High Level Database Models

Thomas Schwarz, SJ

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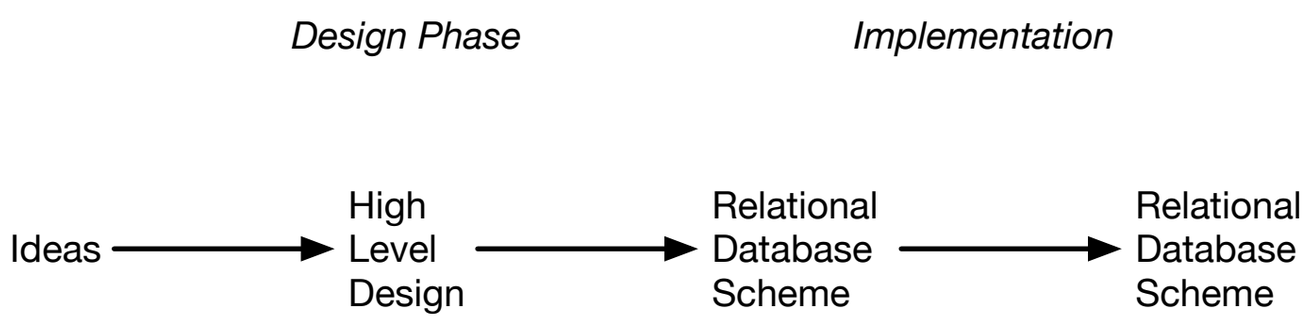


- Design Language:
  - Entity Relationship Model (ERM)
  - Unified Modeling Language (UML)
  - (Object Description Language ODL)

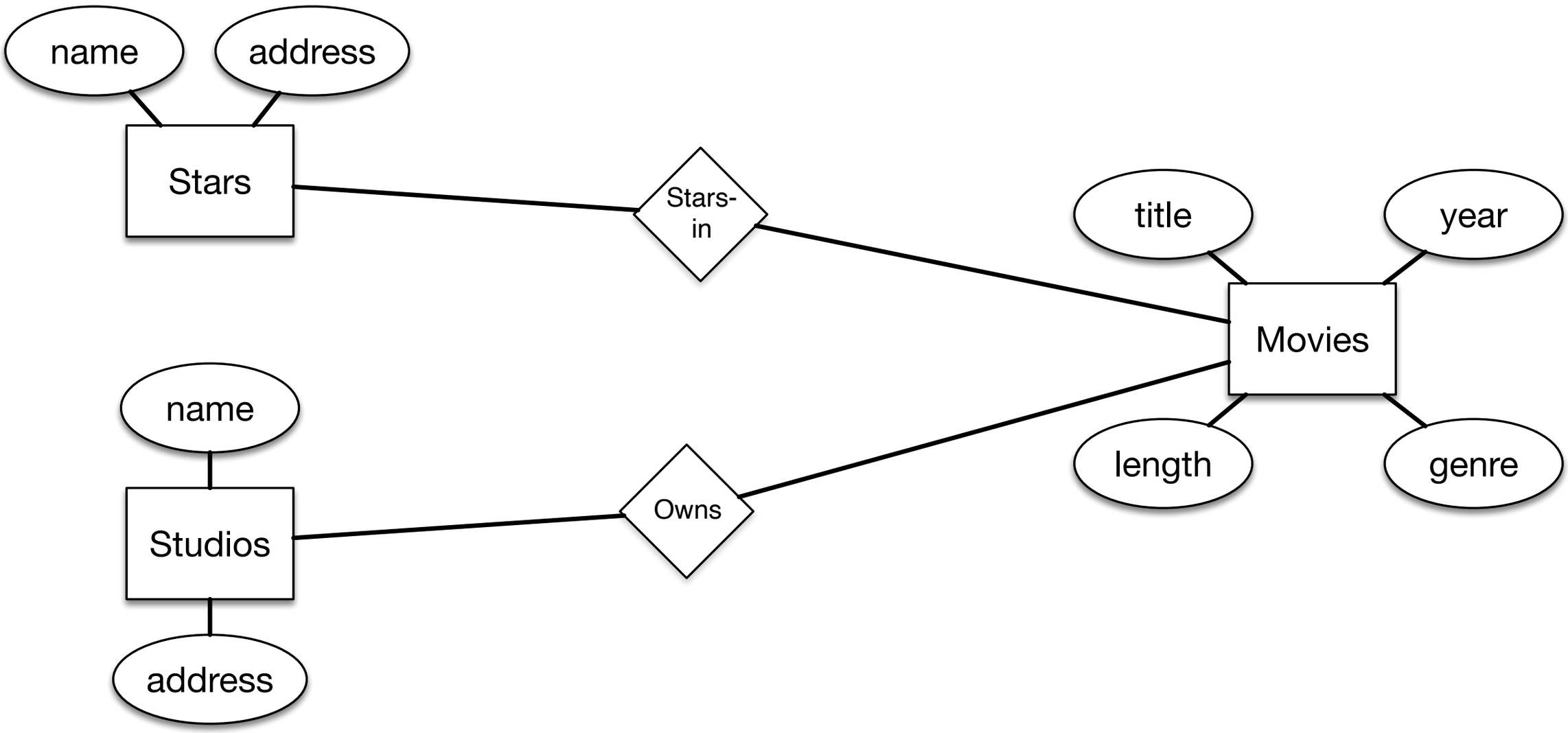
E/R Model

- Entities: Abstract object
  - Have Attributes
    - Types can be primitive or structures
- Relationships
  - Connections between two or more entity sets

E/R Model

- Graphics
  - Entities are represented by rectangles
  - Attributes are represented by ovals
  - Relationships are represented by diamonds
  - Edges connect attributes and relations

E/R Model

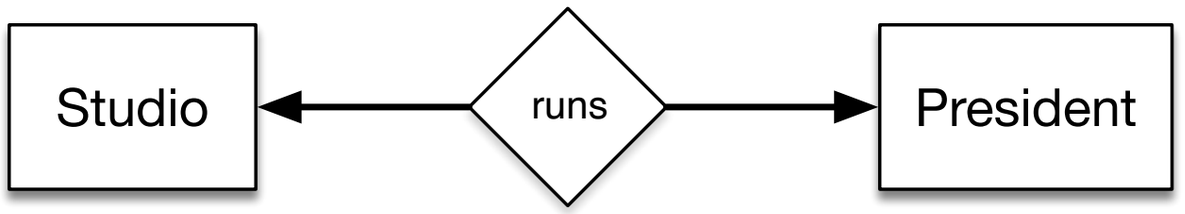

name
address
Stars
Stars-
in
title
year
Movies
length
genre
name
Studios
Owns
address

E/R Model

- Type of binary E/R relationships between entities:
  - Many-to-one
  - One-to-one
  - Many-to-many

E/R Model

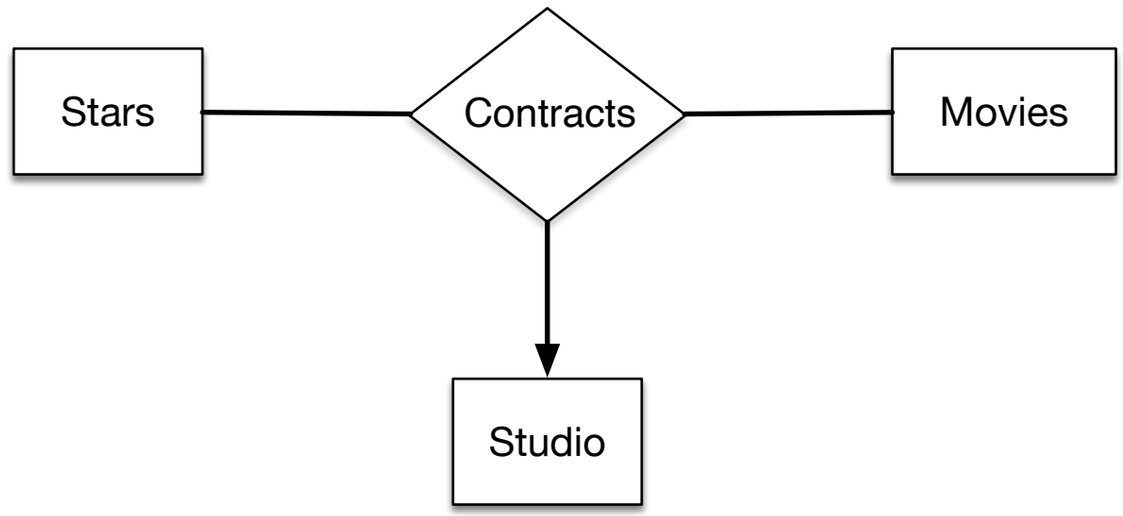
- Example:
  - One president can “run” one studio
  - One studio can only be ‘run” by one president



- The arrow does not guarantee existence, only uniqueness

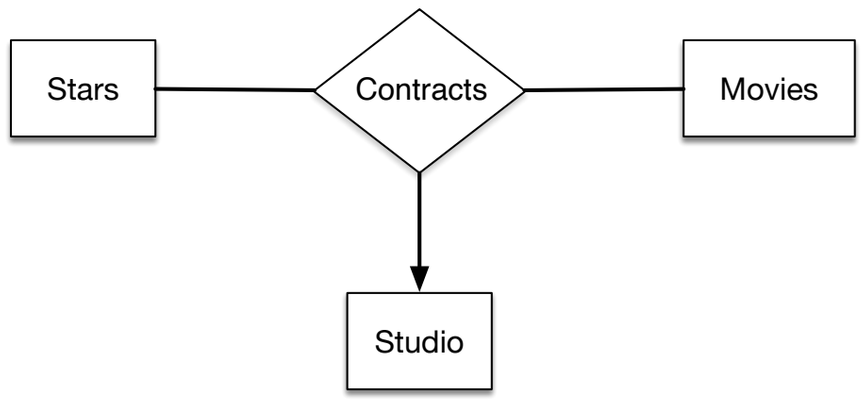
E/R Model

- Ternary relationships
  - Occasionally, relationships involve more than two entities



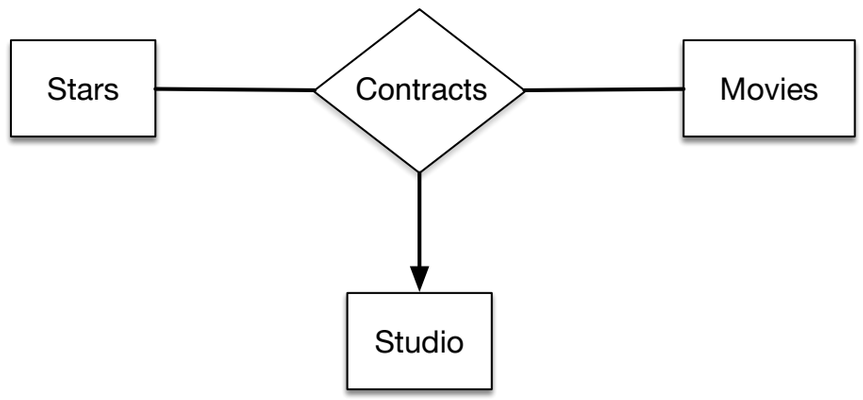
- Contracts involve a studio, a star, and a (set of) movies
  - Each relationship is a triple `(star, movie, studio)`

E/R Model



- The many-to-one relationship means that for a star and for a movie, there can only be one studio
- However, a star can have a contract over many movies
- The studio can contract with several stars for a given movie

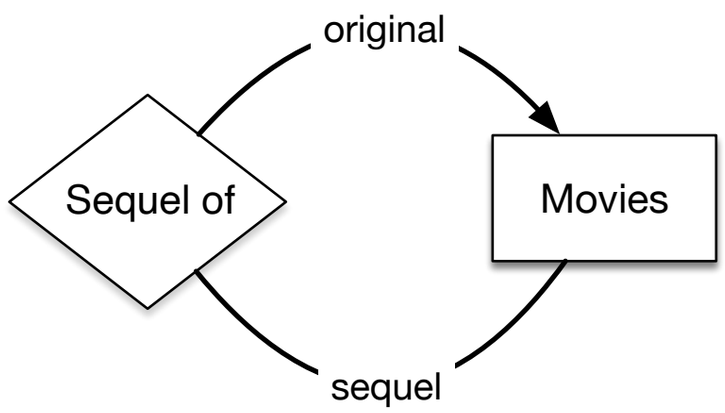
E/R Model



- The arrow notation is limited
  - Studio is only a function of the movie
  - Diagram cannot distinguish between
    - Studio is a function of movie
    - Studio is a function of movie and star

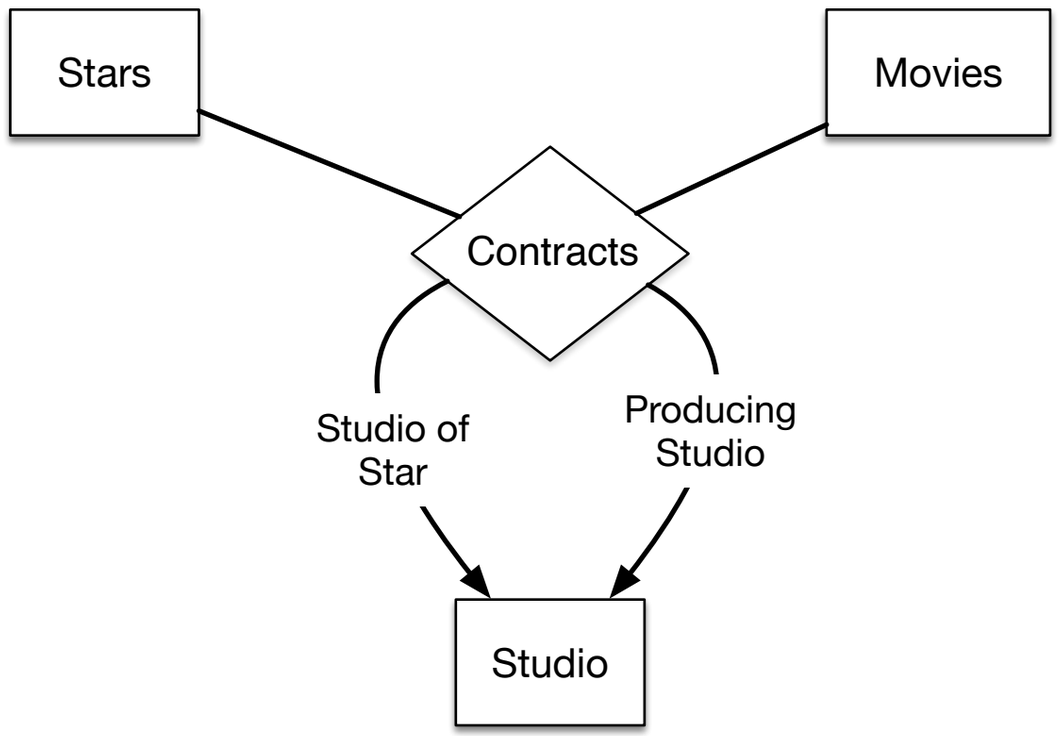
E/R Model

- Roles
  - Entities can appear several times in a relationship
  - Question: Explain the arrow heads or their absence



