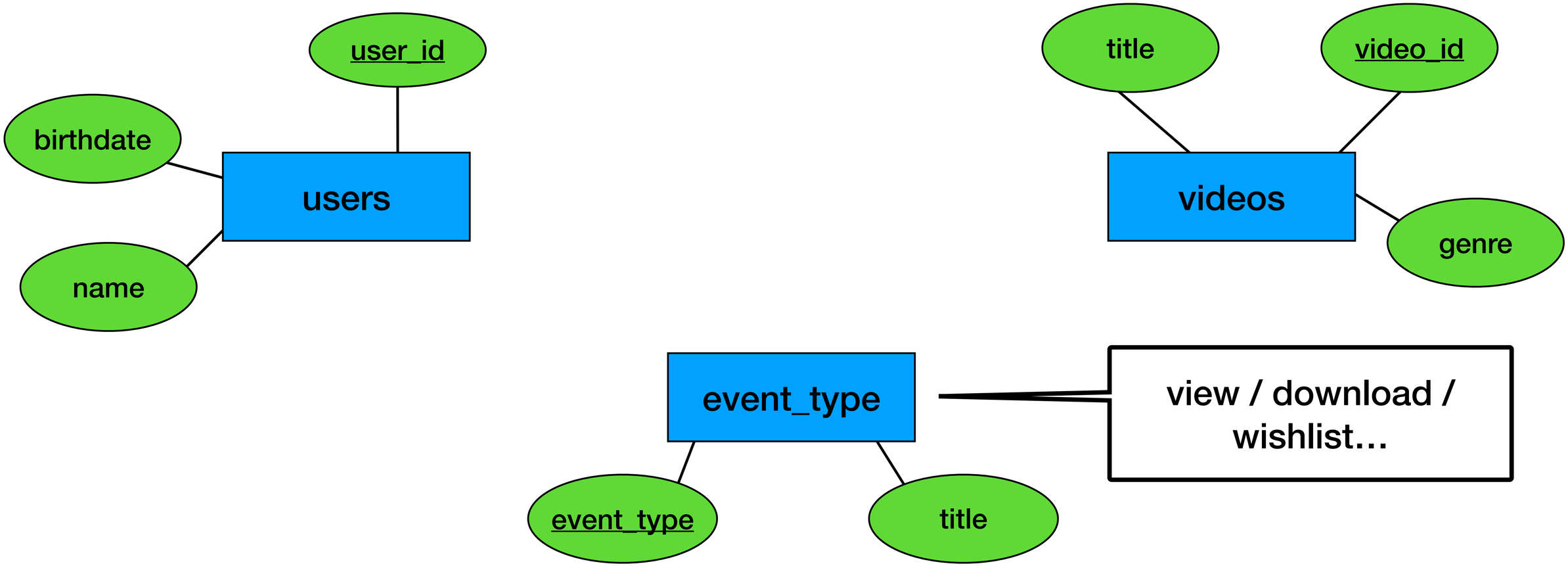

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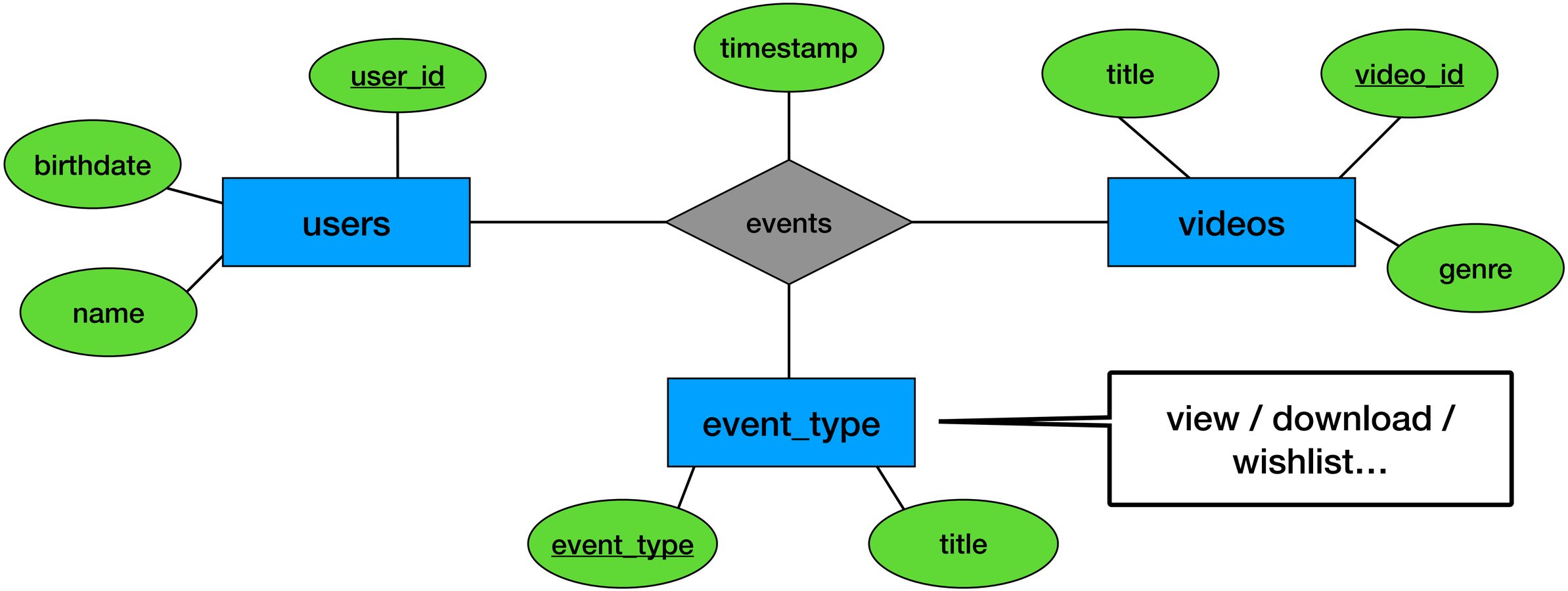

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- How would the tables look like for both versions?

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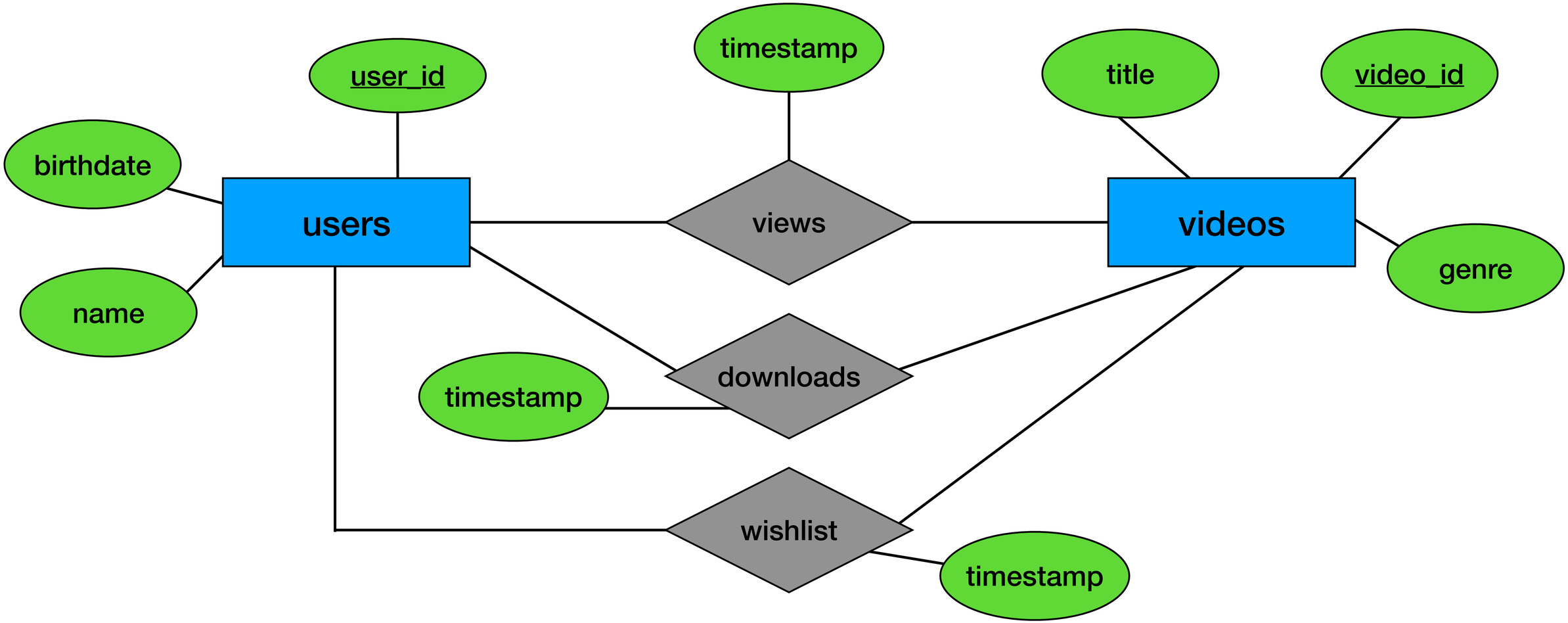

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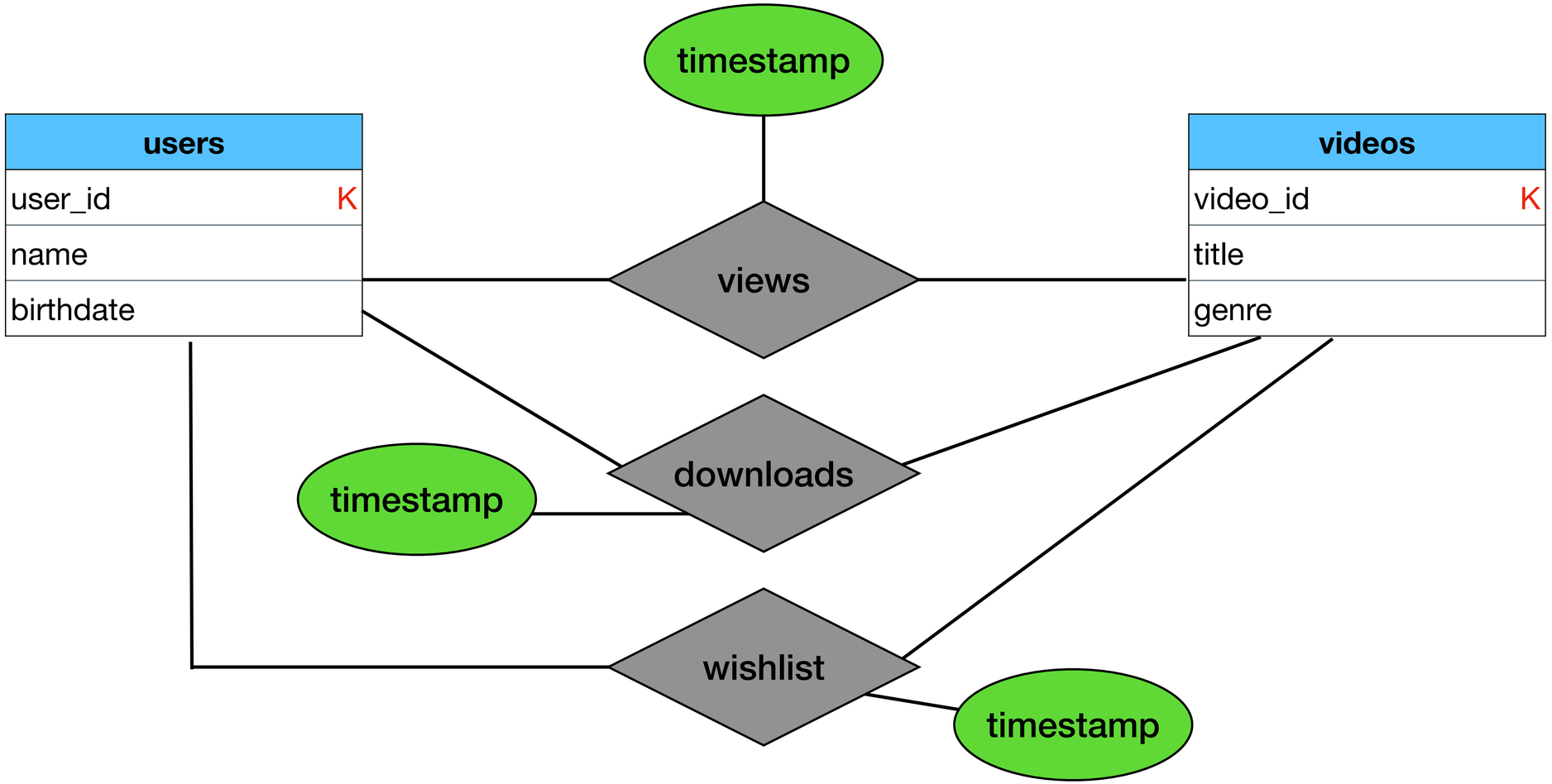