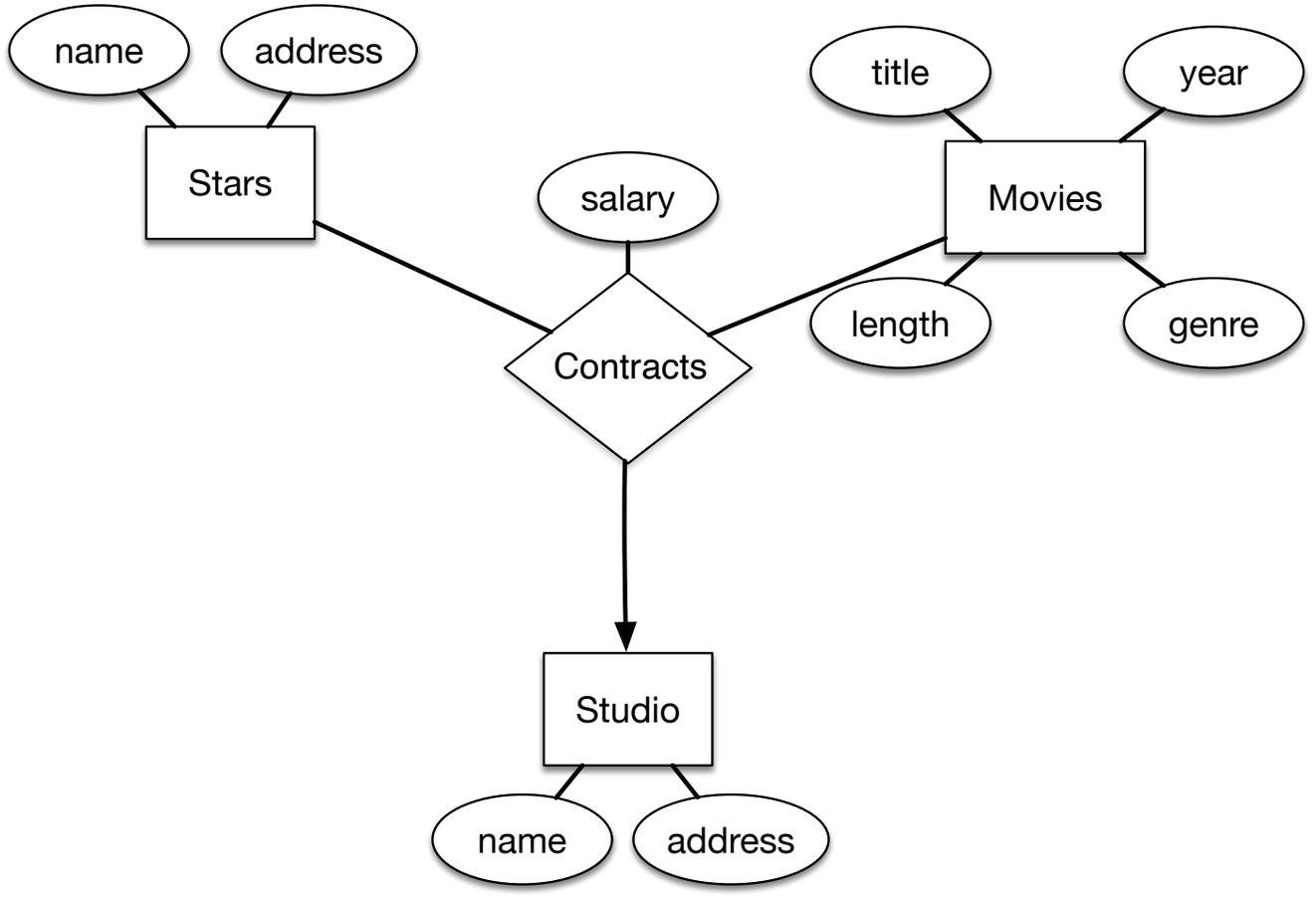
E/R Model

- Example for a multi-way relationship and an entity set with multiple roles
  - Hollywood stars would “belong” to a studio that could lent them out to another studio



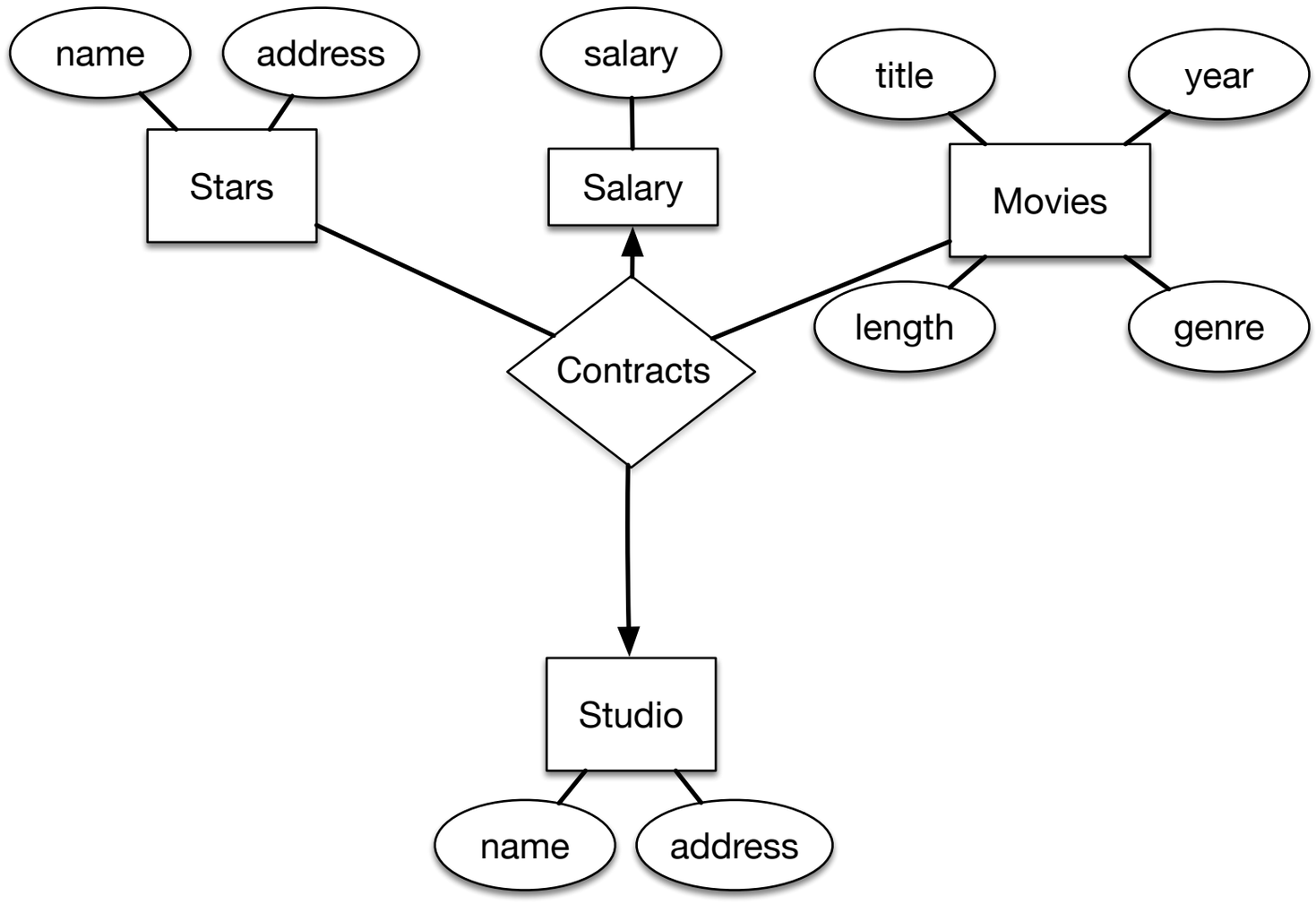
E/R Model

- Relationships can also have attributes
  - The attribute is functionally dependent on all parties to the relationship



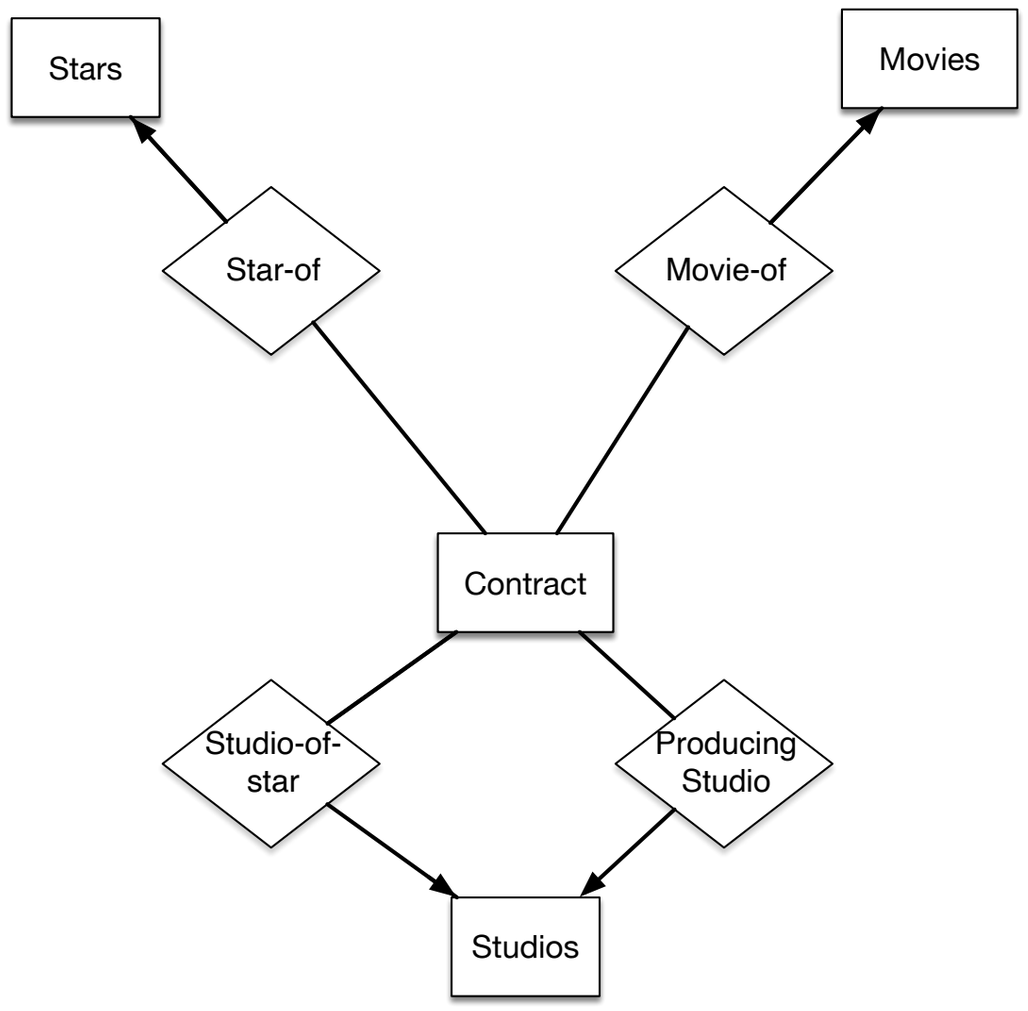
E/R Model

- Some models (UML, ODL) limit relationships to binary
  - Move attributes to an entity set



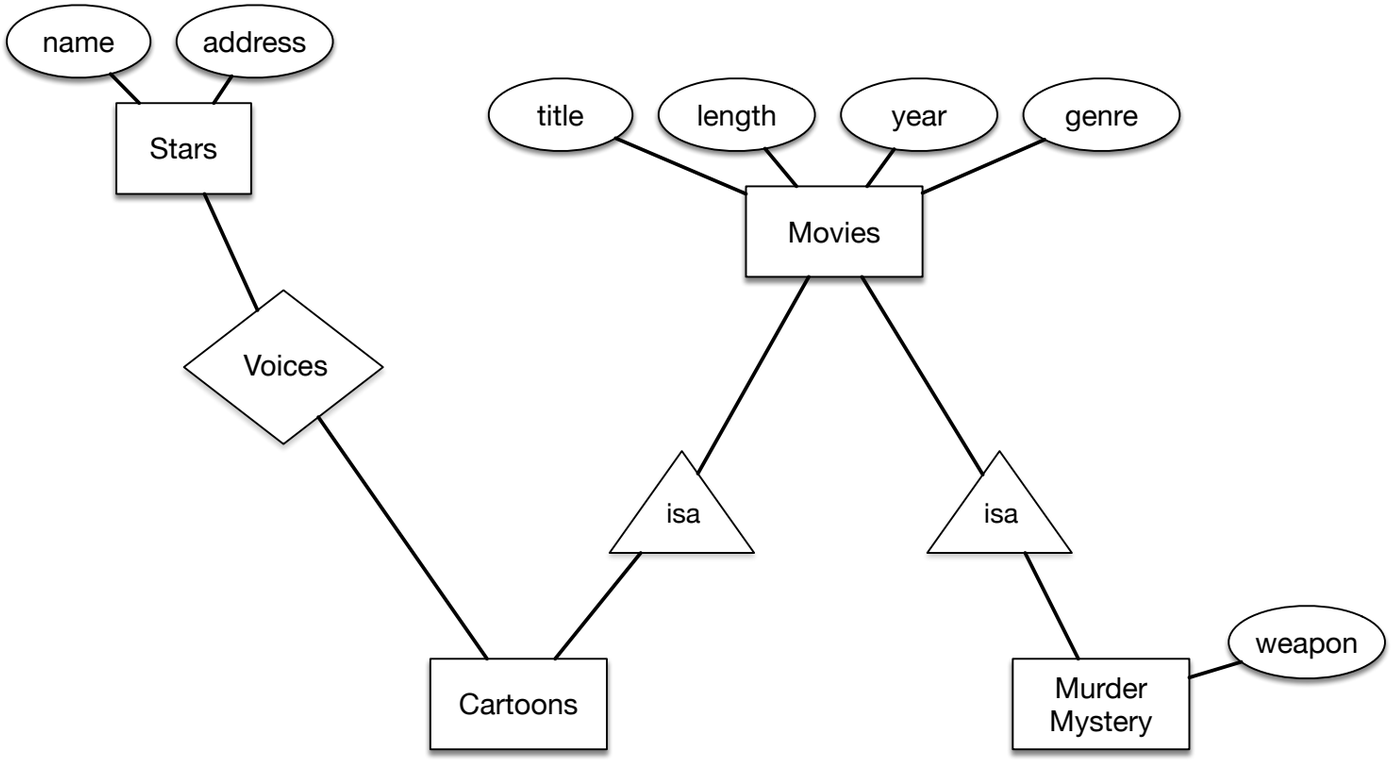
E/R Model

- Multi-way relationships can be modeled through an entity as well



E/R Model

- Subclasses
  - Some entities are special
    - Use an is-a relationship (a triangle)

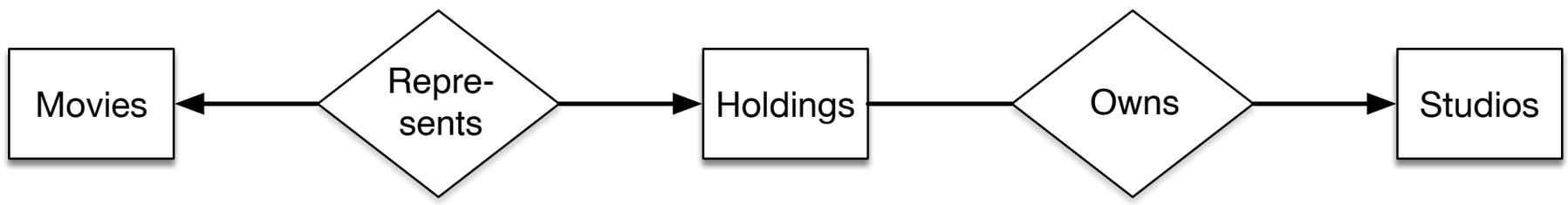


Design Principles

- Faithfulness
  - Can be difficult: Is “teaches” between instructors and courses many to many or one to many?
- Avoid Redundancy
  - Example: Add relationship ‘owns’ between movies and studios and add an attribute “studio” to movies.
    - This results in an update anomaly

Design Principles

- Simplicity
  - Avoid introducing more elements than is necessary
    - A studio can own movies, so each studio has a holding
    - Could be represented by this diagram, but entity holdings can also be done away with



    - Keeping it just means more storage space and longer computations

Design Principles

- Smart Selection
  - Not every relationship in the real world is worth-while using
  - Information can be redundant
    - Assume relationships contracts, stars-in, and owns
      - Since a movie has an owning studio, and the owning studio has contracts for each star, we do not need the stars-in relationship

Design Principles

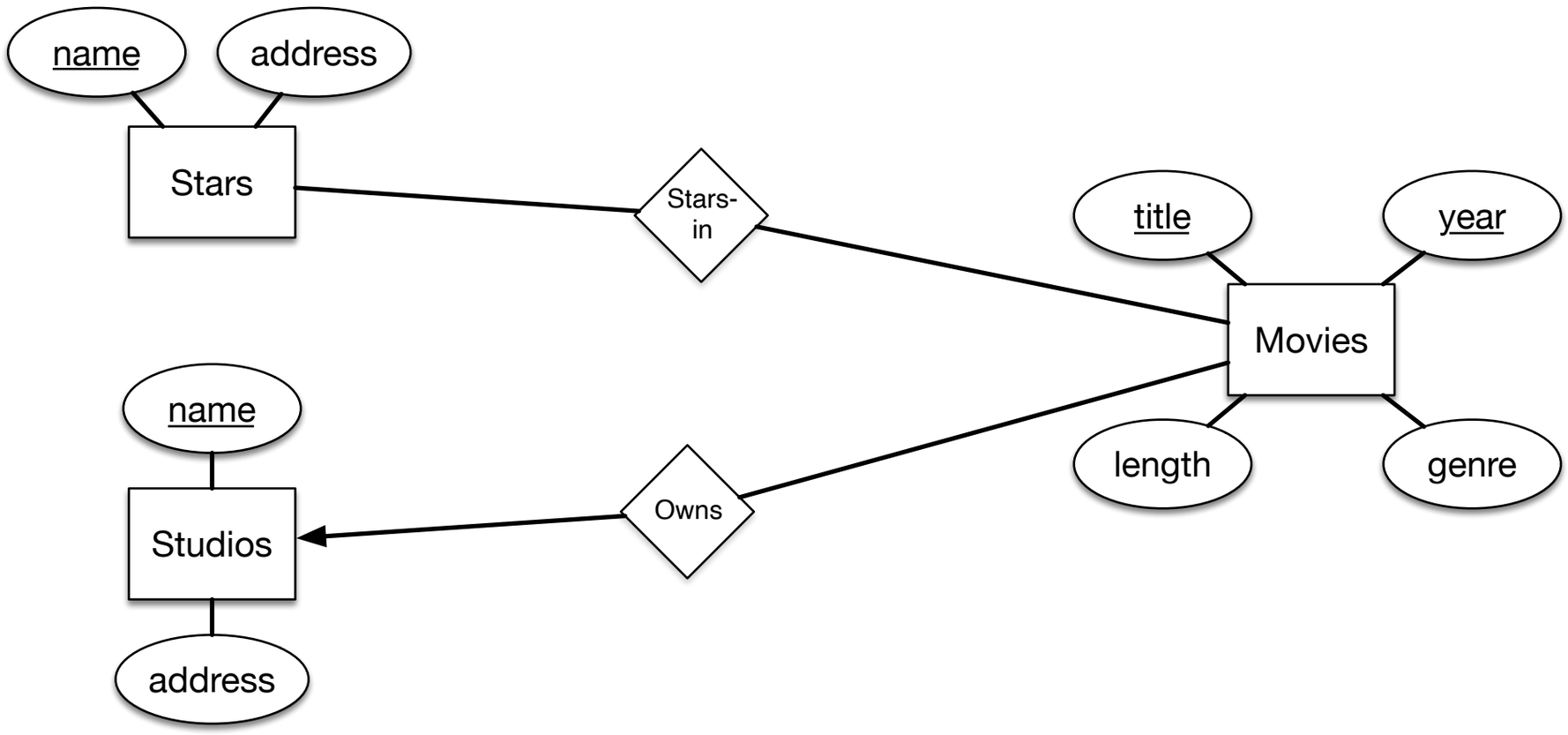
- Picking the right kind of element
  - Should studio be an entity set or can we add its attributes to a movie
    - Depends on the number of attributes for studio
      - If there is only studio name, we can incorporate it in movies
      - If there are more attributes, we probably run into an update anomaly

Constraints in the E/R Model

- Keys
  - Every entity set must have a key
  - There can be more than one key
  - For is-a relationships:
    - Root entity set needs to have all the attributes for a key

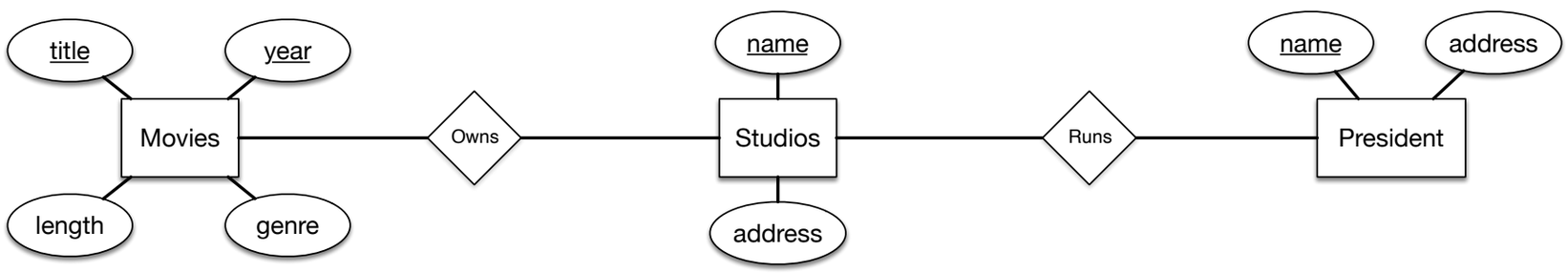
Constraints in the E/R Model

- Representing keys: Underline attributes that make up the primary key



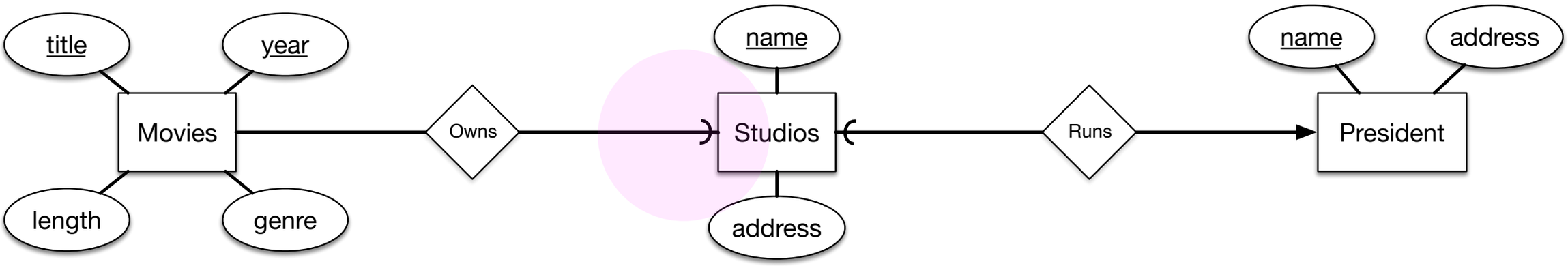
Constraints in the E/R Model

- Referential Integrity Constraint
  - E.g. Foreign key constraint
  - Example:



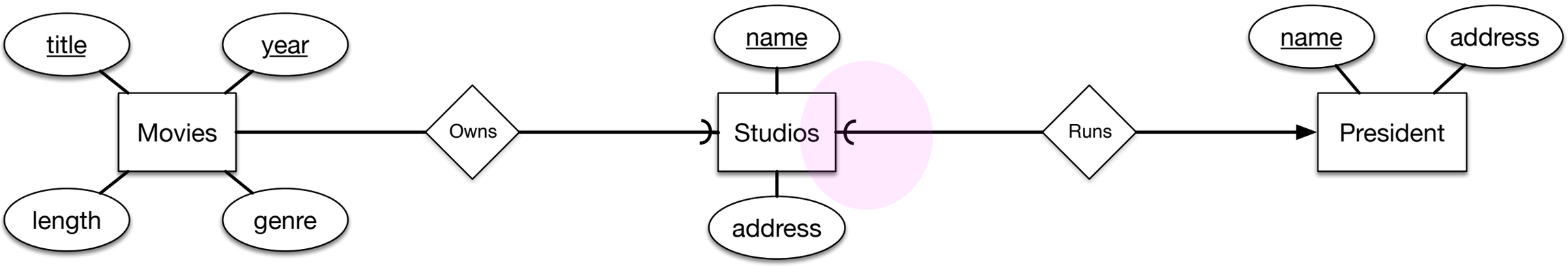
- Every movie has at most one studio owning it
- Every movie is owned by a studio
- Every studio has at most one president
- Every president has a studio to run

Constraints in the E/R Model



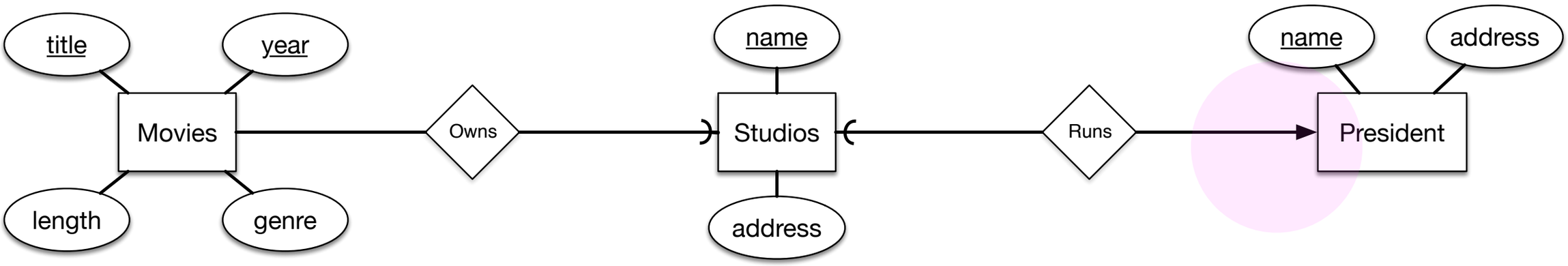
- Use rounded arrows to indicate existence of the foreign entity:
  - Every movie is owned by a studio (existence)
  - But not owned by more than one studio (uniqueness)

Constraints in the E/R Model



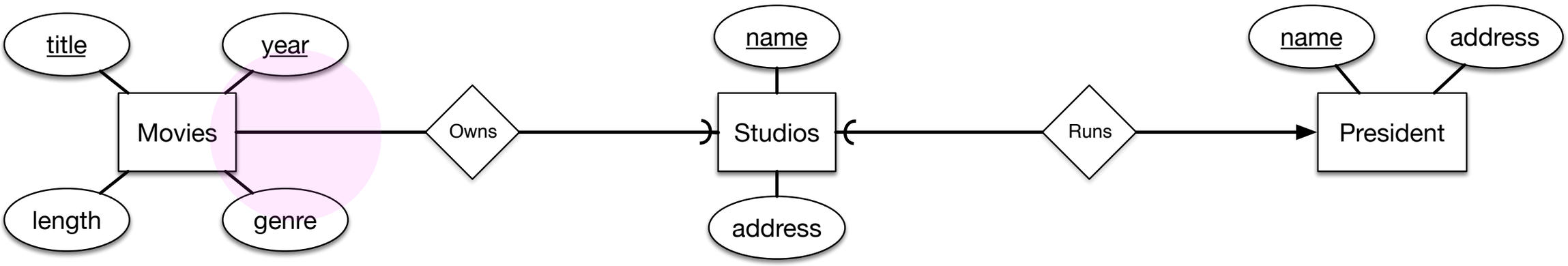
- Use rounded arrows to indicate existence of the foreign entity:
  - Every president needs to run a studio
  - Cannot run more than one studio
  - If (s)he stops running a studio, they get deleted from the president table

Constraints in the E/R Model



- Use rounded arrows to indicate existence of the foreign entity:
  - A studio cannot have more than one president
  - But if the president has been fired, the studio still persists

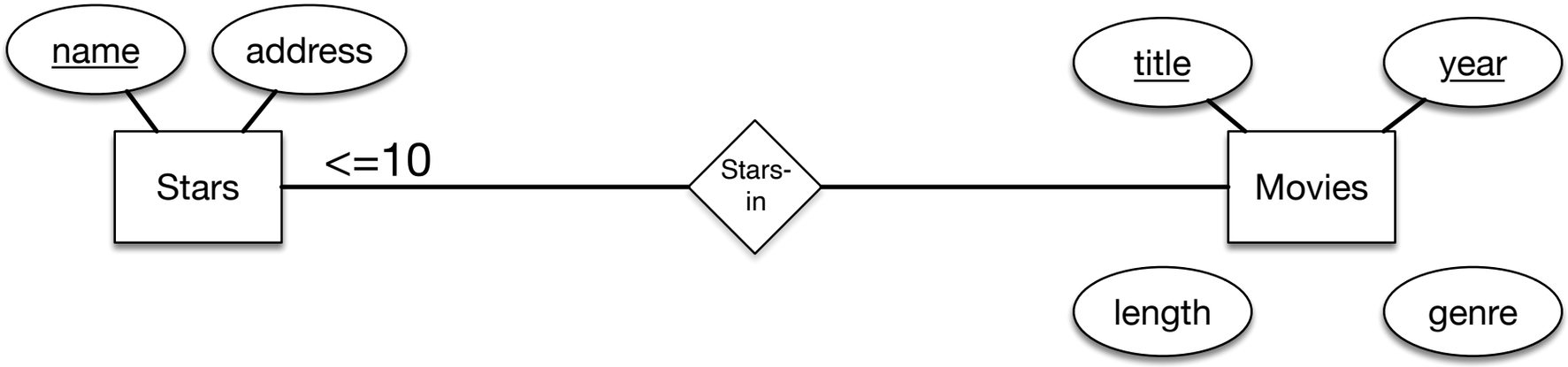
Constraints in the E/R Model



- Use rounded arrows to indicate existence of the foreign entity:
  - A studio does not need to own a movie
  - But it can own more than a single movie

Constraints in the E/R Model

- Degree constraints
  - Limit the number of entities that can be connected to an entity set



- The same star can only appear in 10 movies

Constraints in the E/R Model

- Degree constraints
  - <=1 means pointed arrow
  - ==1 means curved arrow

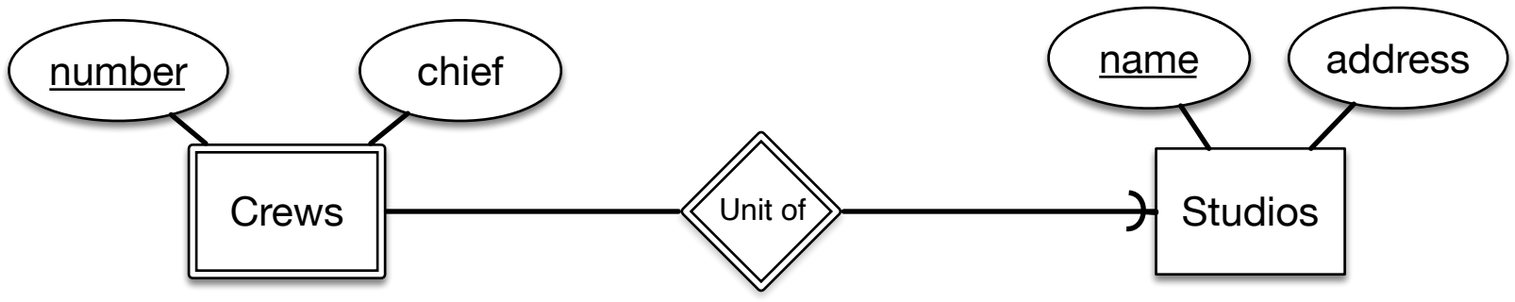
Weak Entity Sets

- An entity's key can be composed of attributes belonging (all or some) to another entity
- Called ***weak entity sets***