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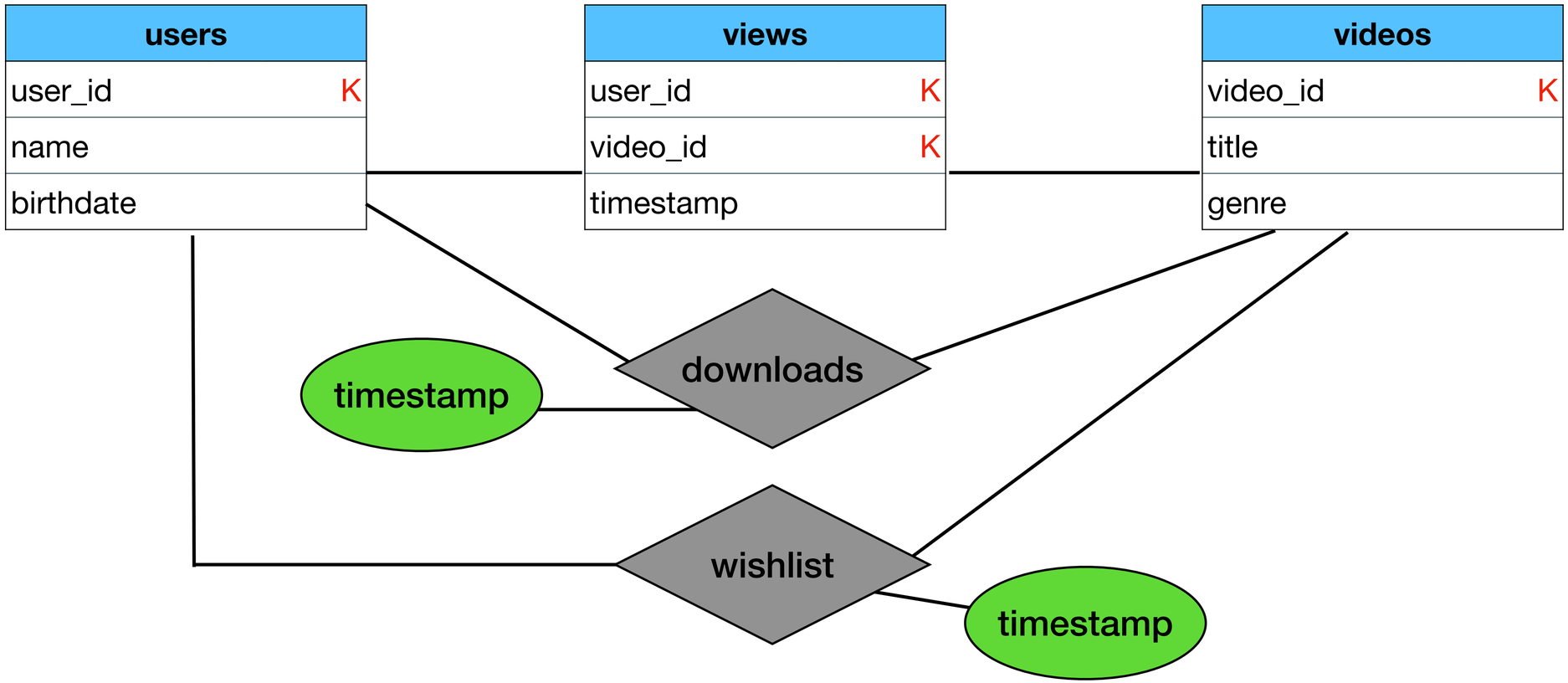

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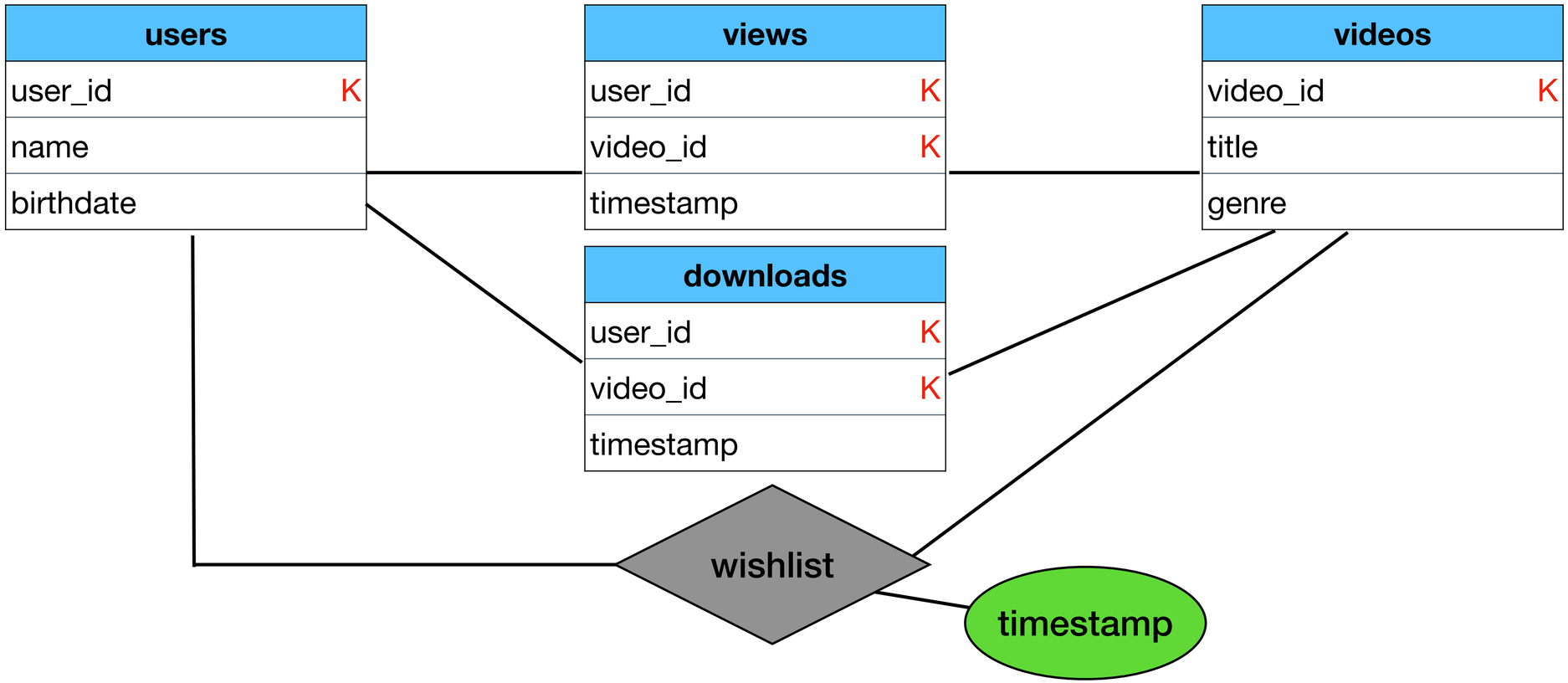

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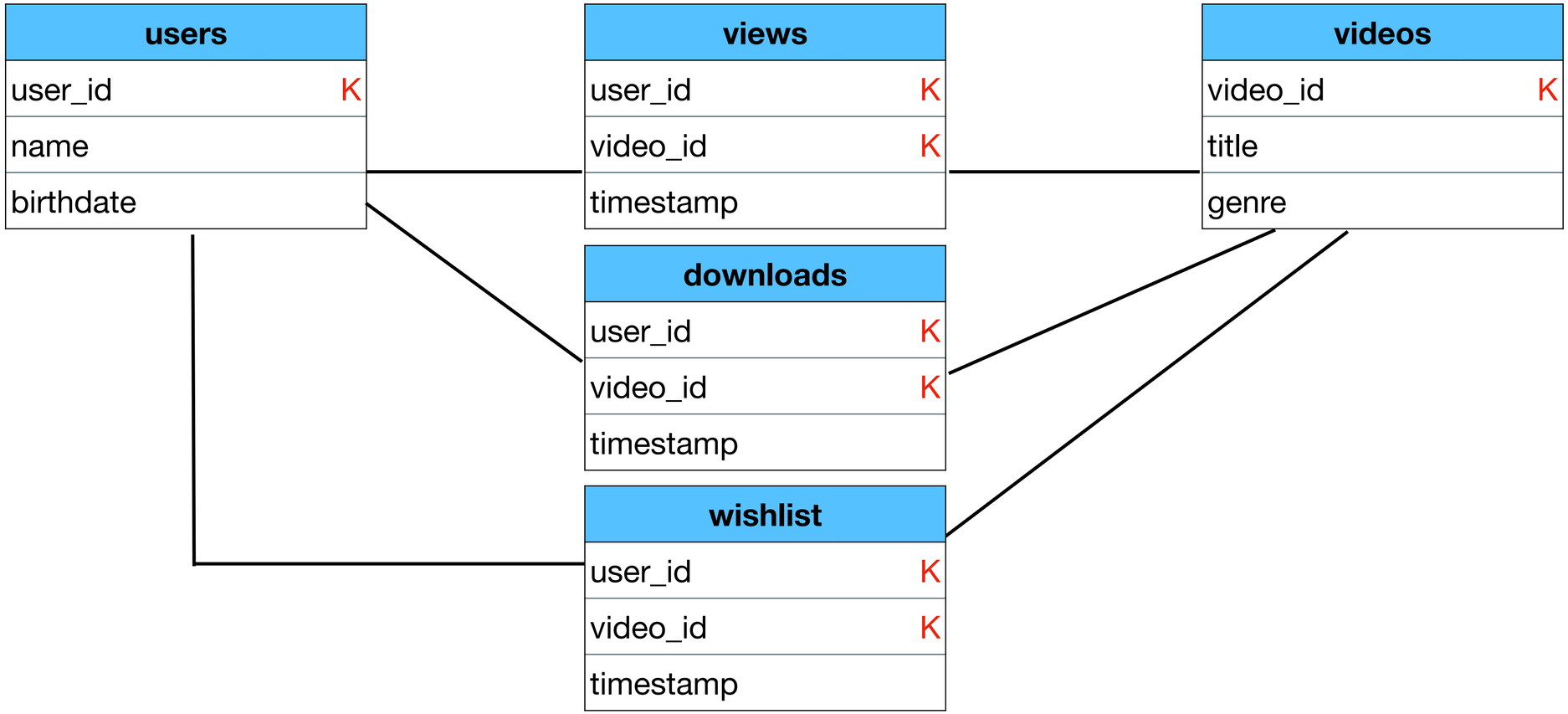