Weak Entity Sets

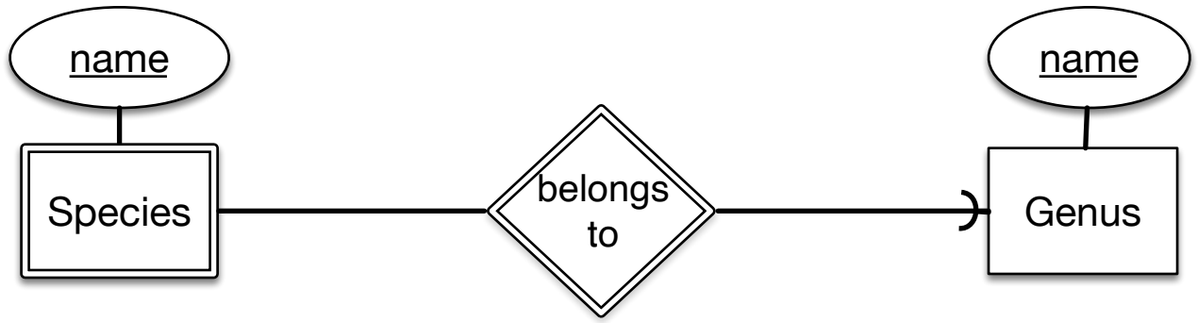
- Example:
  - Movie studio has several film crews, given by a number
    - (First unit, second unit, ...)
  - The numbering can be used also by other studios

Weak Entity Sets



- Double stroke indicates a weak entity set
- Crews has key `(number, studios.name)`
- Mediated through the “unit-of” relationship

Weak Entity Sets

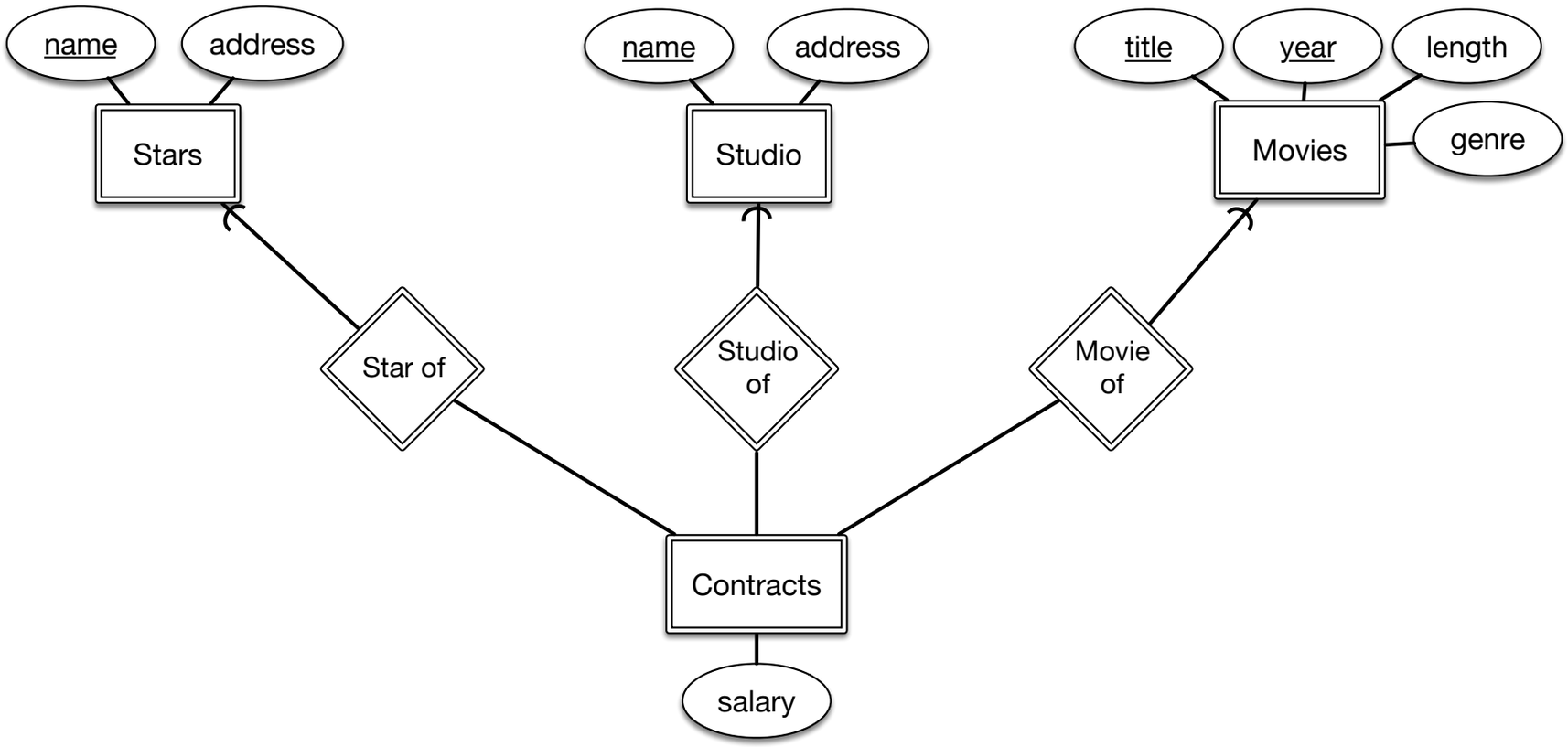


- Biological species are given by genus and species
  - *Homo neanderthalensis*
- First is genus, then species
- The species has a key `(species.name, genus.name)`

Weak Entity Sets

- Connecting entity sets used to replace ternary relationships
- Often have no attributes of their own
- Keys are attributes of other entities

Weak Entity Sets

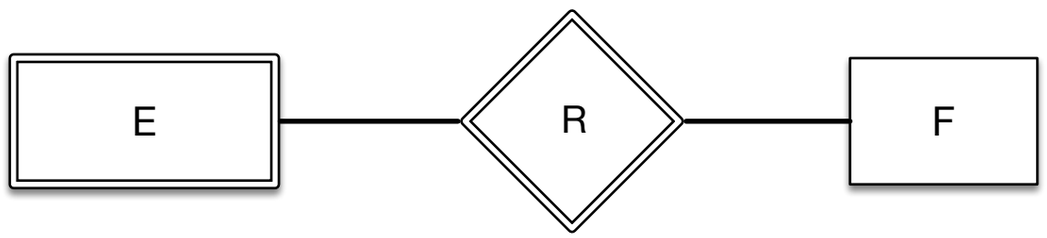


- Contracts have a key made up of `stars.name, studio.name, movies.title, movies.year`
- Own attribute salary is not a key

Weak Entity Sets

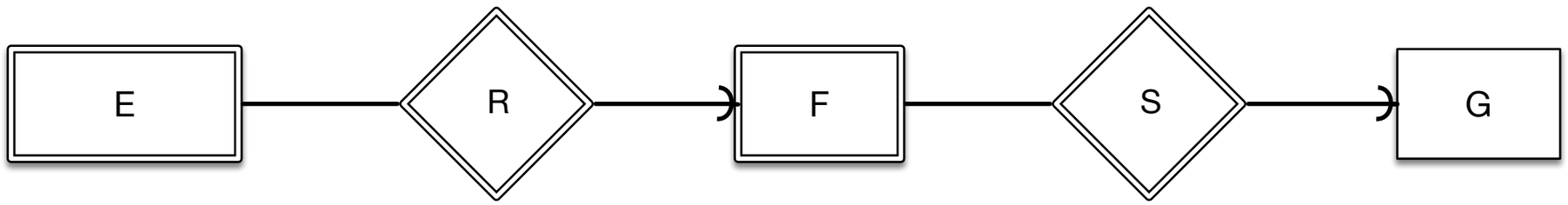
- Key attributes for weak entity sets:
  - Made up of zero or more of its own attributes
  - Key attributes from entity sets that are reached by certain many-to relationships
  - These are called supporting relationships and supporting entity sets, resp.

Weak Entity Sets



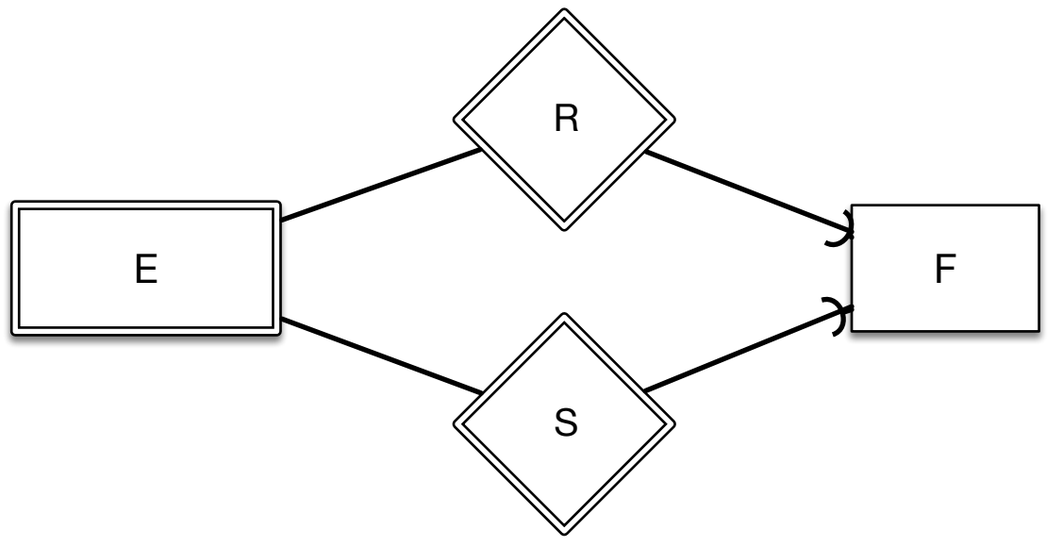
- R is a supporting relationship for E to F if the following conditions are true
- R binary, many to one or one to one
- R must have referential integrity:
  - For every E, there must be exactly one F entity in R
  - The attributes in F that supply (parts of the) key for E are also keys for F

Weak Entity Sets



- However, if F itself is weak, then the key attributes for F might be supplied by an entity G, etc.

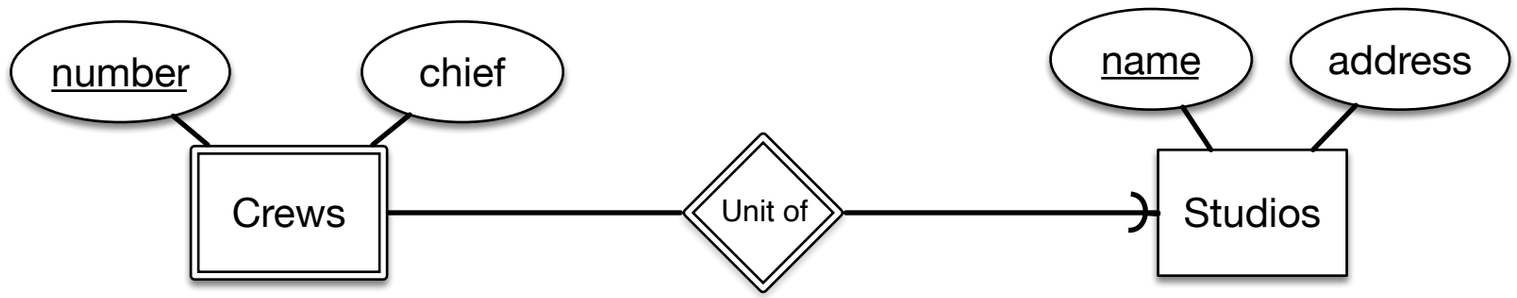
Weak Entity Sets



- If there are several different supporting relationships:
  - Each relationship is used to supply a copy of the key attributes of F to help form the key of E
  - The relationships can associated an entity $e \in E$ with *different* entities $f_1, f_2 \in F$ and so the parts of the key of E can come from different entities

Weak Entity Sets

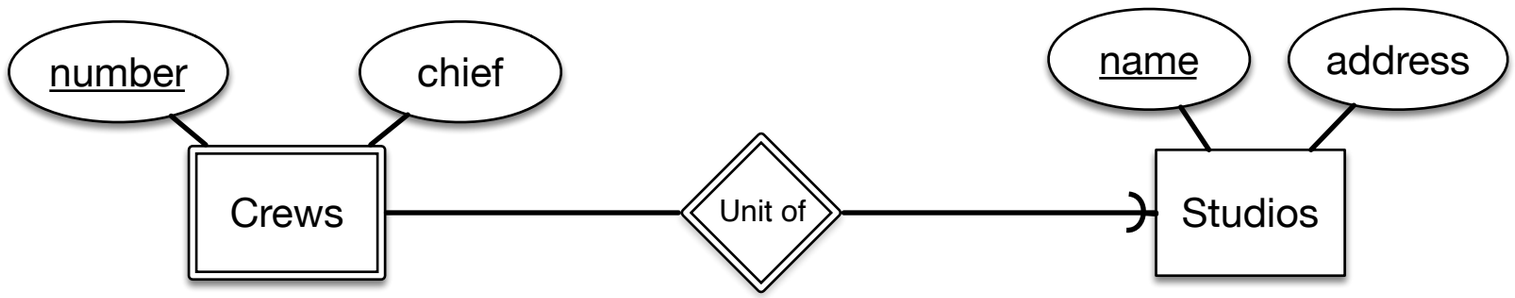
- Example



- Each crew is unique
- But to identify a crew, we need data from the supporting relationship
- There needs to be a deterministic process to obtain this data.

Weak Entity Sets

- Example

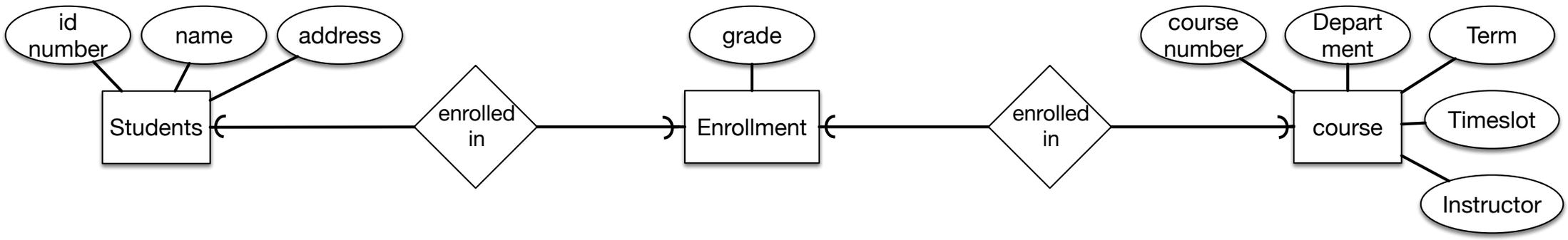


- Values for a crew are obtained from their attributes ***and*** by following the relationship “Unit of”
- Thus, the supporting relationship needs to be many-to-one

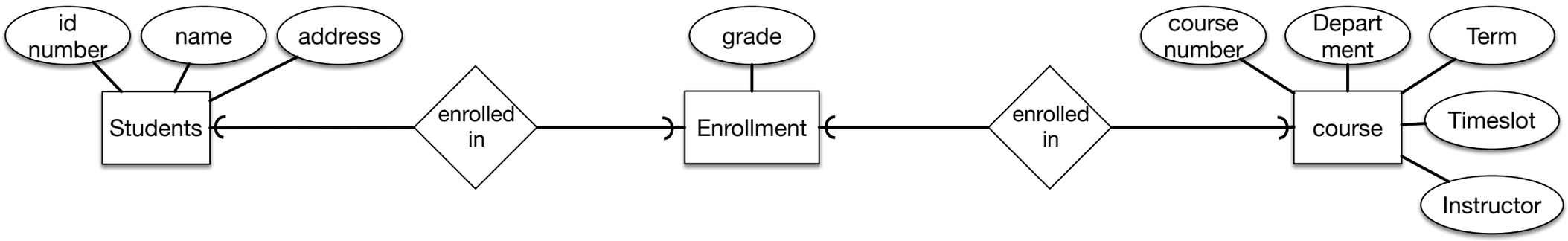
Weak Entity Sets

- In class exercise:
  - Develop a university grading roster DB as an E/R diagram
  - You have courses and students as entities and enrollment as a connecting entity
  - Enrollment can have grade as an attribute

Weak Entity Sets



Weak Entity Sets

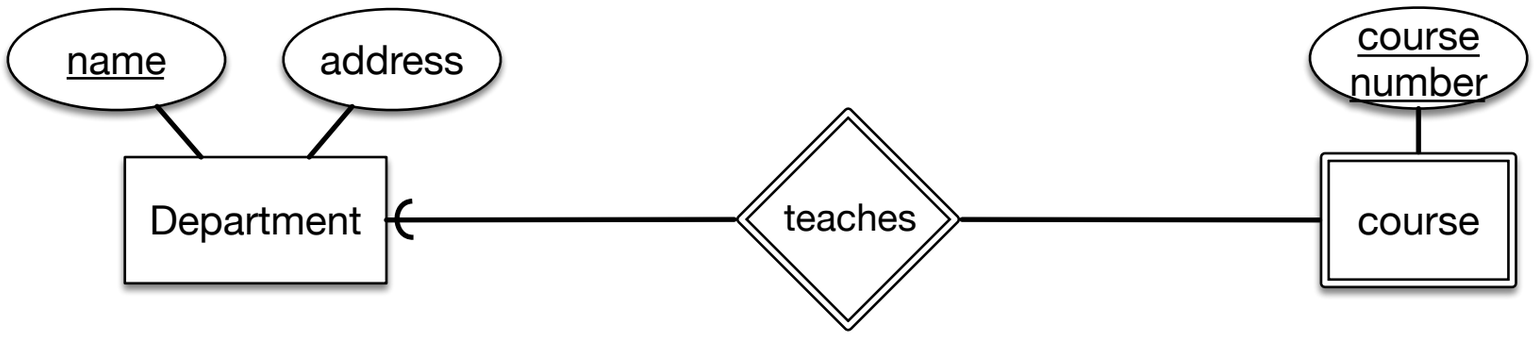


- Every enrollment record needs to have exactly a student and exactly a course

Weak Entity Sets

- In class exercise
  - Draw E/R diagrams involving weak entity sets
    - Courses and Departments
      - A course is given by a unique department, but its only attribute is its number
      - Different departments can offer courses with the same number

Weak Entity Sets



From E/R Diagrams to Relational Design

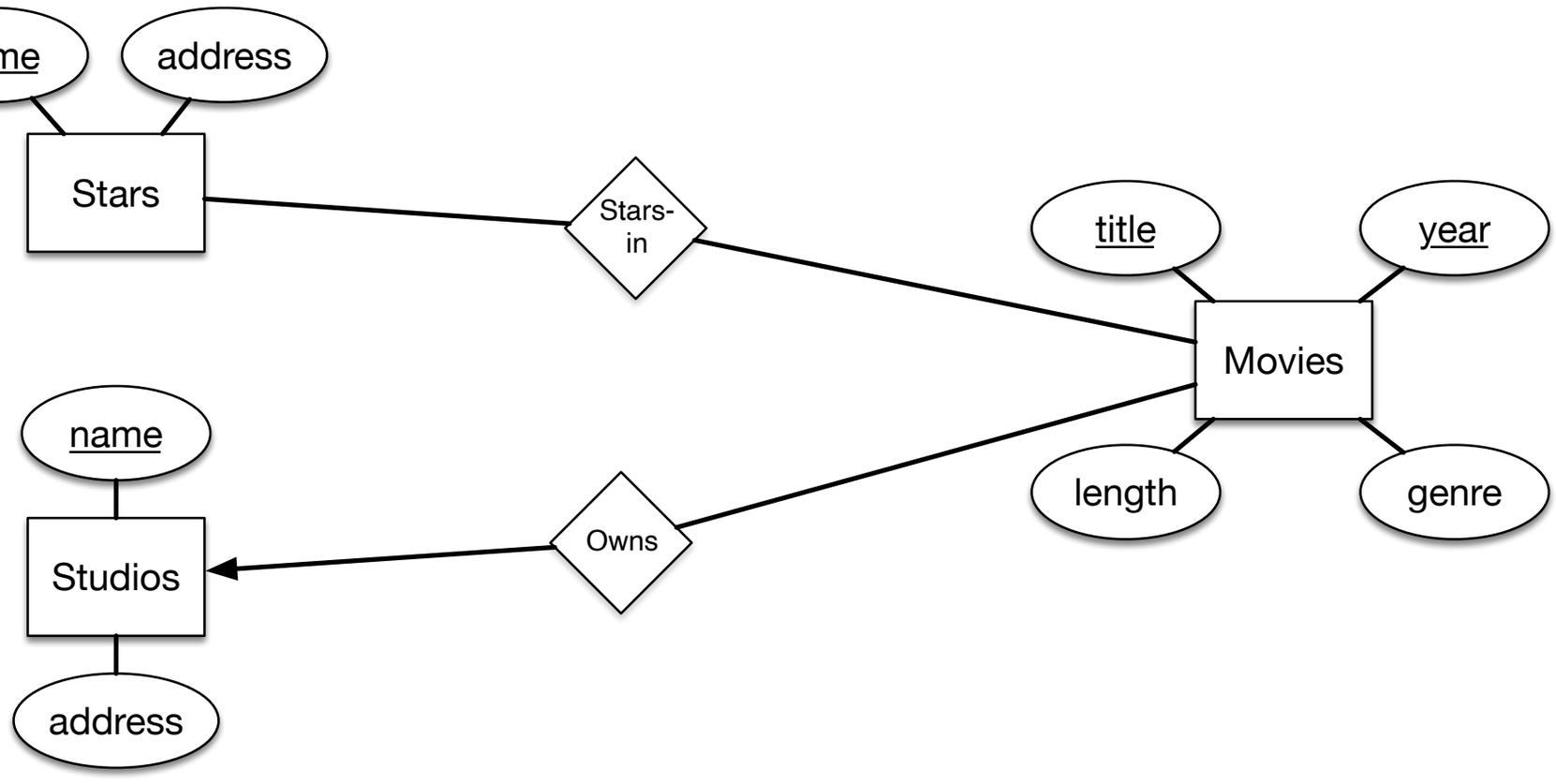
- Each entity set becomes a relation with the same set of attributes
- Each relationship becomes a relation with attributes being the keys for the connected entity set

From E/R Diagrams to Relational Design

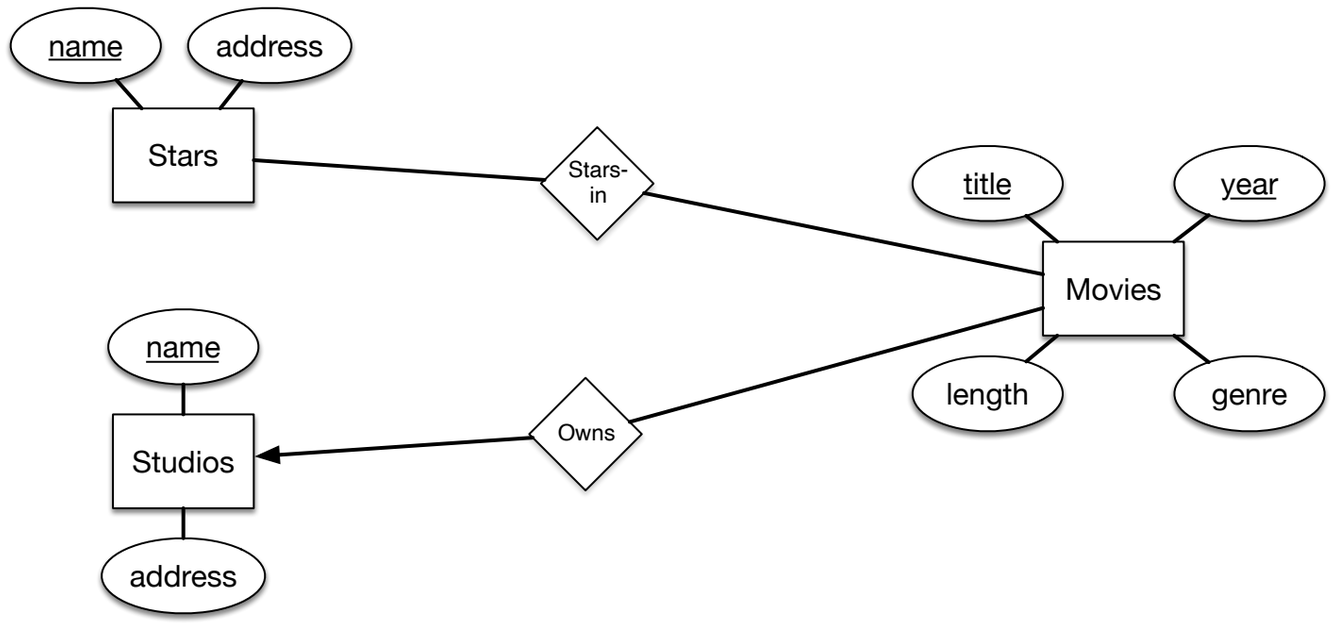
- Problems:
  - Weak entity sets cannot be translated straightforwardly
  - Isa relationships are difficult
  - Sometimes, makes sense to combine relations when connected by a many-to-one relationship

From E/R Diagrams to Relational Design

- In class test:



From E/R Diagrams to Relational Design



stars(<u>name</u>, address)

movies(<u>title</u>, <u>year</u>, length, genre)

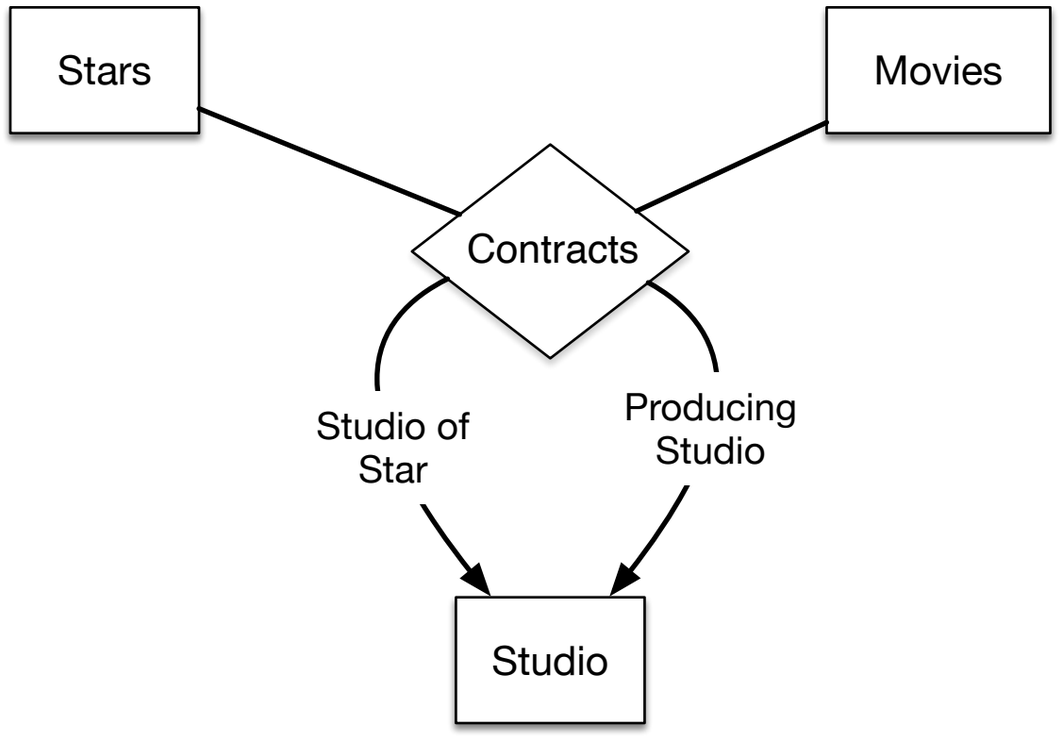
studios(<u>name</u>, address)

starsIn(<u>name</u>, <u>title</u>, <u>year</u>)

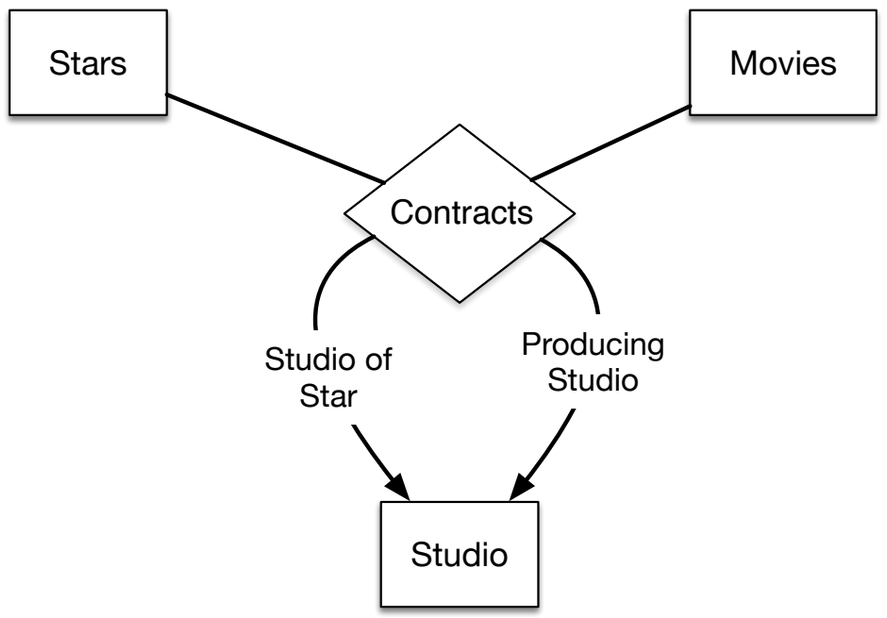
owns(<u>name</u>, <u>title</u>, <u>year</u>)

From E/R Diagrams to Relational Design

- In class exercise



From E/R Diagrams to Relational Design



stars(<u>name</u>, address) movies(<u>title</u>, <u>year</u>, length, genre)

studios(<u>name</u>, address)

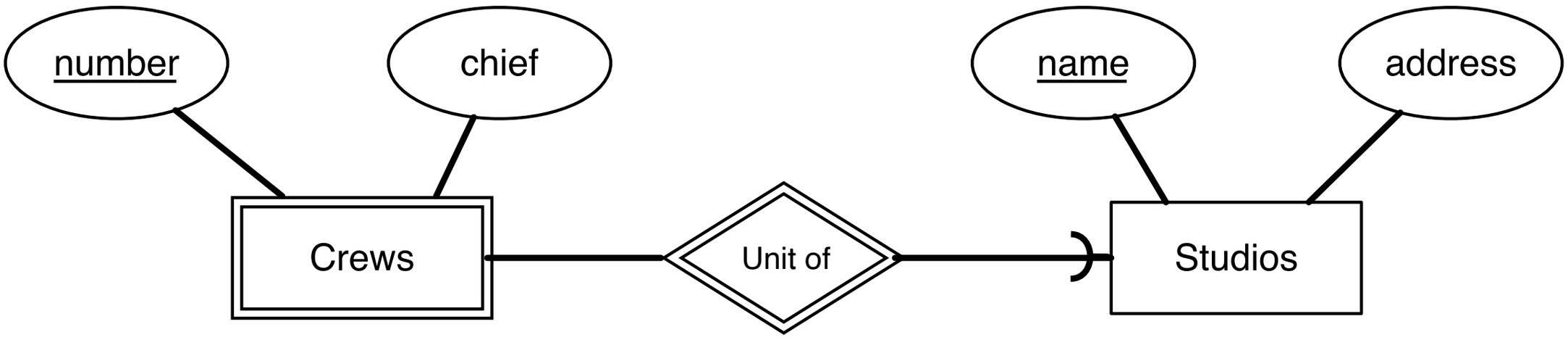
contracts(<u>name</u>, <u>title</u>, <u>year</u>, studioOfStar, producingStudio)