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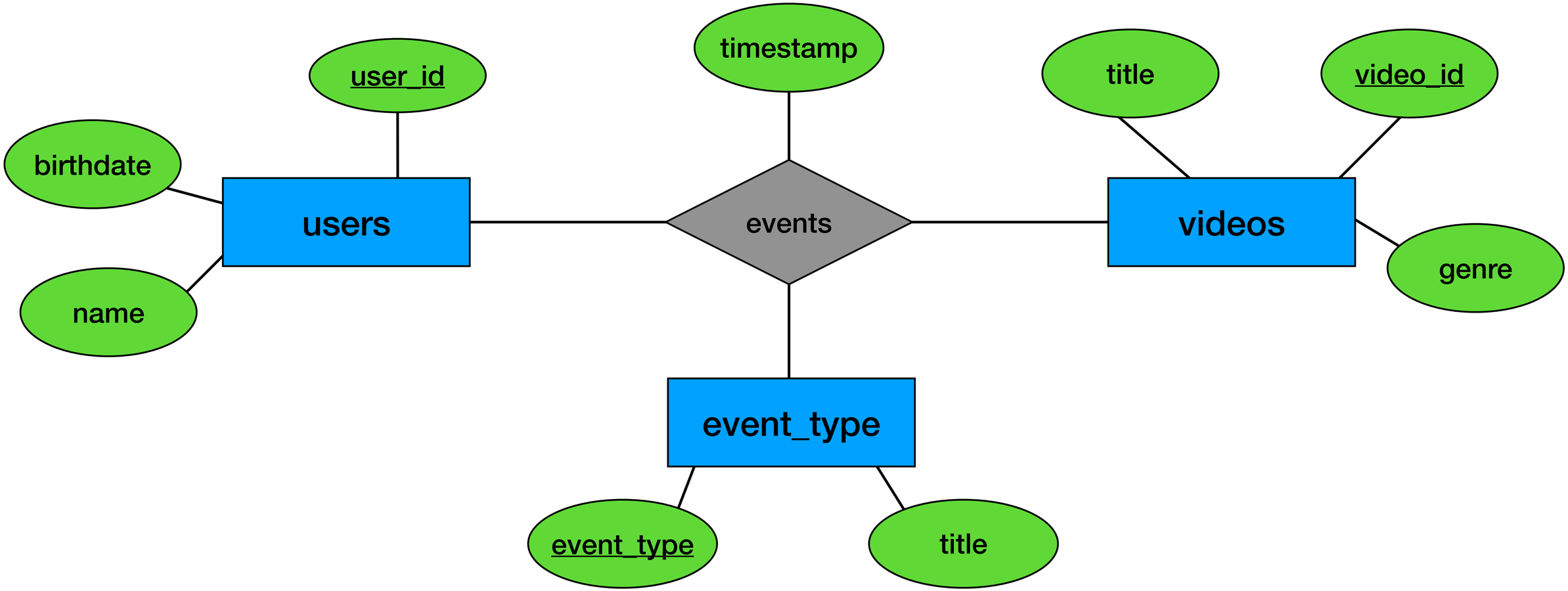

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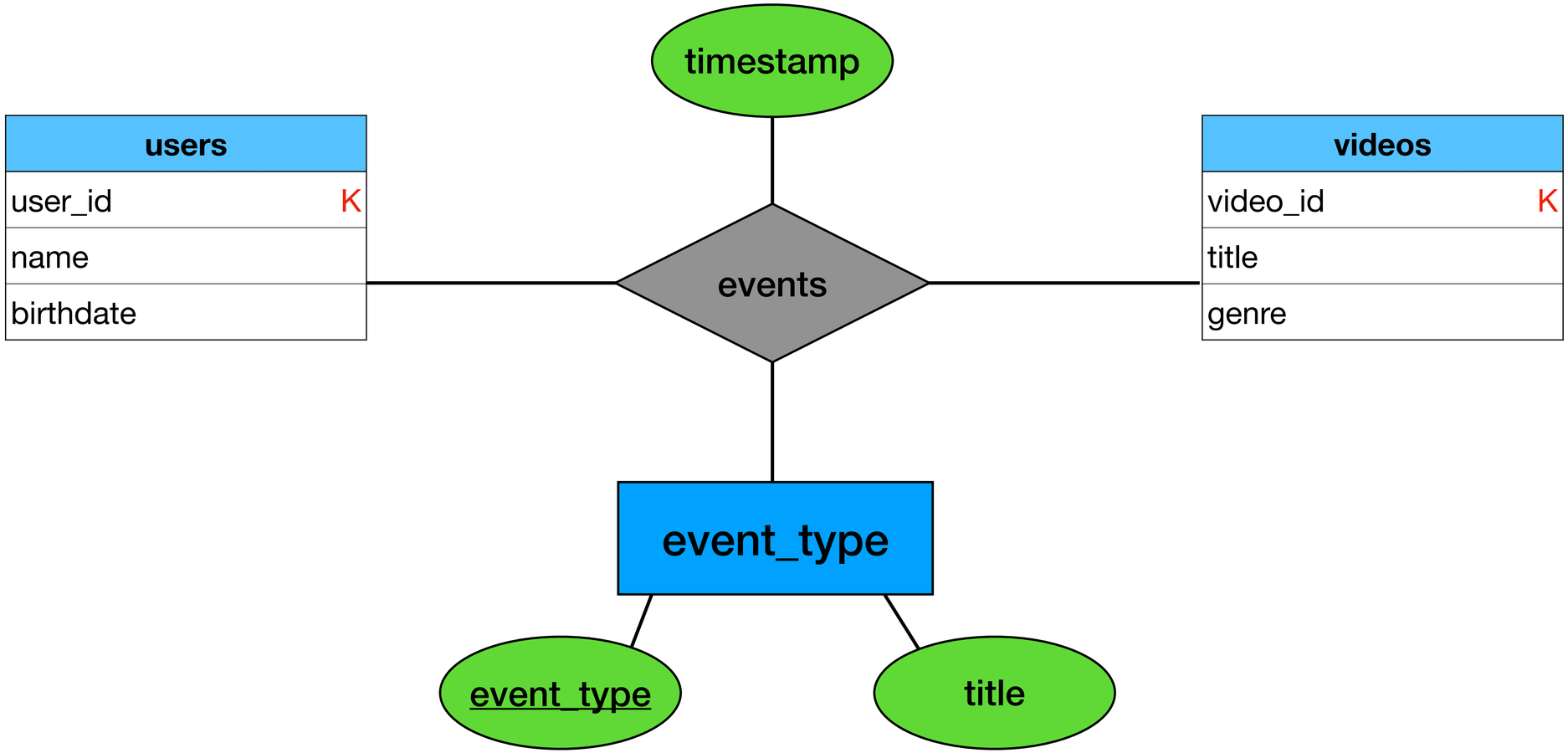

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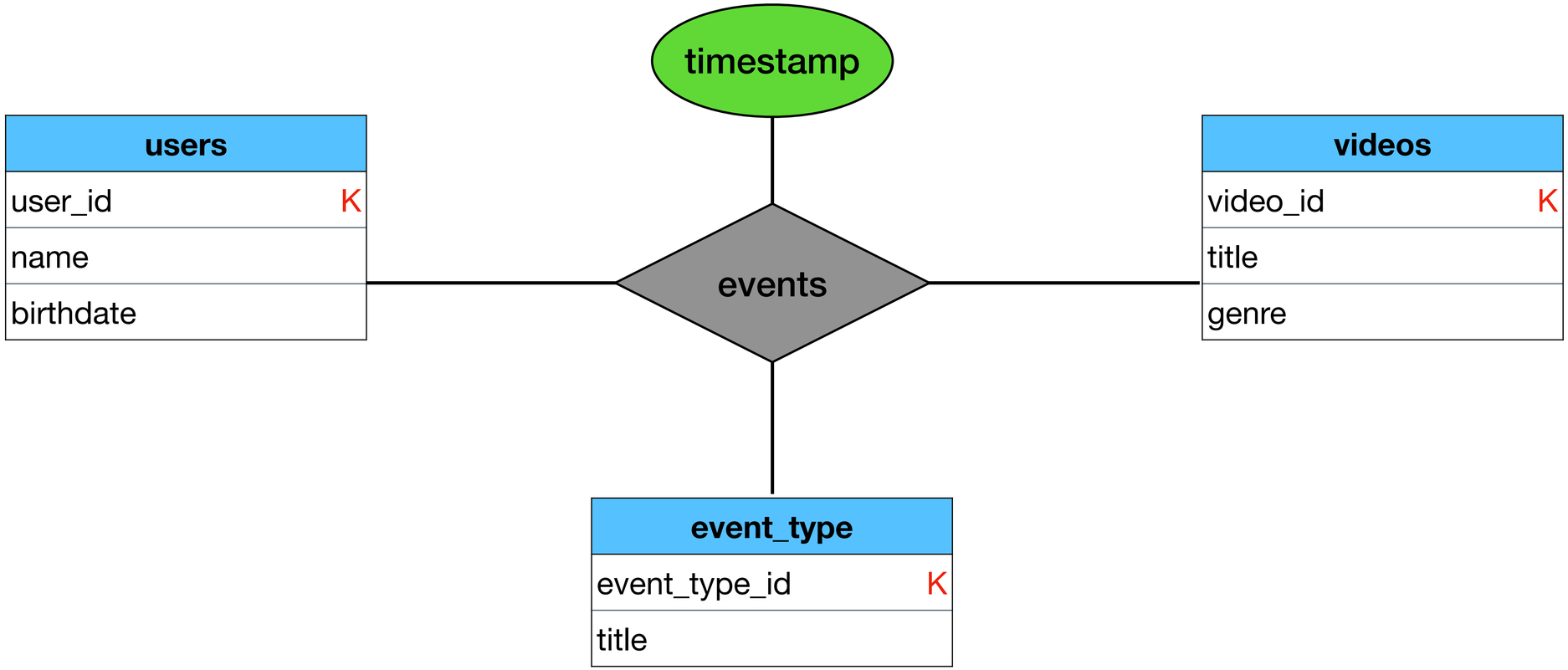

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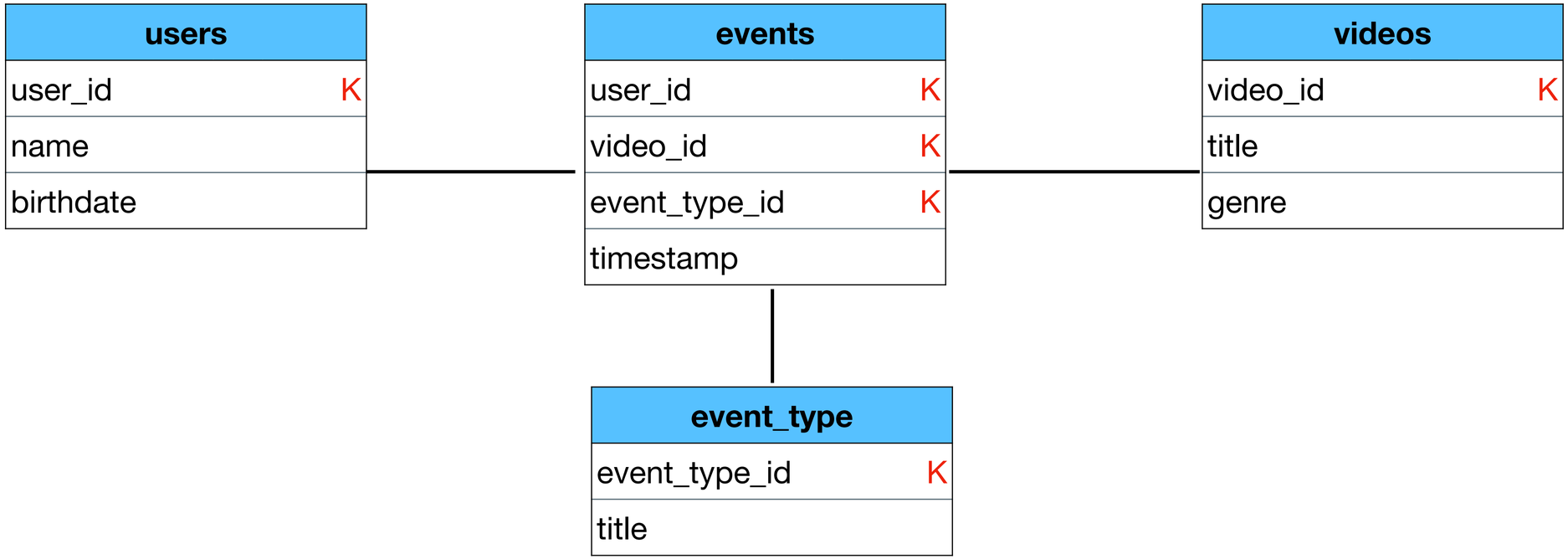