From E/R Diagrams to Relational Design

- Handling weak entity sets
  - Relation for a weak entity set needs to include key attributes of supporting entity sets
  - Relation for any relationship that includes a weak entity set must use as a key all of its key attributes, including those in supporting entities
  - A supporting relationship does not need to be represented in an entity itself
    - This is because the rule for the weak entity already force it to have these relationships

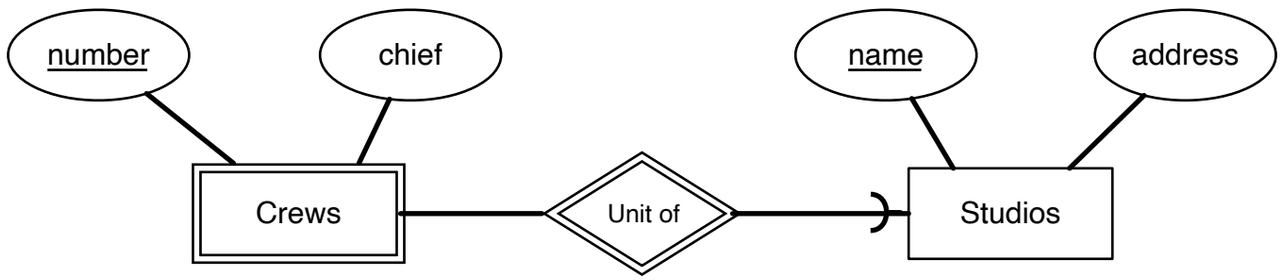
From E/R Diagrams to Relational Design

- Example



From E/R Diagrams to Relational Design

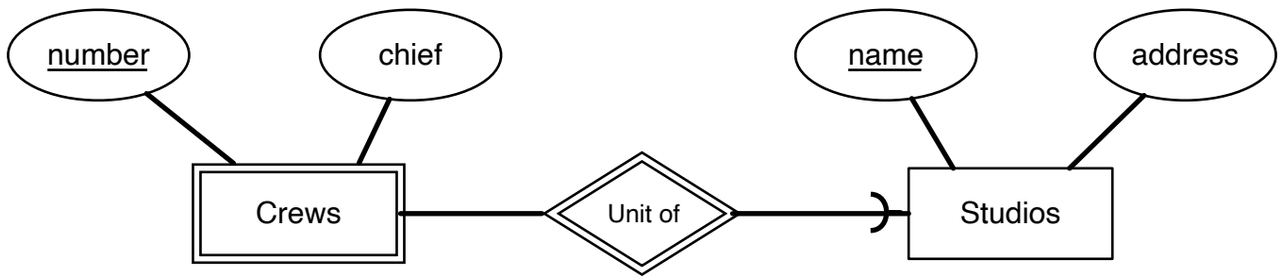
- Example



- First pick:
  - `studios(name, address)`
  - `crews(number, chief, studioName)`
  - `unitOf(number, studioName, name)`

From E/R Diagrams to Relational Design

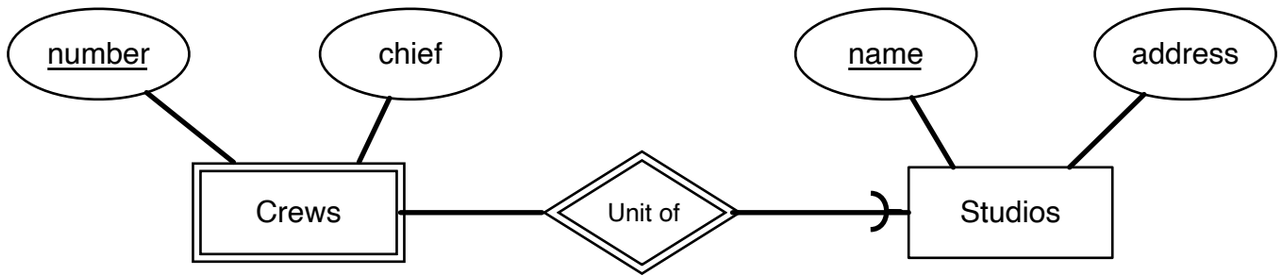
- Example



- Second pick: studioName and name are the same
  - `studios(name, address)`
  - `crews(number, chief, studioName)`
  - `unitOf(number, studioName)`

From E/R Diagrams to Relational Design

- Example



- Final pick: can dispense with unitOf
  - `studios(name, address)`
  - `crews(number, chief, studioName)`

From E/R Diagrams to Relational Design

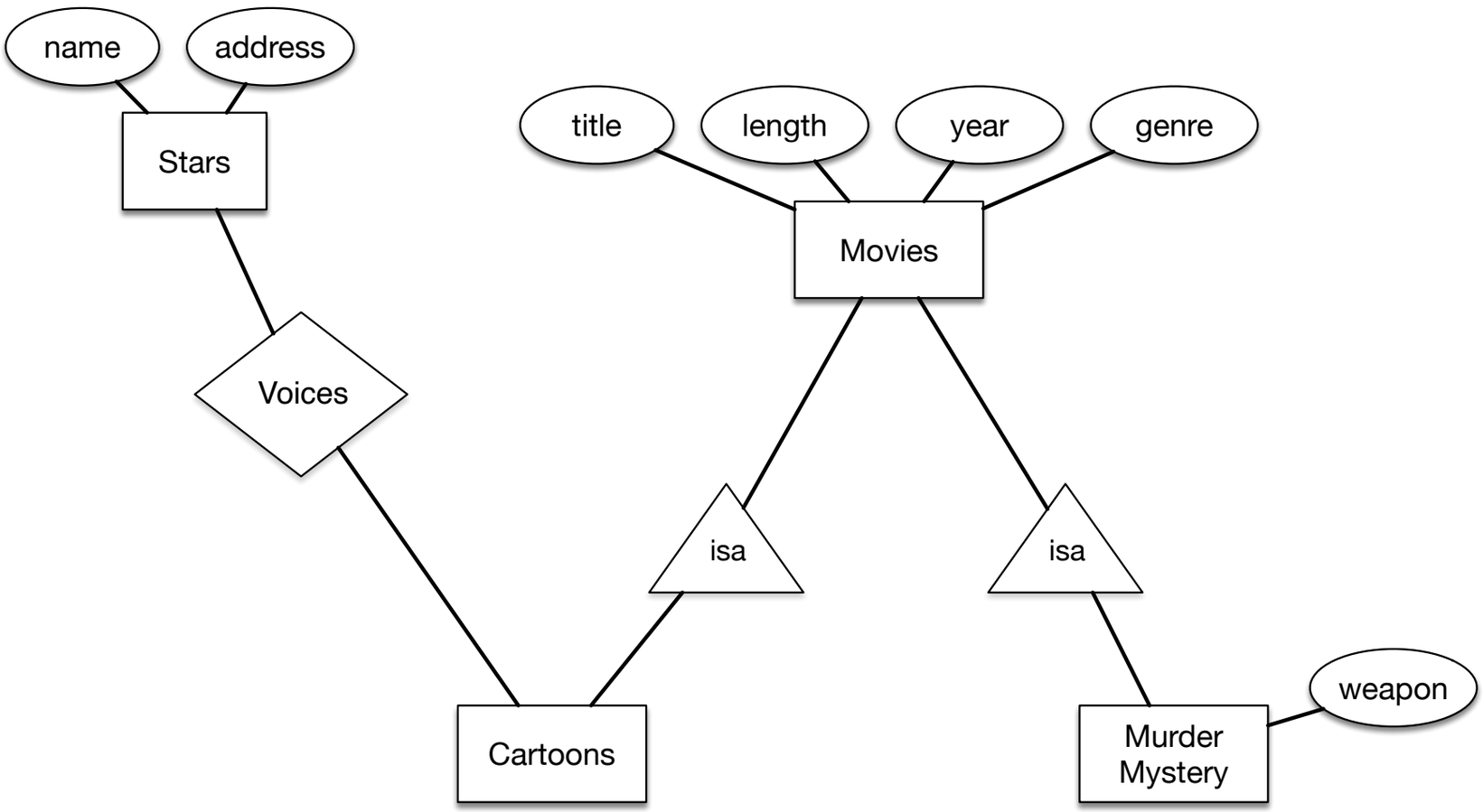
- Converting subclass structures to relations
  - is-a relationship:
    - There is a root entity
    - Root entity has a key that identifies <u>all</u> entities in the hierarchy
    - A given entity may have *components* that belong to the entity sets of any subtree of the hierarchy that includes root

From E/R Diagrams to Relational Design

- Converting subclass structures to relations
  - Three strategies
    - Follow the E/R viewpoint
    - Treat entities as objects belonging to the same class
    - Use null values

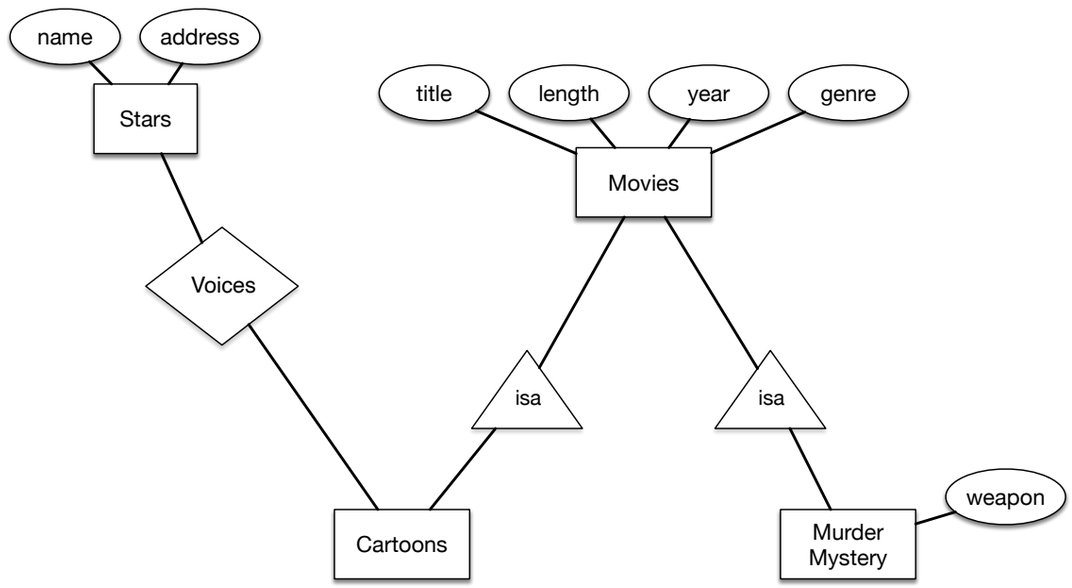
From E/R Diagrams to Relational Design

- Follow the E/R view
  - Make a relation for each entity



From E/R Diagrams to Relational Design

- movies(<u>title</u>, length, <u>year</u>, genre)
- murderMysteries(<u>title</u>, <u>length</u>, weapon)
- cartoons(<u>title</u>, <u>year</u>)



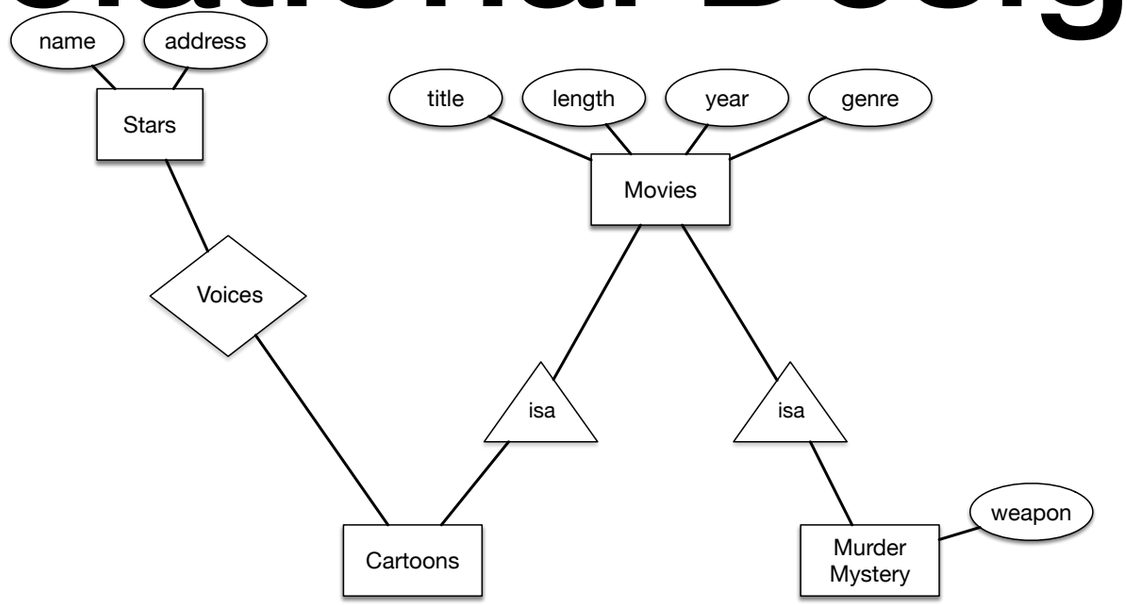
From E/R Diagrams to Relational Design

- E/R view:
  - `movies(title, length, year, genre)`
  - `murderMysteries(title, length, weapon)`
  - `cartoons(title, year)`
- A cartoon has a tuple in two tables
- “Who framed Roger Rabbit” has tuples in all three tables
- Add
  - `voices(starName, title, year)`
- Would still have to retain cartoons relationship since we might have silent cartoons

From E/R Diagrams to Relational Design

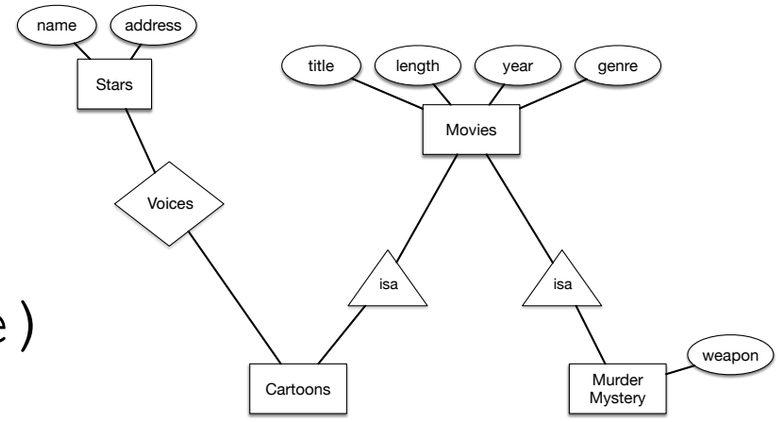
- Object-Oriented Approach to subclasses
    - Entities can only belong to one class
    - Enumerate all possible subtrees of the hierarchy
    - Create a relationship for all of them

From E/R Diagrams to Relational Design



- `movies(`<u>`title`</u>`, `<u>`year`</u>`, length, genre)`
- `moviesC(`<u>`title`</u>`, `<u>`year`</u>`, length, genre)`
- `moviesMM(`<u>`title`</u>`, `<u>`year`</u>`, length, genre, weapon)`
- `moviesCMM(`<u>`title`</u>`, `<u>`year`</u>`, length, genre, weapon)`
- A movie is in only one relationship

From E/R Diagrams to Relational Design



- movies(<u>title</u>, <u>year</u>, length, genre)
- moviesC(<u>title</u>, <u>year</u>, length, genre)
- moviesMM(<u>title</u>, <u>year</u>, length, genre, weapon)
- moviesCMM(<u>title</u>, <u>year</u>, length, genre, weapon)
- Add voices:
  - voices(<u>title</u>, <u>year</u>, <u>starName</u>)
- Should we have two (depending on CMM or C)?
  - Probably not, no good reason at this point

From E/R Diagrams to Relational Design

- Using Null values
  - Only have the root relation, but add to it all attributes in the hierarchy
    - `movies(title, year, length, genre, weapon)`
- Use null value when movie not in MM