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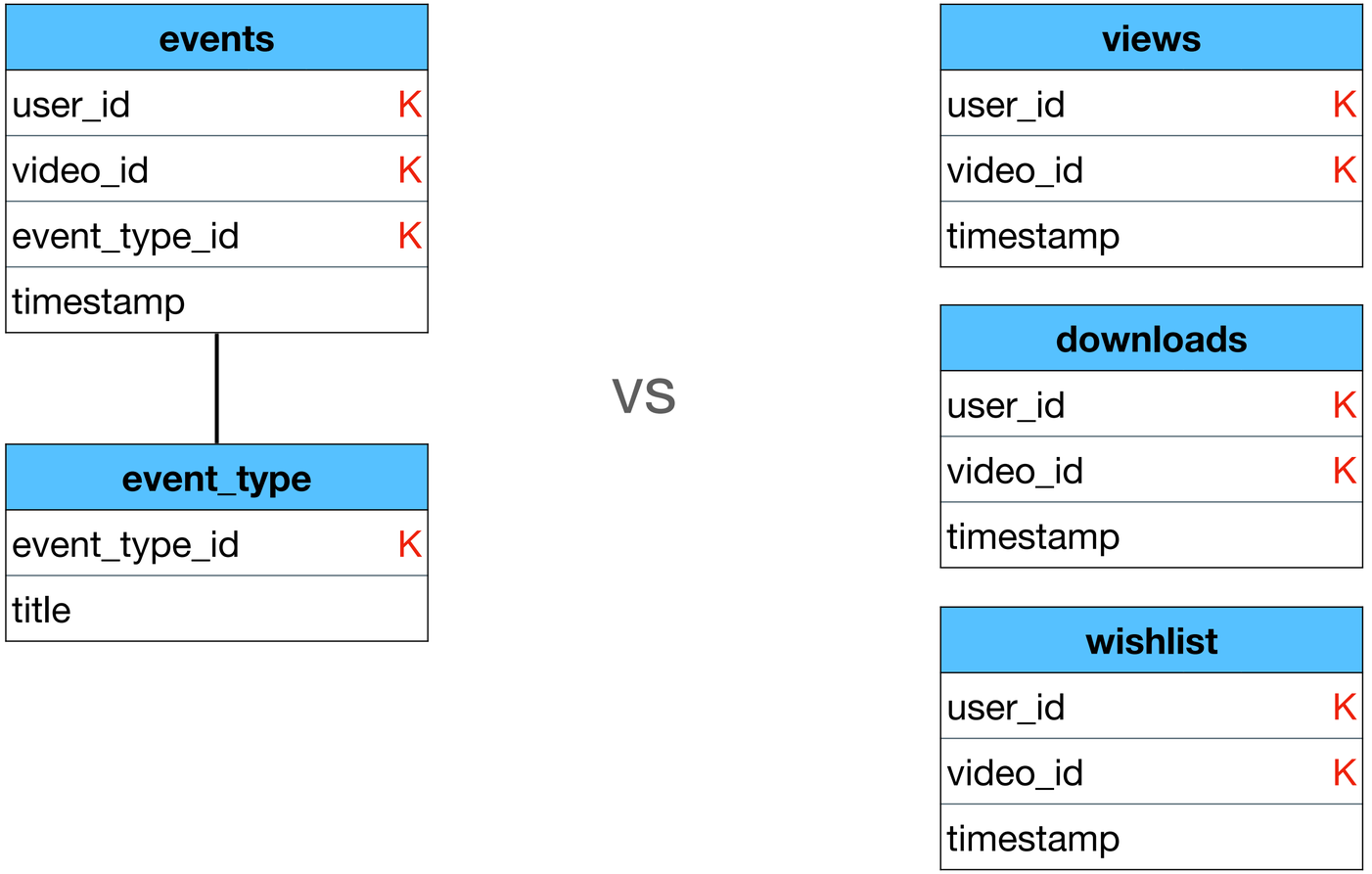
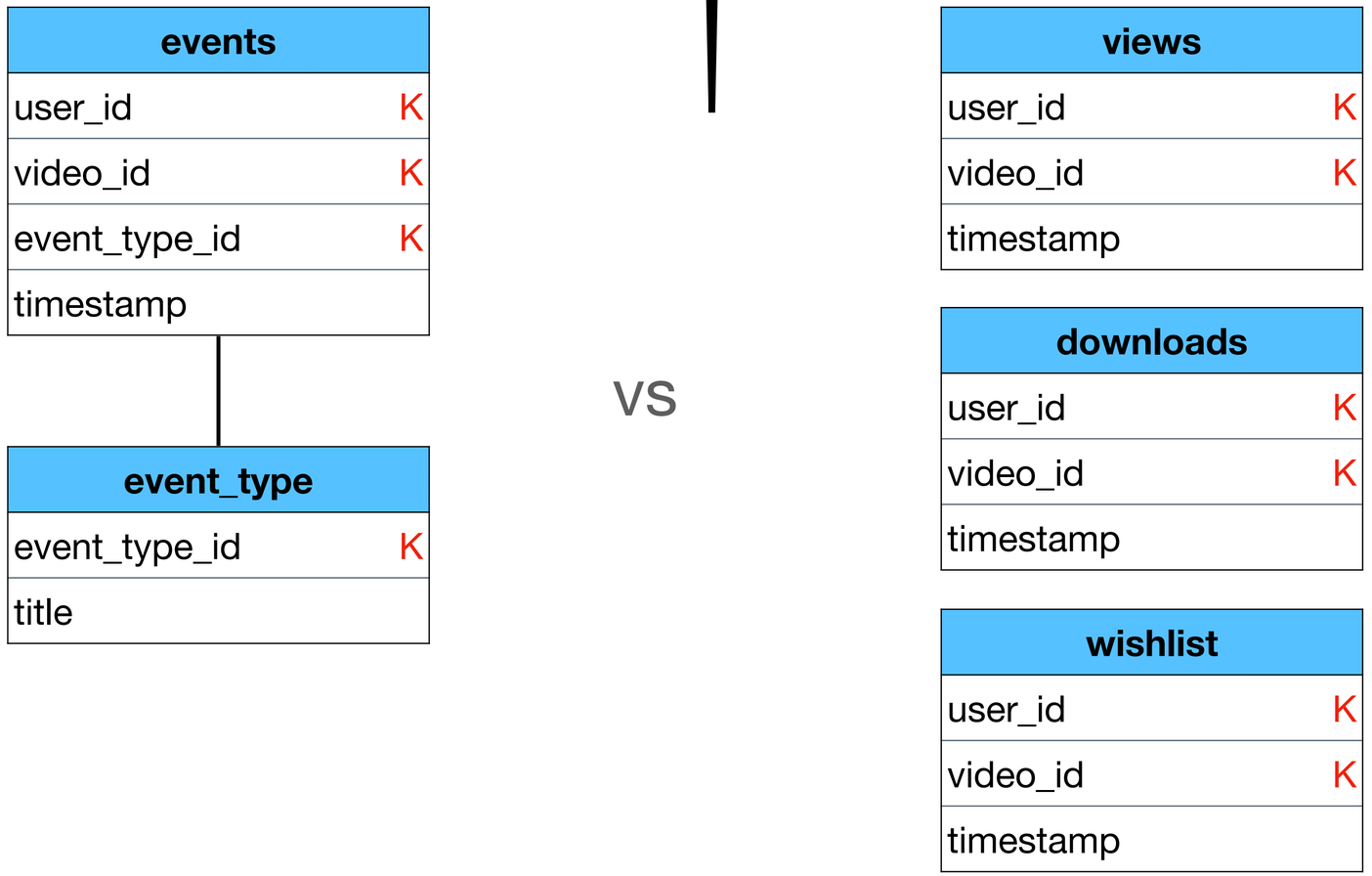


Example (6)

If we might have new types of events in the future

- So which version is better?



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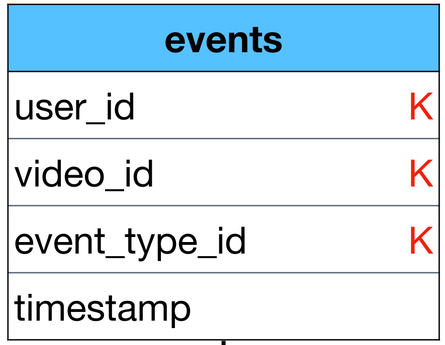
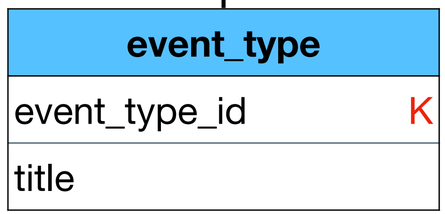
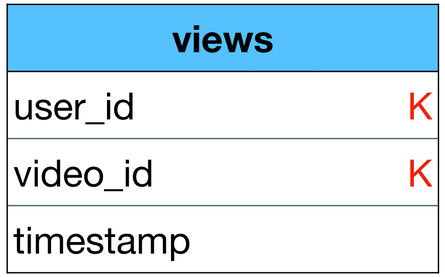
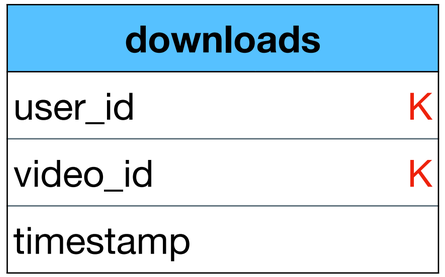


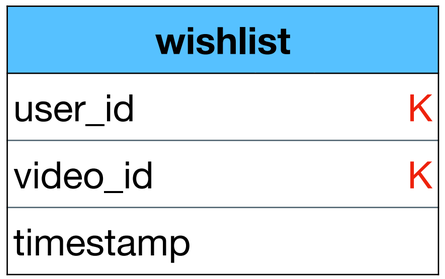


This is better. Why?

VS







Example (6)

If we might have new types of events in the future

- So which version is better?

events	
user_id	K
video_id	K
event_type_id	K
timestamp	

event_type	
event_type_id	K
title	

New types do not require schema changes

This is better. Why?

vs

views	
user_id	K
video_id	K
timestamp	

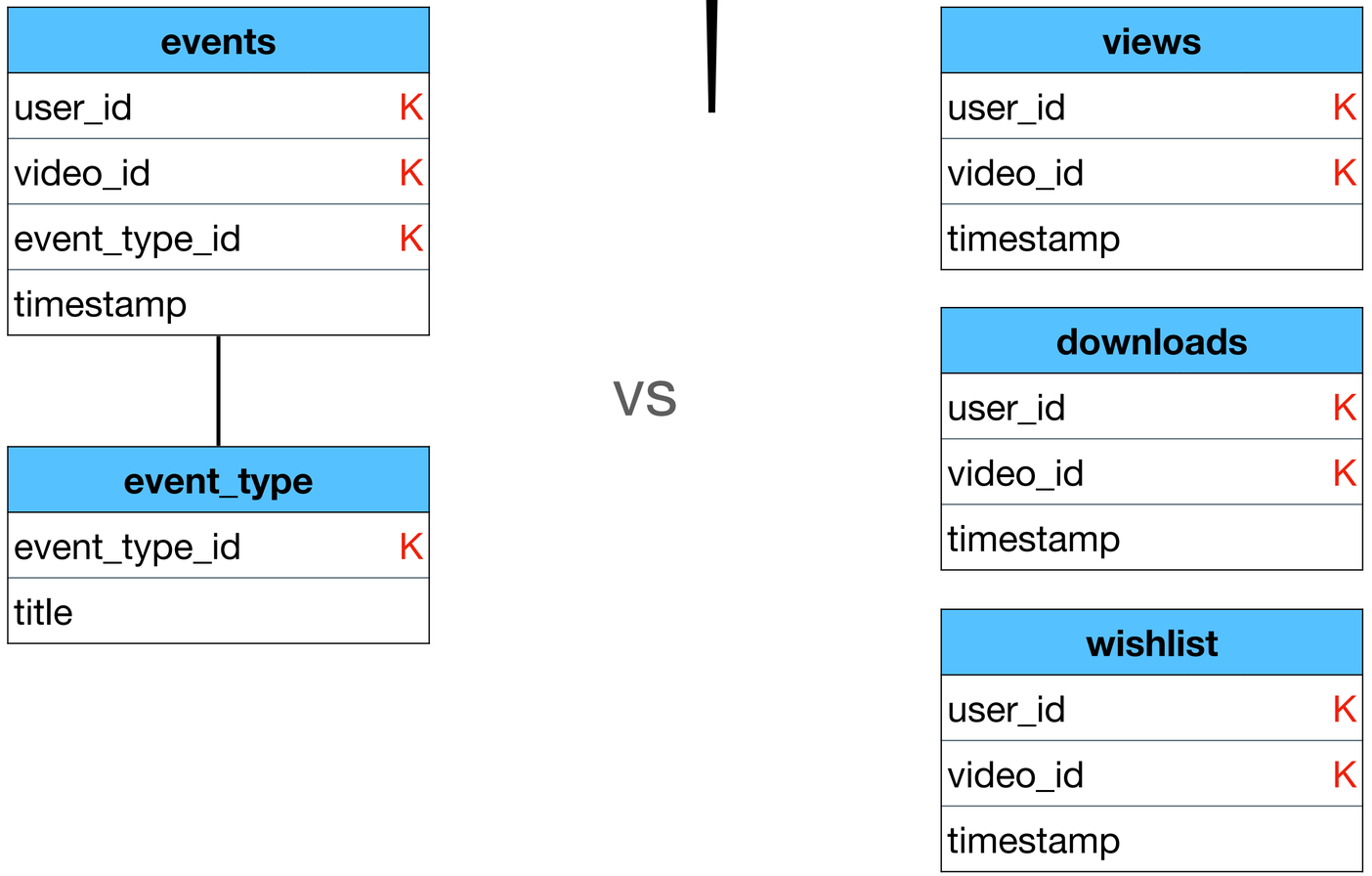
downloads	
user_id	K
video_id	K
timestamp	

wishlist	
user_id	K
video_id	K
timestamp	

Example (6)