From E/R Diagrams to Relational Design

- Comparison of approaches
  - It can be expensive to answer queries involving several relations
  - “Null Value” approach wins
  - Different queries favor different set ups
    - What films of 2008 were longer than 150 minutes?
      - E/R approach is easy
      - OO approach needs to access four different relations

From E/R Diagrams to Relational Design

- Comparison of approaches
    - Different queries favor different set ups
        - “What weapons were used in cartoons over 120 minutes?”
            - OO approach needs to access one relation, moviesCMM
            - E/R approach: Access movies to find movies over 120 minutes, then access cartoons to see whether the movie is a cartoon, then access murderMysteries to find out the weapon

From E/R Diagrams to Relational Design

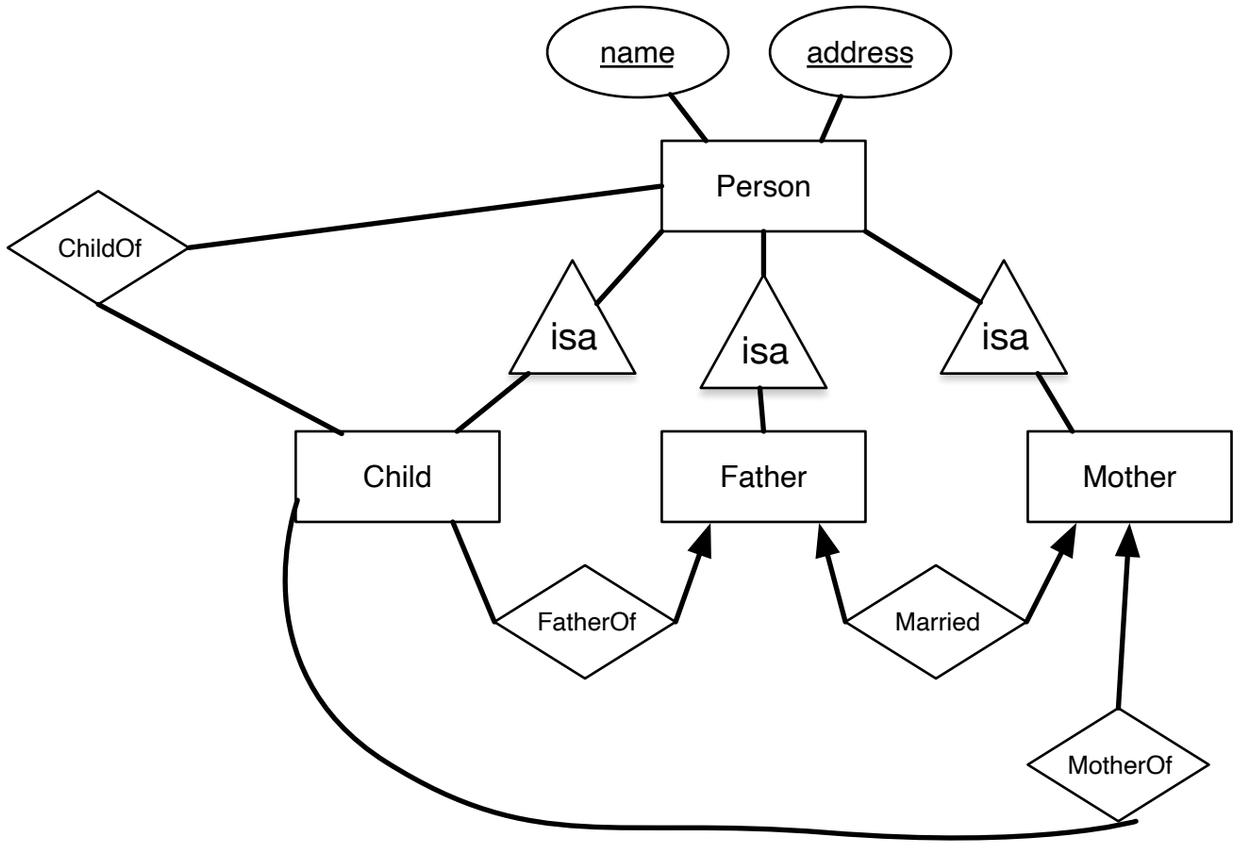
- We want few relations
  - “Null” approach works best
  - OO approach is worst

From E/R Diagrams to Relational Design

- We want to minimize space and avoid repetition
  - Null approach avoids repetition but tuples can now be very long
  - E/R approach: repeats data
  - OO approach: uses one tuple per entity

From E/R Diagrams to Relational Design

- Use E/R, OO, and Null approach on



Unified Modeling Language

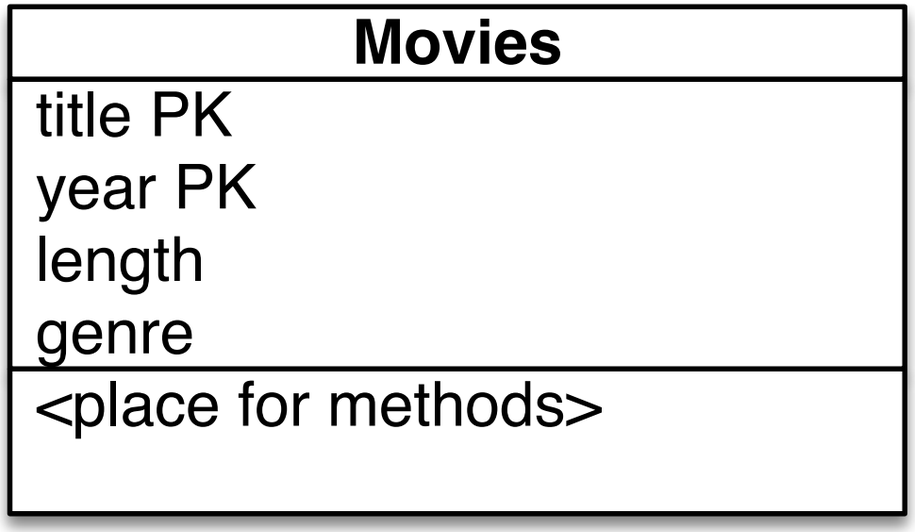
- Developed as graphical notation for OO software design

Unified Modeling Language

UML	E/R
class	entity set
association	binary relationship
association class	attributes on a relationship
subclass	Is-a hierarchy
aggregation	many-one relationship
composition	many-one relationship with rreferential integrity

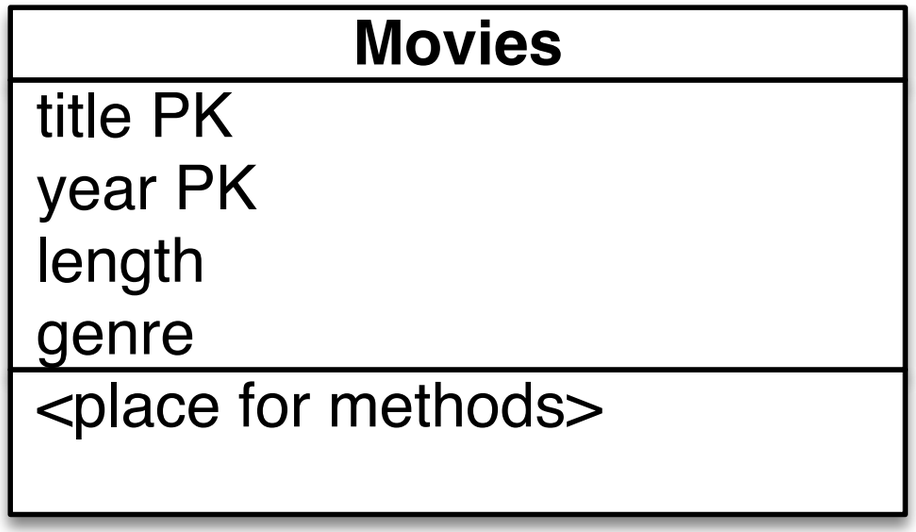
Unified Modeling Language

- UML classes
  - Classes:
    - 3 field box
      - name
      - instance variables (attributes)
      - bottom: methods
        - Used only in OO relational databases



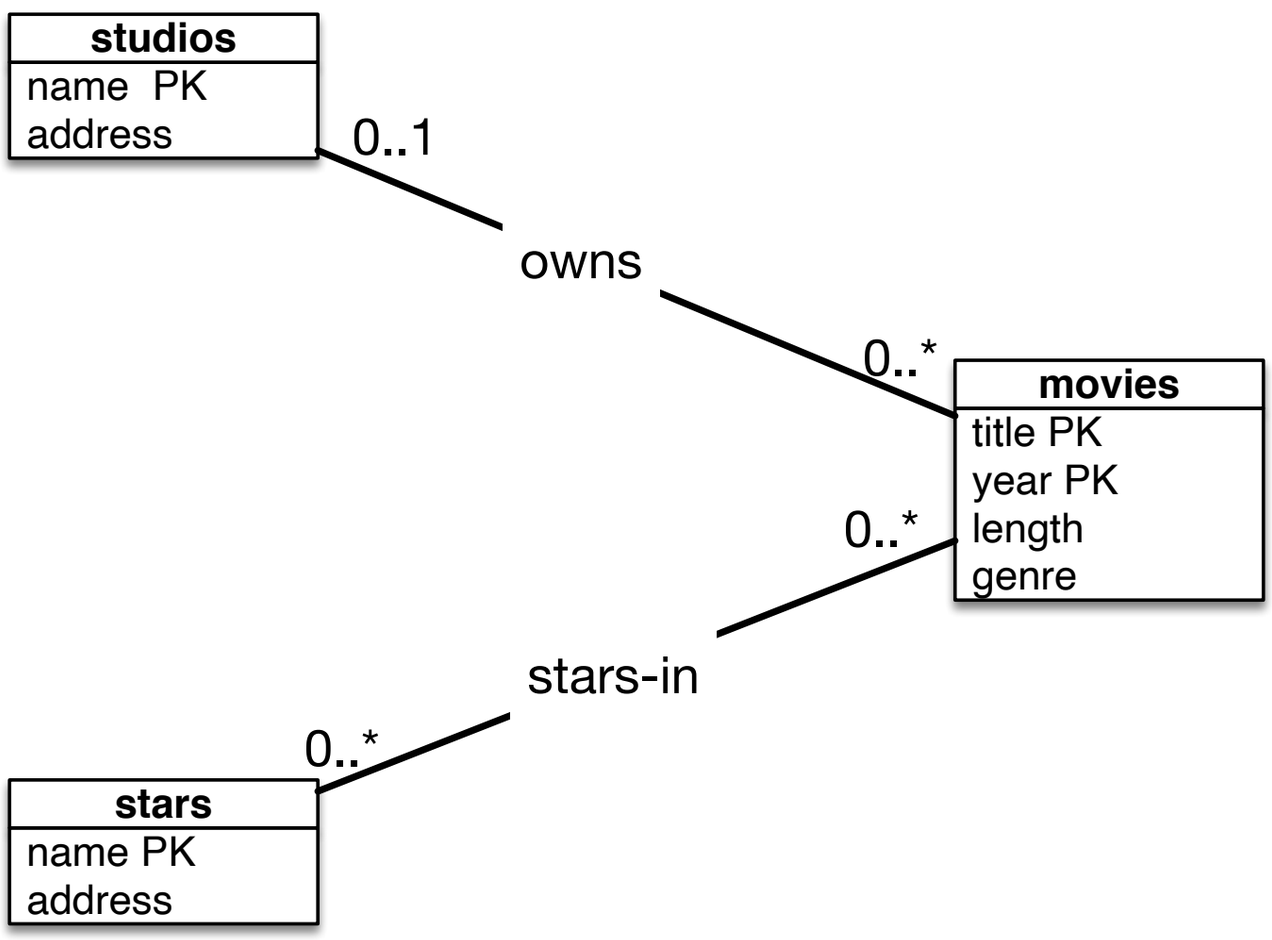
Unified Modeling Language

- UML keys
  - Add PK (primary key) after attribute



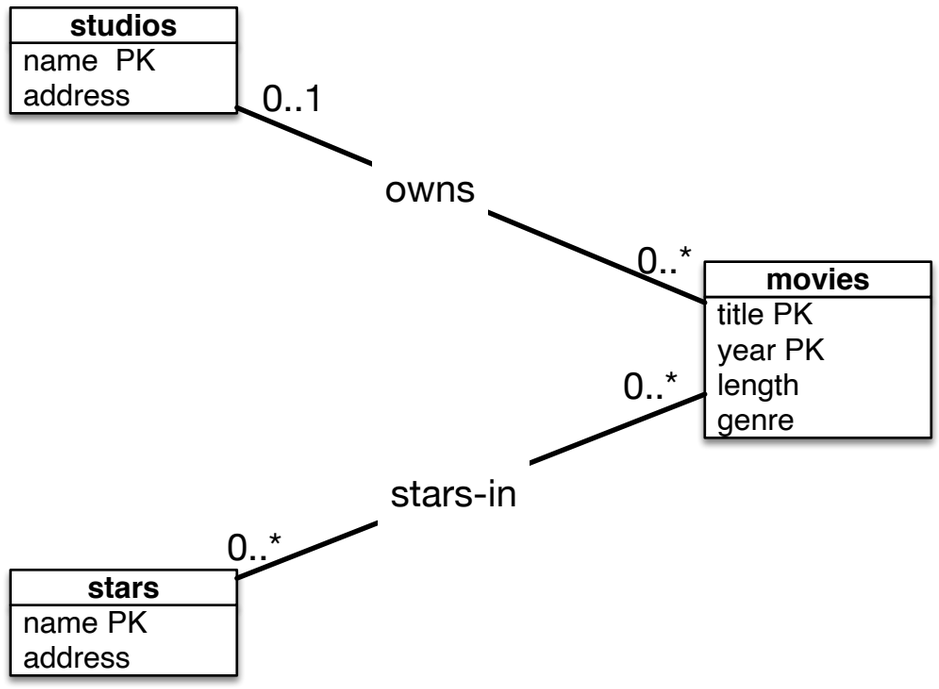
Unified Modeling Language

- Binary relationships are called *associations*
- No multiway relationships in UML

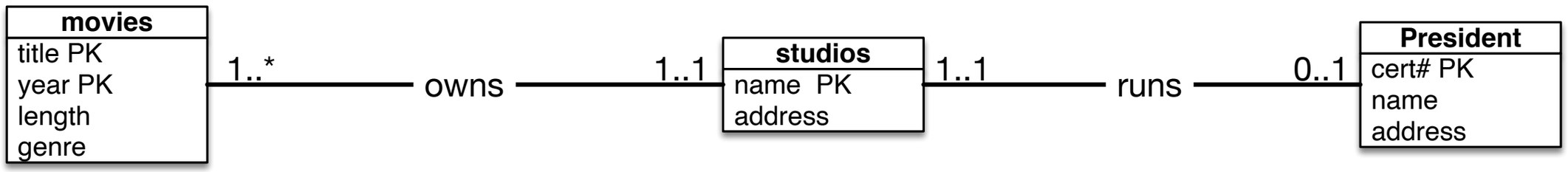


Unified Modeling Language

- Write down numerical restriction on associations at the other end
  - 0..1 at most one
    - a movie has at most one studio
  - 0..* any number
    - A studio owns any number of movies
    - A movie has any number of stars
    - A star has any number of movies
- No label means: 1..1 (exactly one)