Not all dev teams have access to “views” data

- So which version is better?



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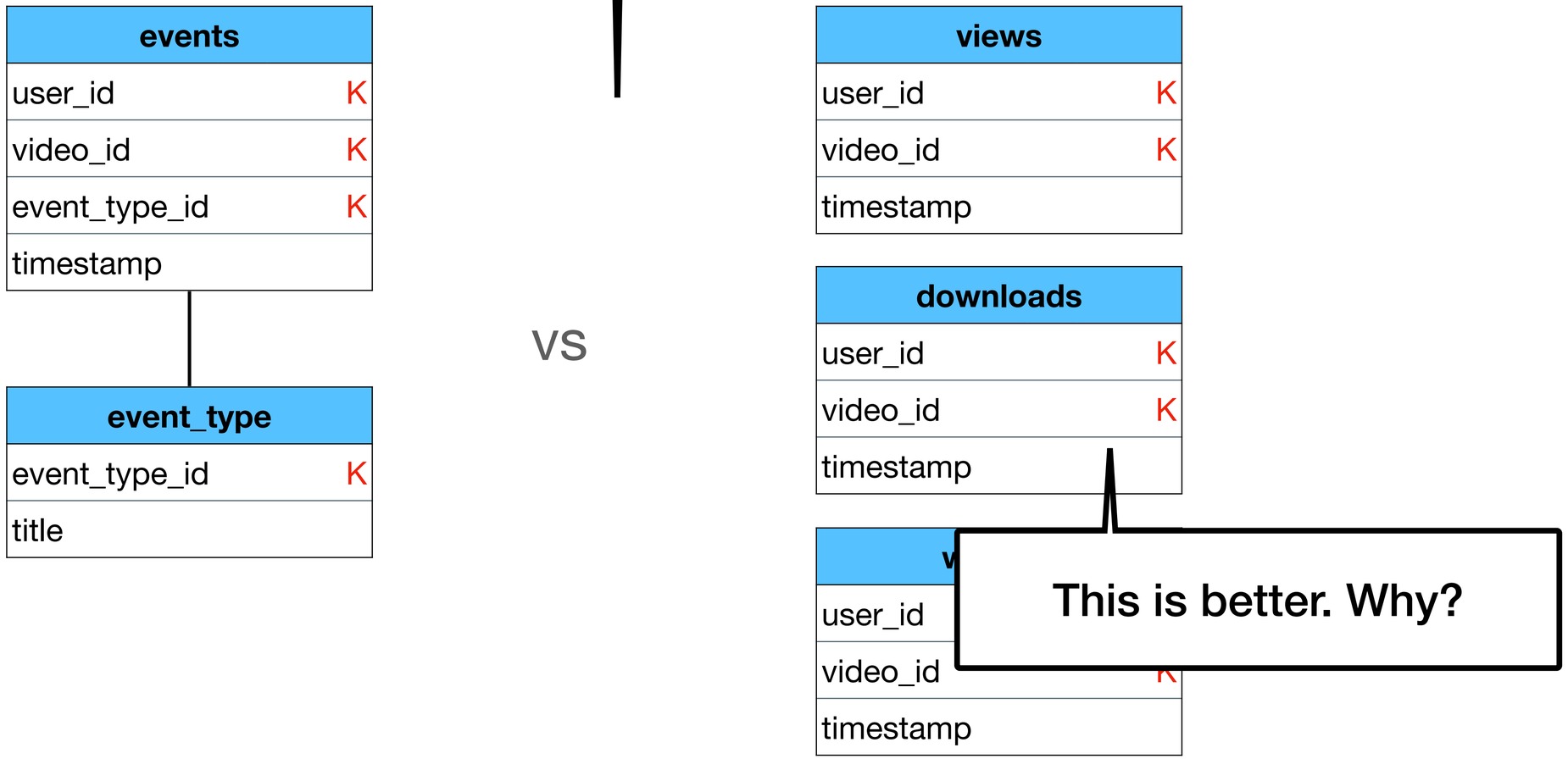

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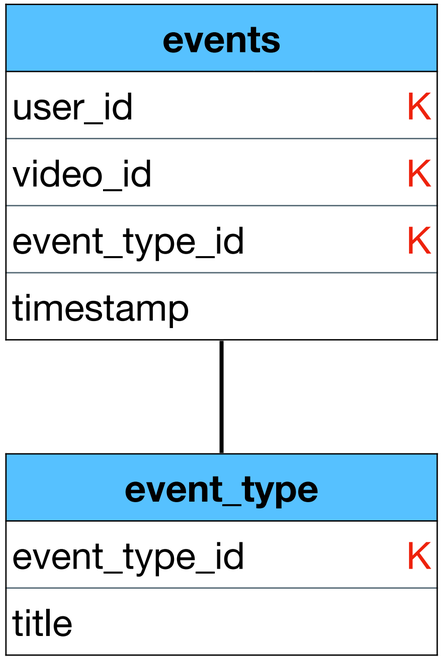
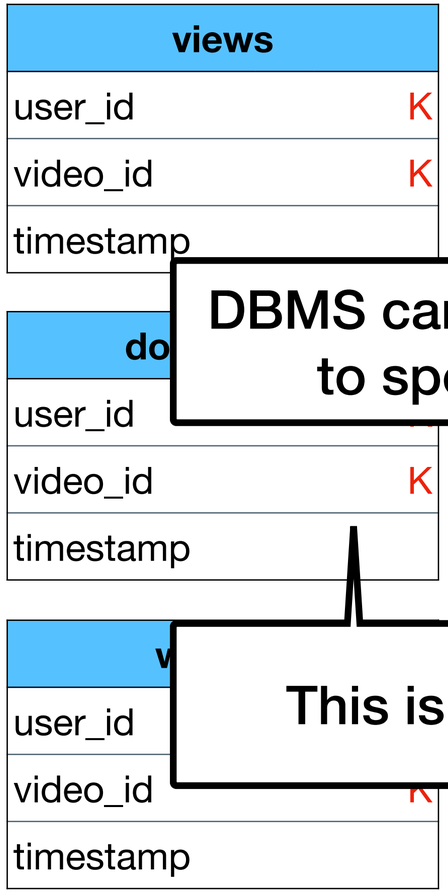


vs



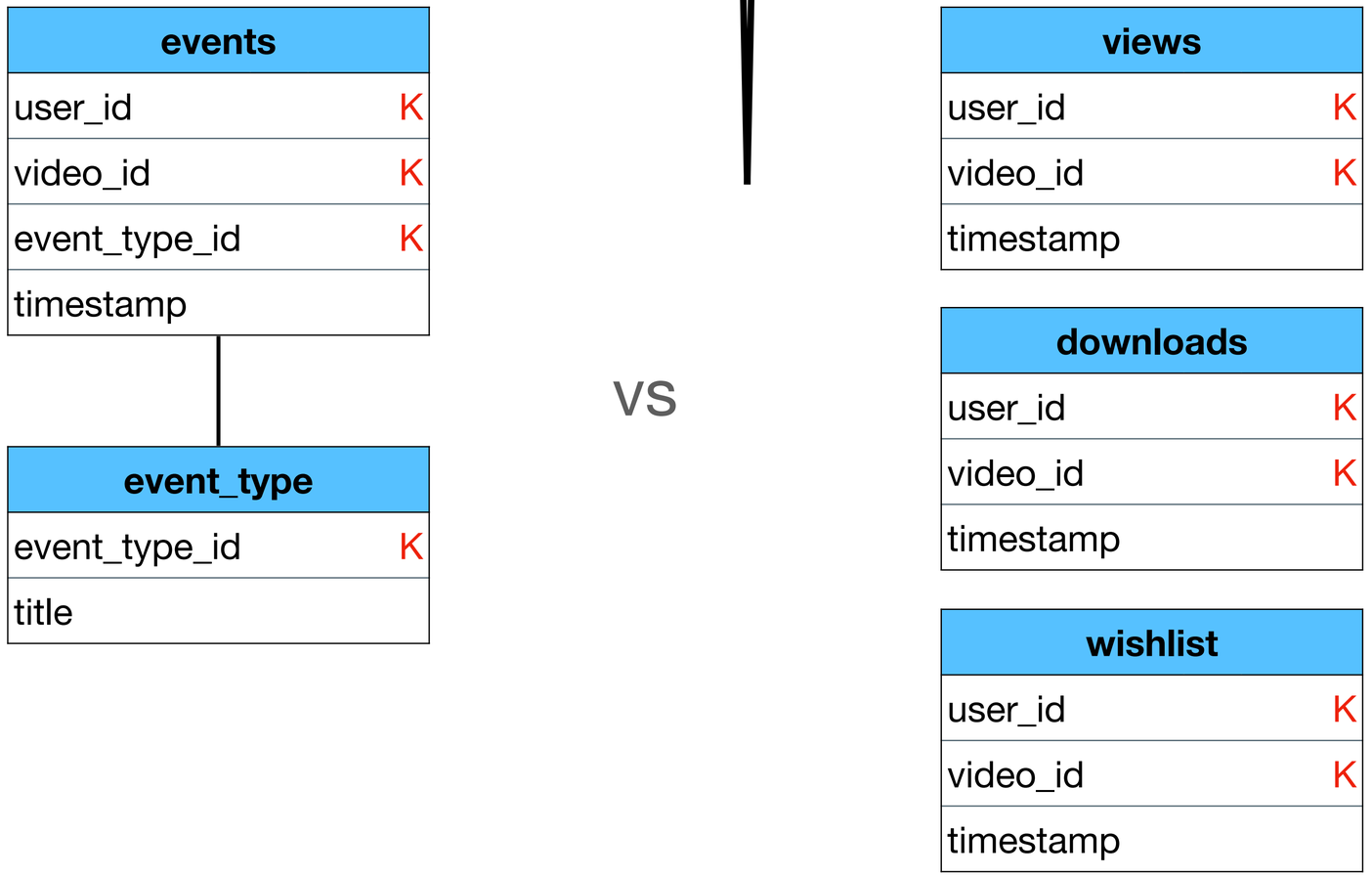
DBMS can restrict access to specific tables

This is better. Why?

Example (6)

Assume most of our queries requires only the wishlist data.
How many queries we need for each version?
How much each query “cost”?

- So which version is better?



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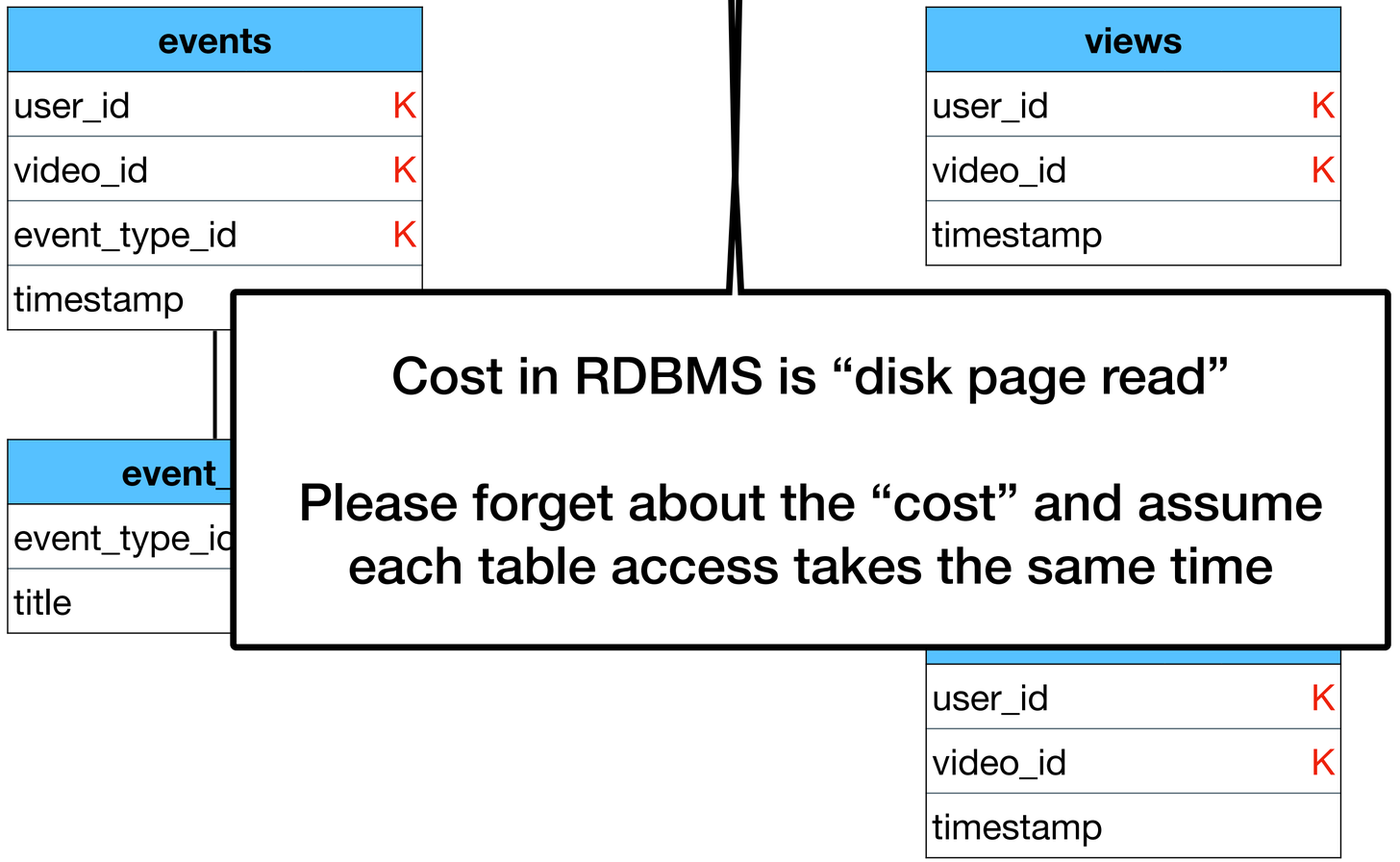

Cost in RDBMS is “disk page read”

Please forget about the “cost” and assume each table access takes the same time

Example (6)

Assume most of our queries requires only the wishlist data.
How many queries we need for each version?
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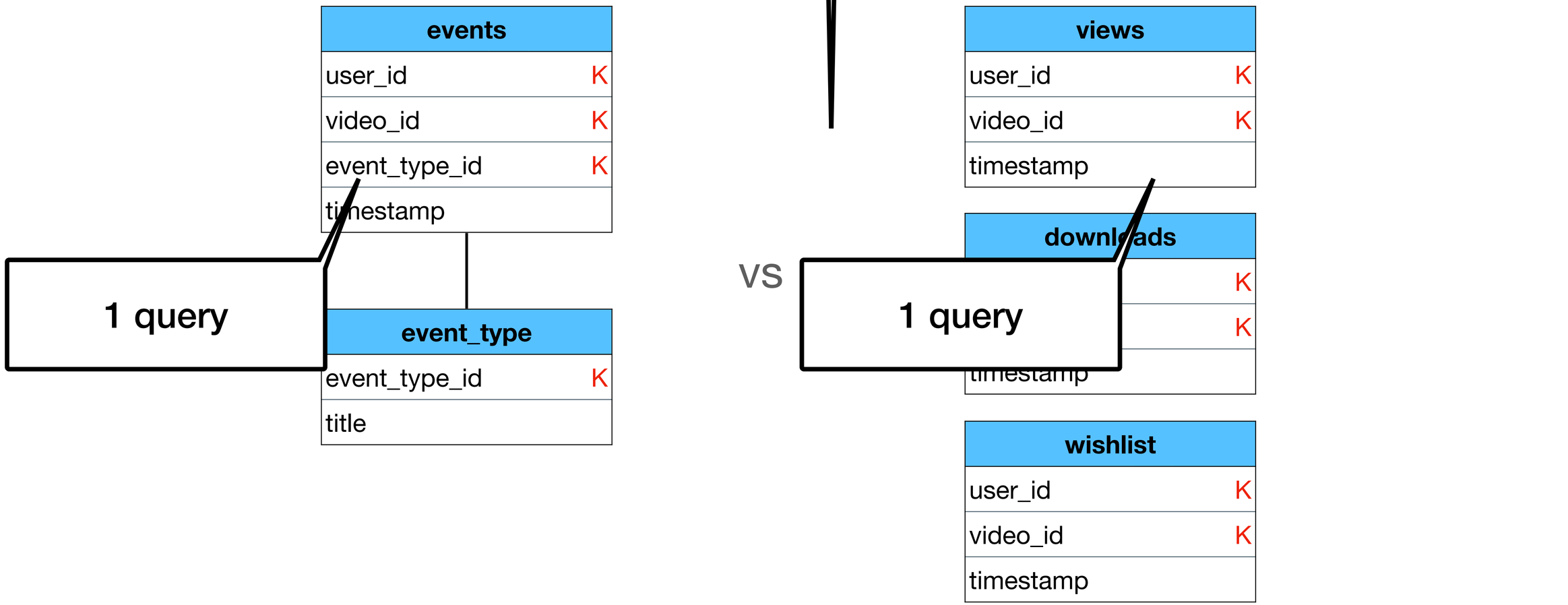
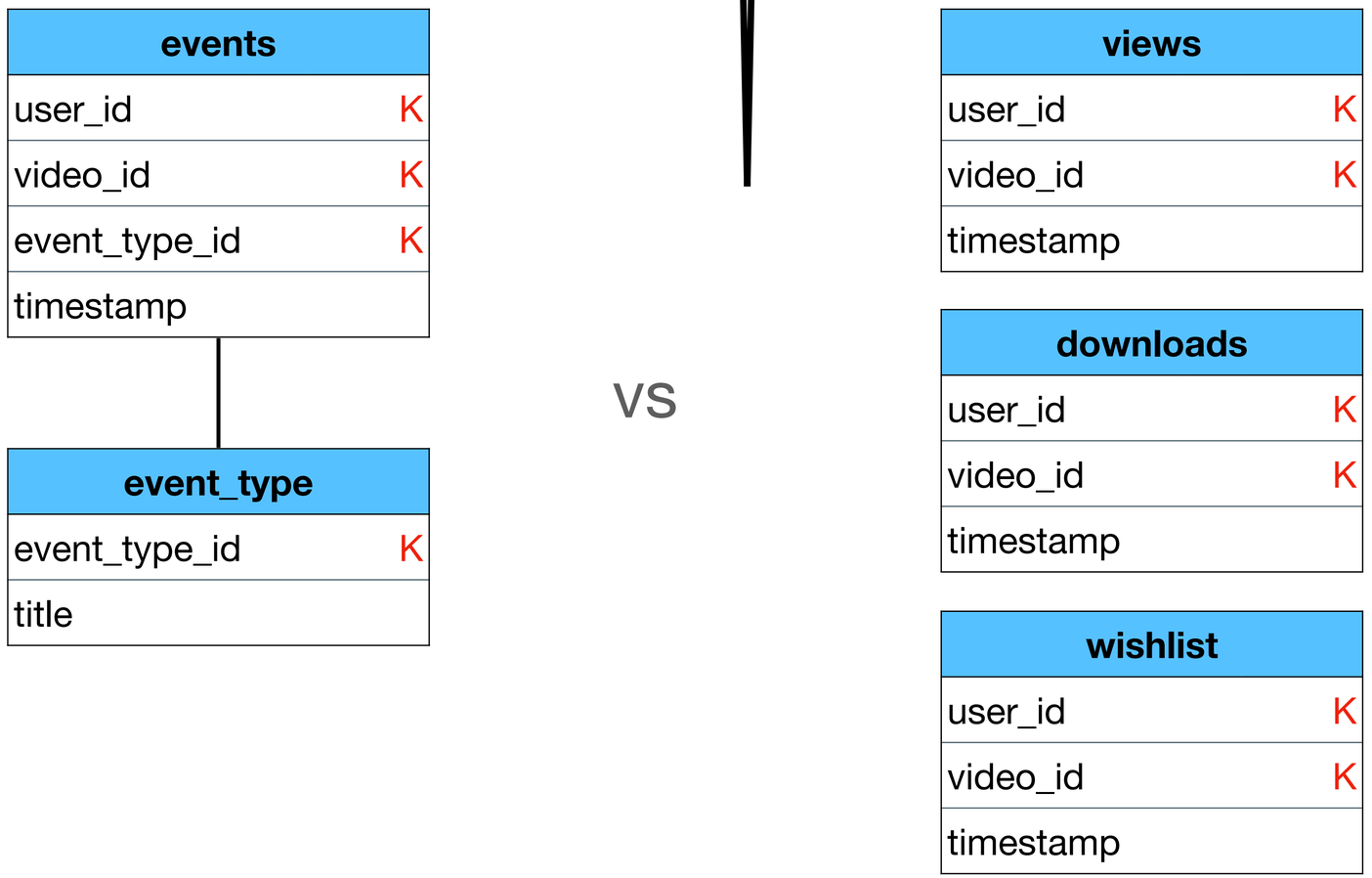


Example (6)

Assume most of our queries requires only the **wishlist** data AND the **downloads**
How many queries we need for each version?

- So which version is better?



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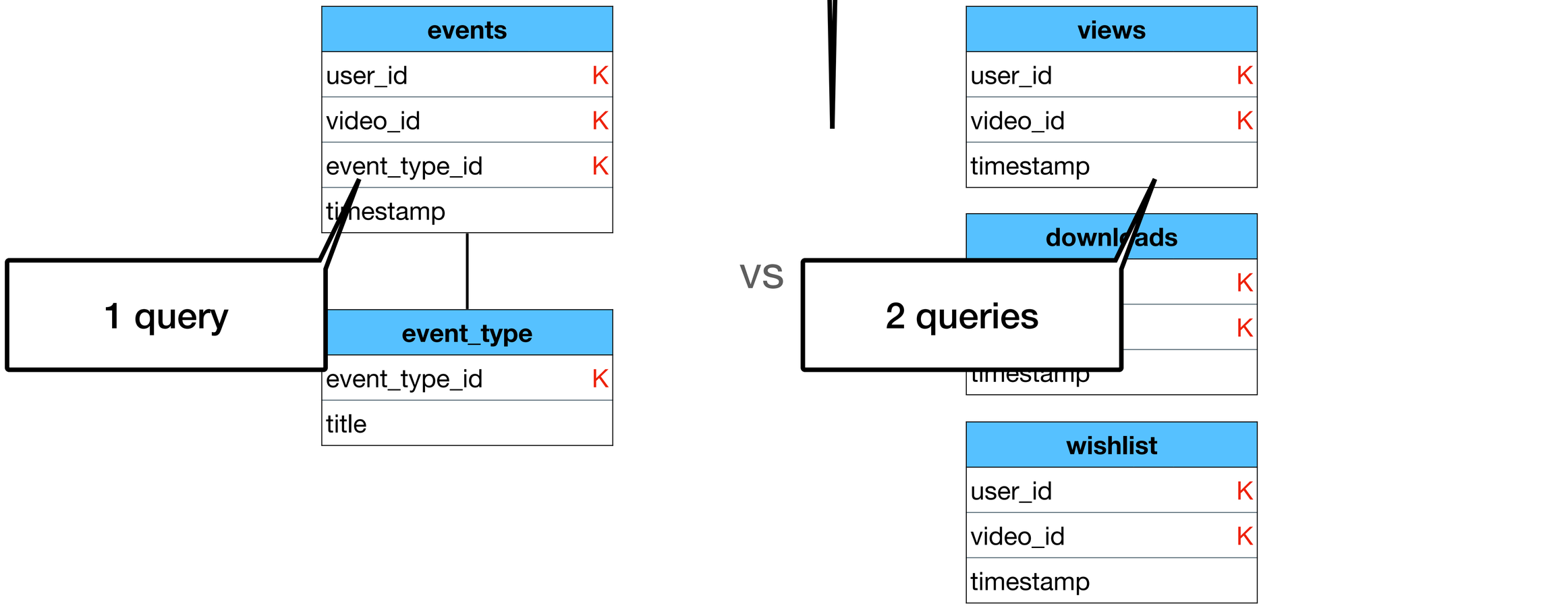

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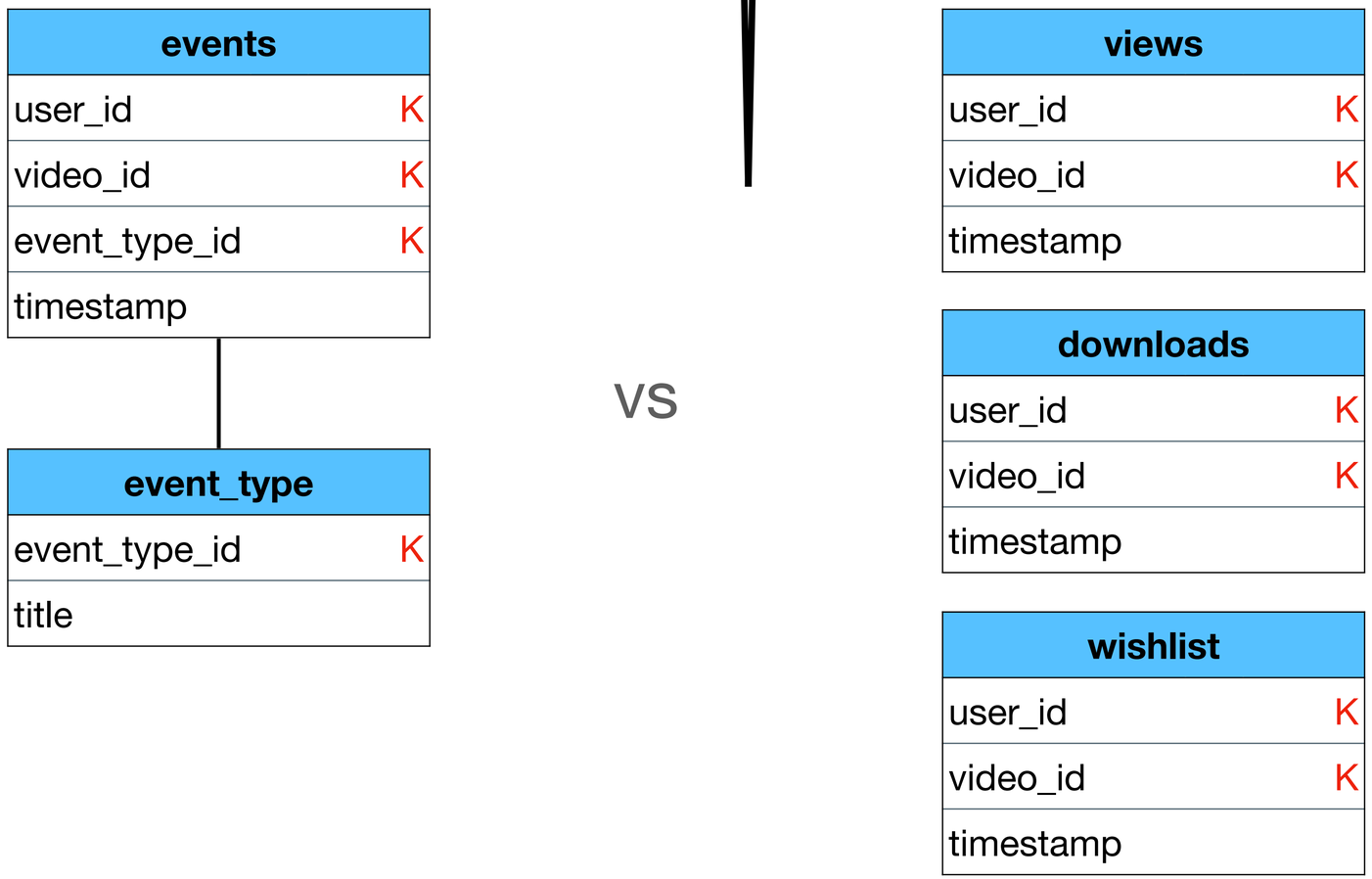

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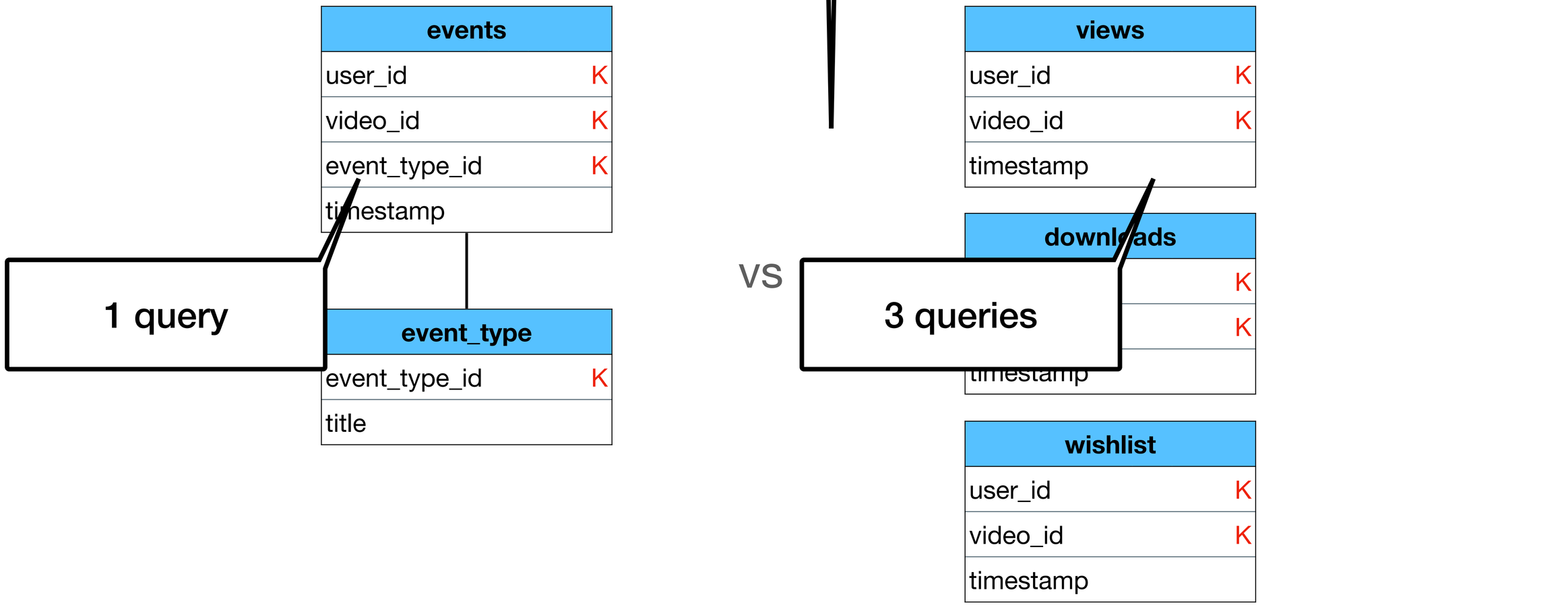

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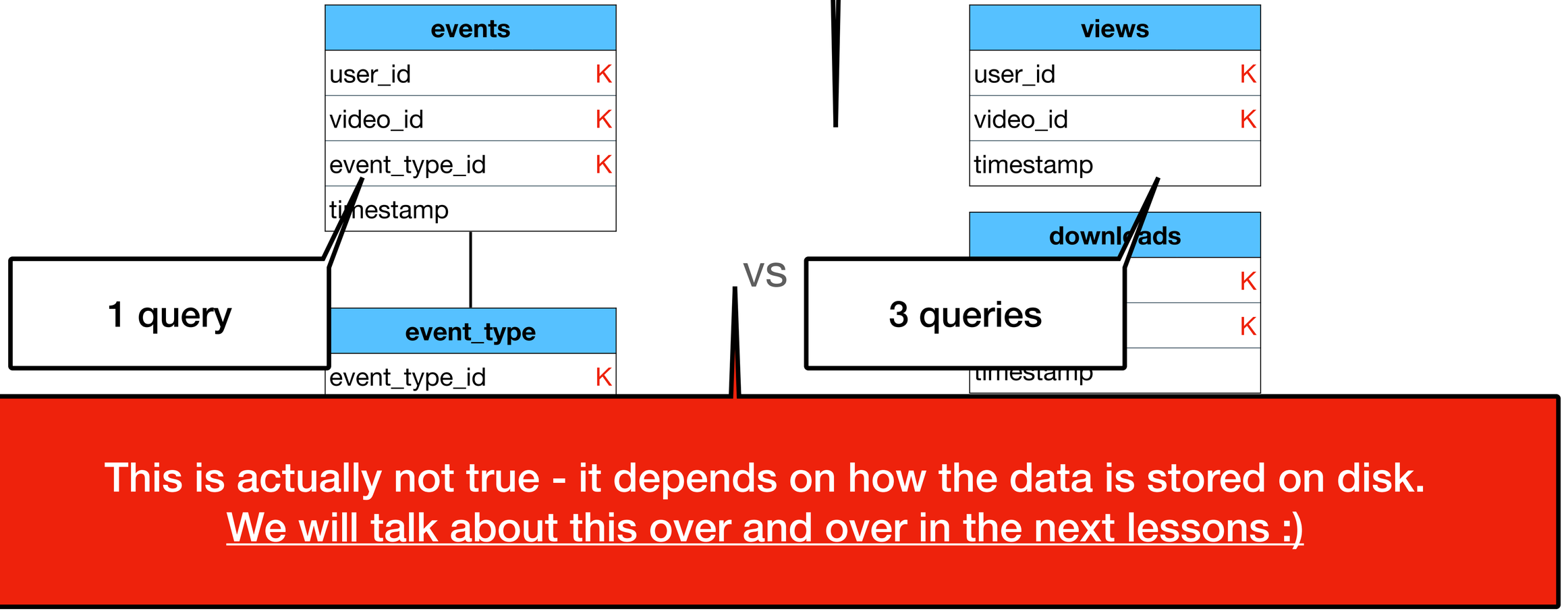
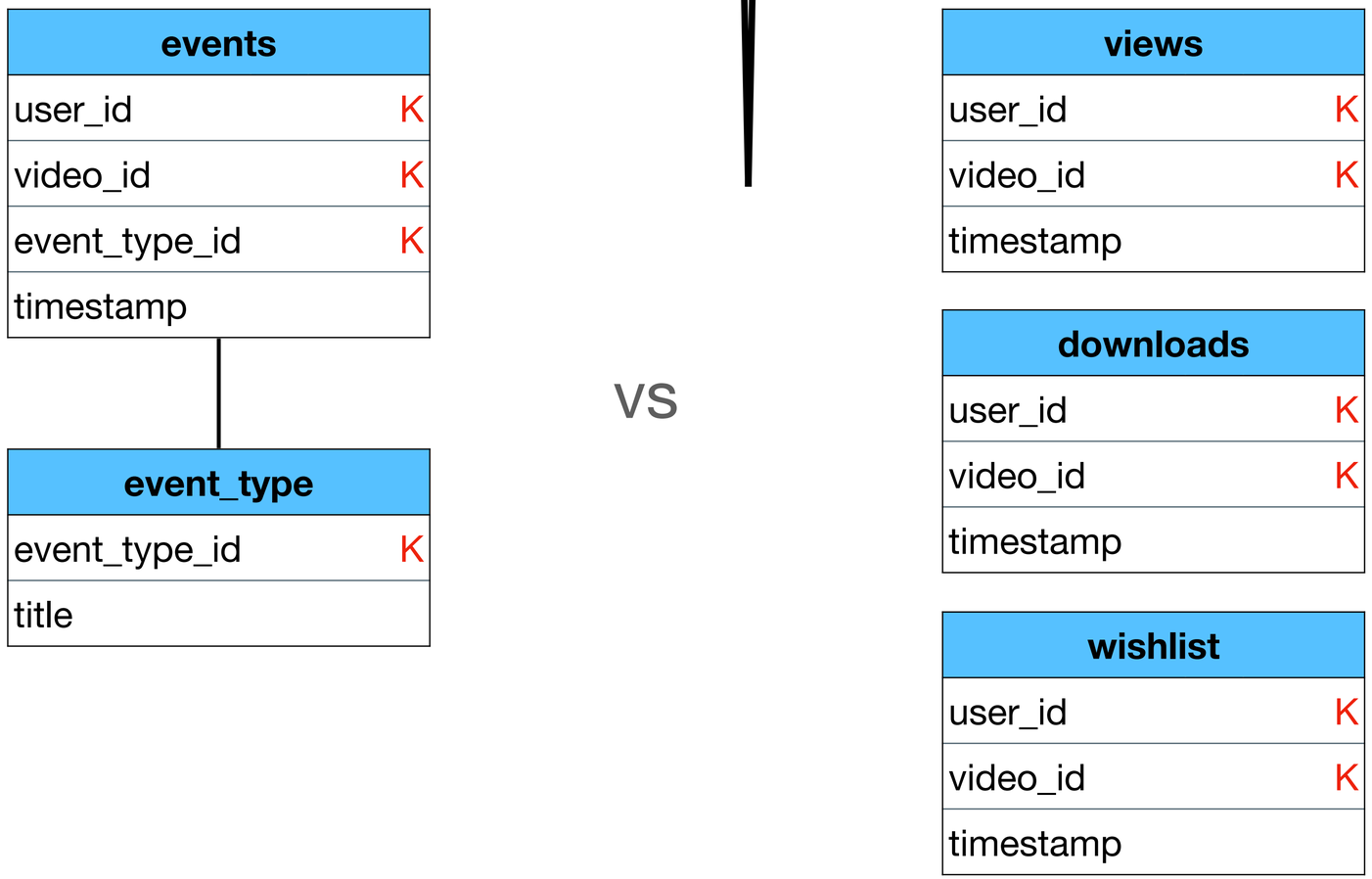


This is actually not true - it depends on how the data is stored on disk.
We will talk about this over and over in the next lessons :)

Example (6)

Assume events have different distributions.
For each 10 views there is 1 download and 1 wishlist events
Would you change your previous answers?

- So which version is better?



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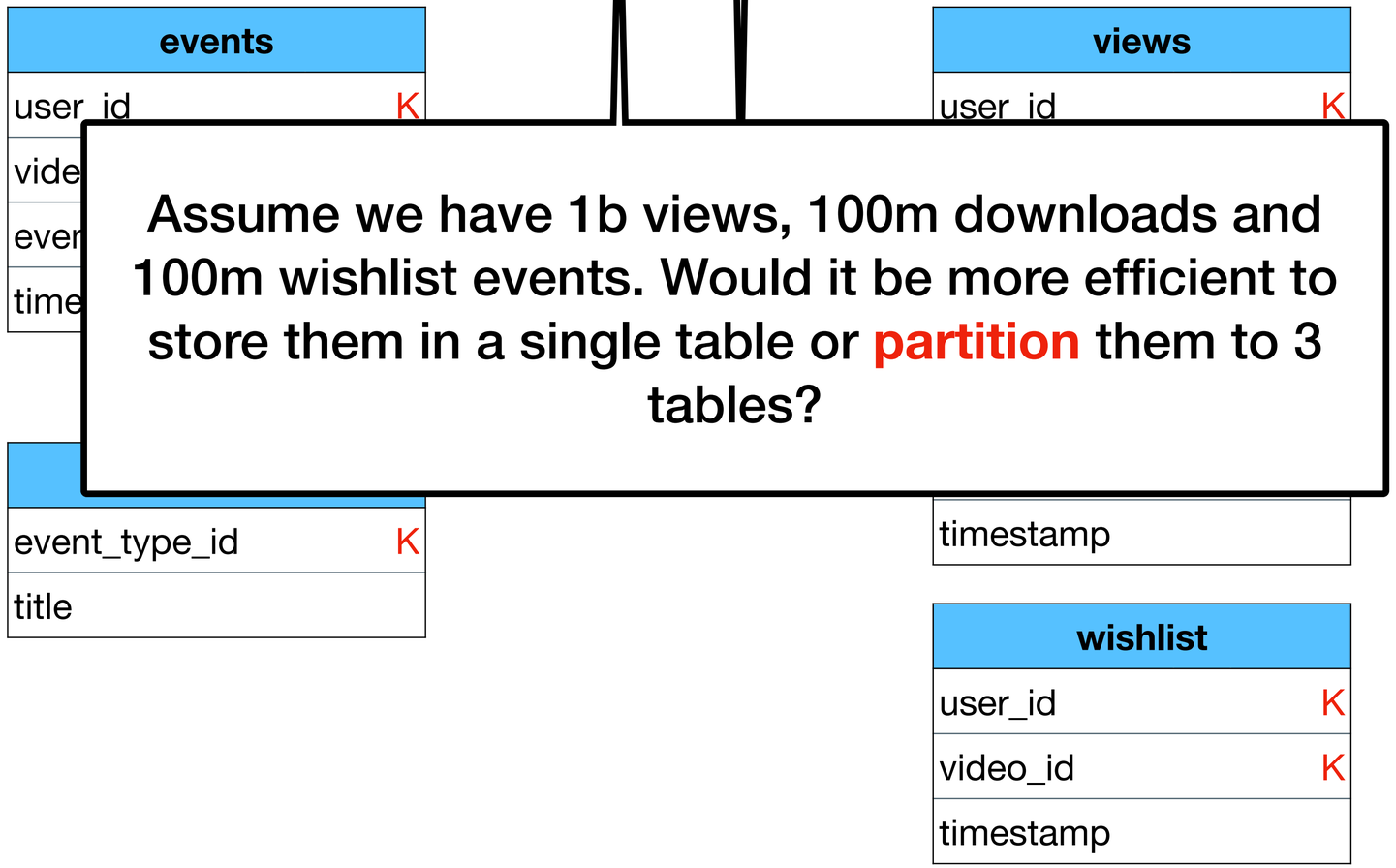

Assume we have 1b views, 100m downloads and 100m wishlist events. Would it be more efficient to store them in a single table or **partition** them to 3 tables?

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For each 10 views there is 1 download and 1 wishlist events
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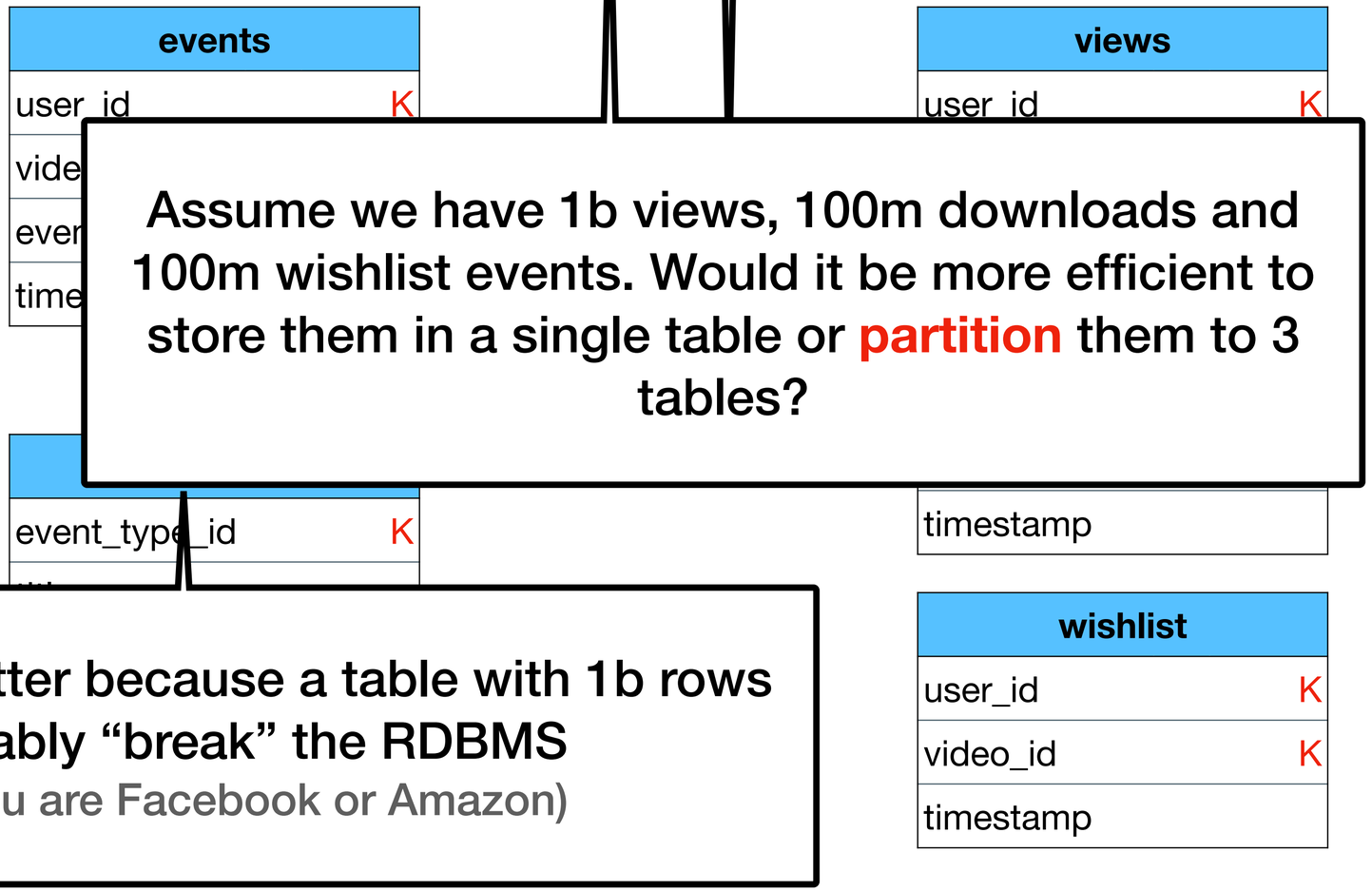

Assume we have 1b views, 100m downloads and 100m wishlist events. Would it be more efficient to store them in a single table or **partition** them to 3 tables?

Doesn't really matter because a table with 1b rows will probably "break" the RDBMS
(Unless you are Facebook or Amazon)

Example (6)

- So which version is better?

Assume events have different distributions.
For each 10 views there is 1 download and 1 wishlist events
Would you change your previous answers?

Don’t worry - this is the “Big Data System” course, not “Database Systems”.
We will solve this soon :)

tables?

event_type_id	K

timestamp

wishlist	
user_id	K
video_id	K
timestamp	

Doesn’t really matter because a table with 1b rows will probably “break” the RDBMS
(Unless you are Facebook or Amazon)