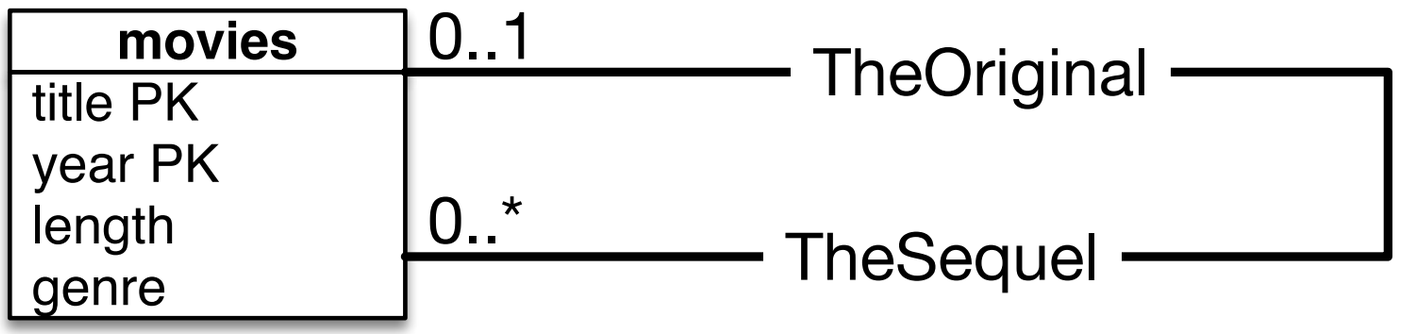


Unified Modeling Language



- Each studio has to have at least one movie it owns
- Each movie is owned by exactly one studio
- Each president runs exactly one studio
- Each studio has one or none president

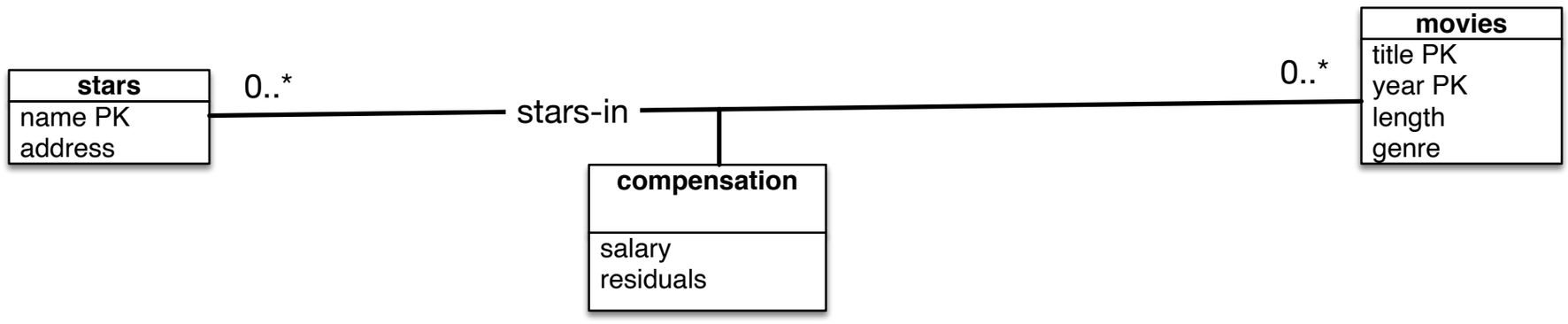
Unified Modeling Language



- Each movie can have none, one, or more sequels
- Each movie can be the sequel of no movie (it’s not a sequel) or one movie (it is a sequel

Unified Modeling Language

- Association classes



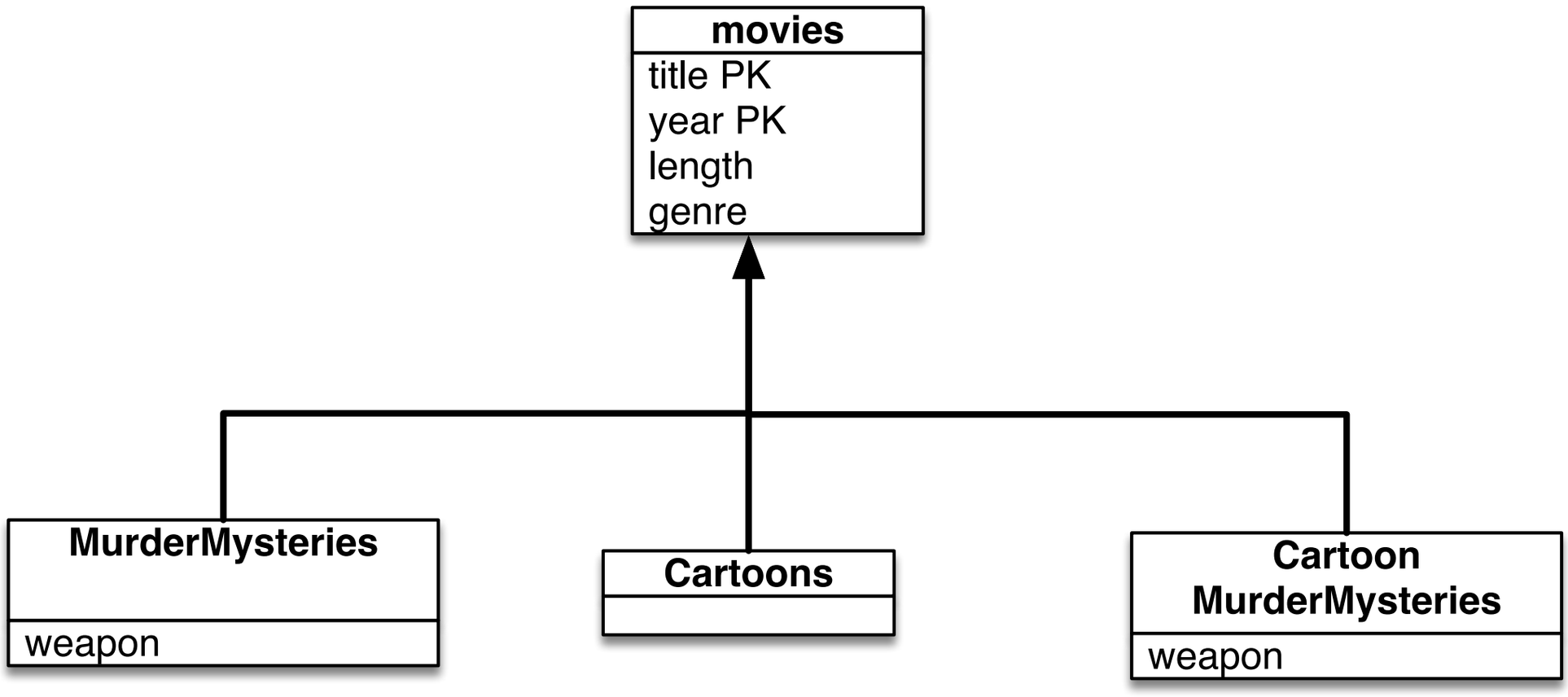
- There is no PK for compensation, the PK will be provided by the objects that are associated

Unified Modeling Language

- Subclasses in UML
  - UML allows four subclass relationships
    - Complete versus partial
      - Is every object a member of a subclass?
    - Disjoint versus overlapping
      - Can an object be in two sub-classes?

Unified Modeling Language

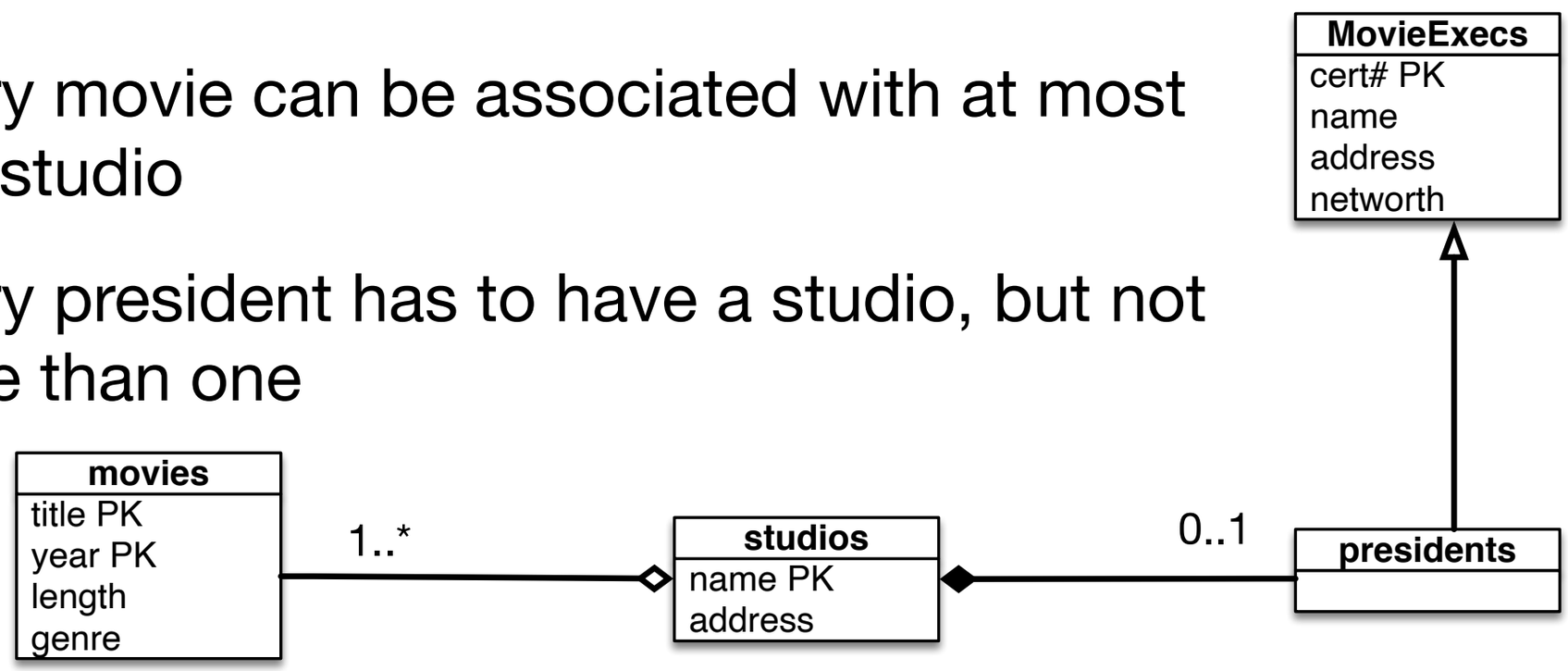
- Subclass objects inherit attributes from the superclass



- The relationship is disjoint, but only partial

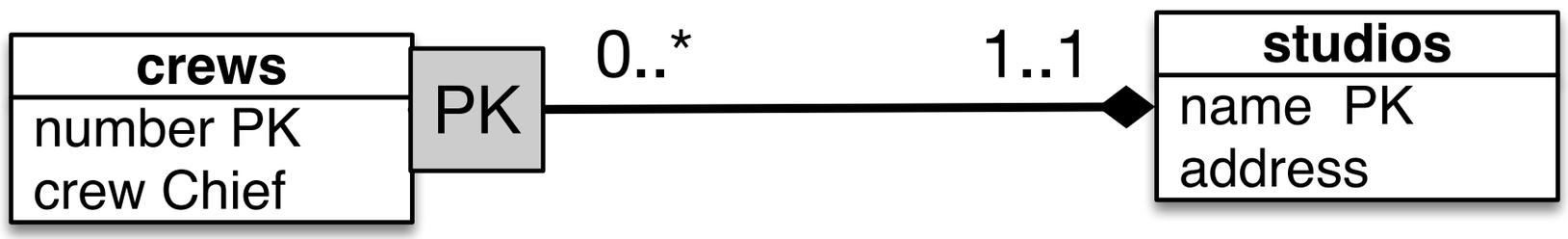
Unified Modeling Language

- Aggregation (diamond) — many to one association
- Composition(filled diamond) — one-to-one association
    - Example:
        - Every movie can be associated with at most one studio
        - Every president has to have a studio, but not more than one



Unified Modeling Language

- Equivalent of weak entities:
  - Not necessary: In UML objects have their own attributes
  - Can use label PK in a composition

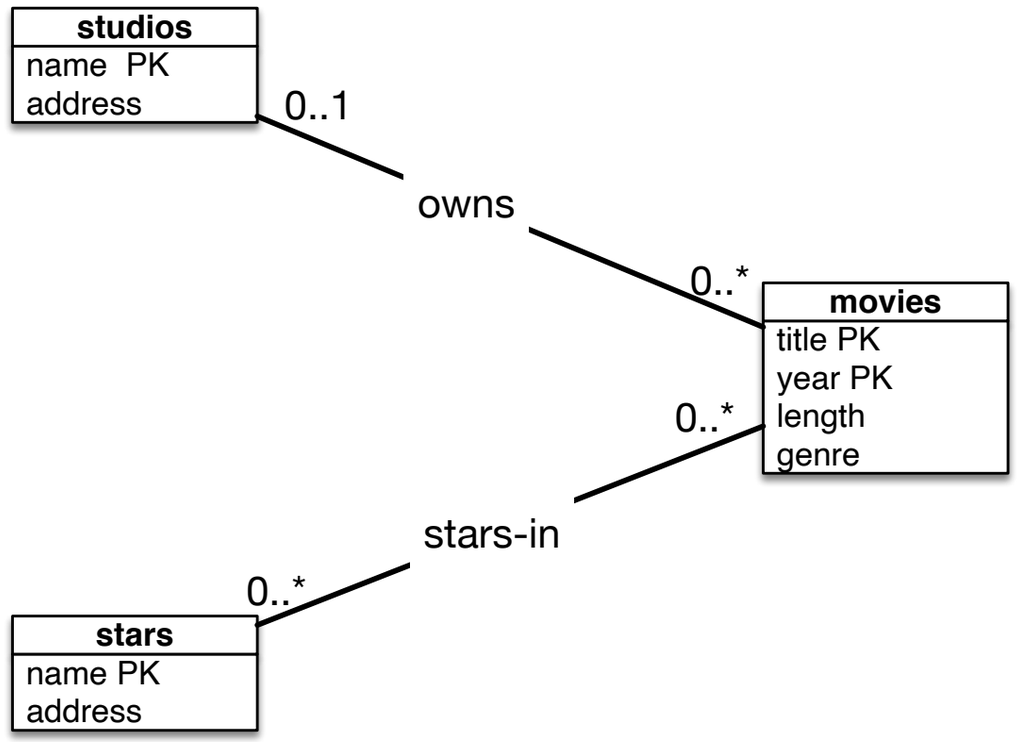


Unified Modeling Language

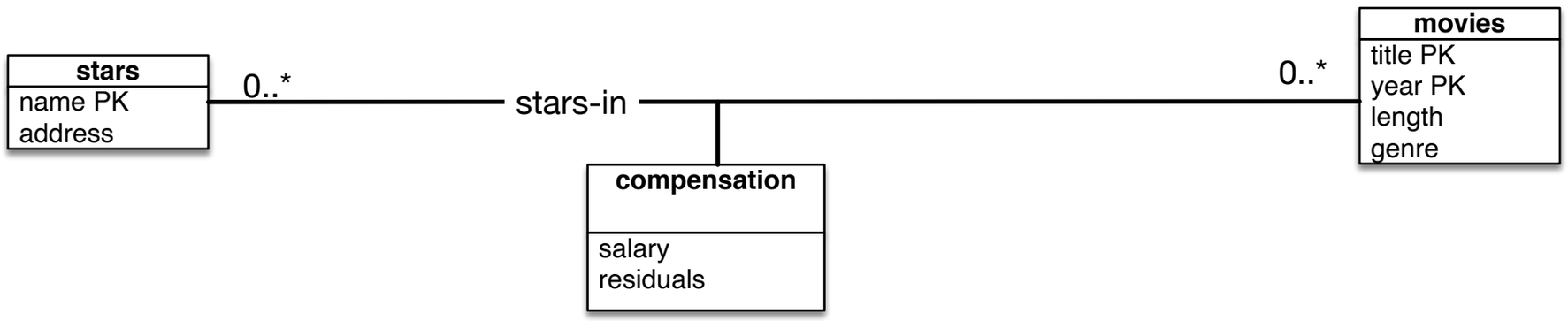
- Translating into Relations
  - Each class converts into a relation
  - Each association converts into a relation with the key attributes of the two connected classes
  - Renaming might be necessary
  - If there is an association class, relation also has attributes of the association class

Unified Modeling Language

- studios(name, address)
- movies(title, year, length, genre)
- stars(name, address)
- owns(studioName, movieTitle, movieYear)
- stars-in(starName, movieTitle, movieYear)



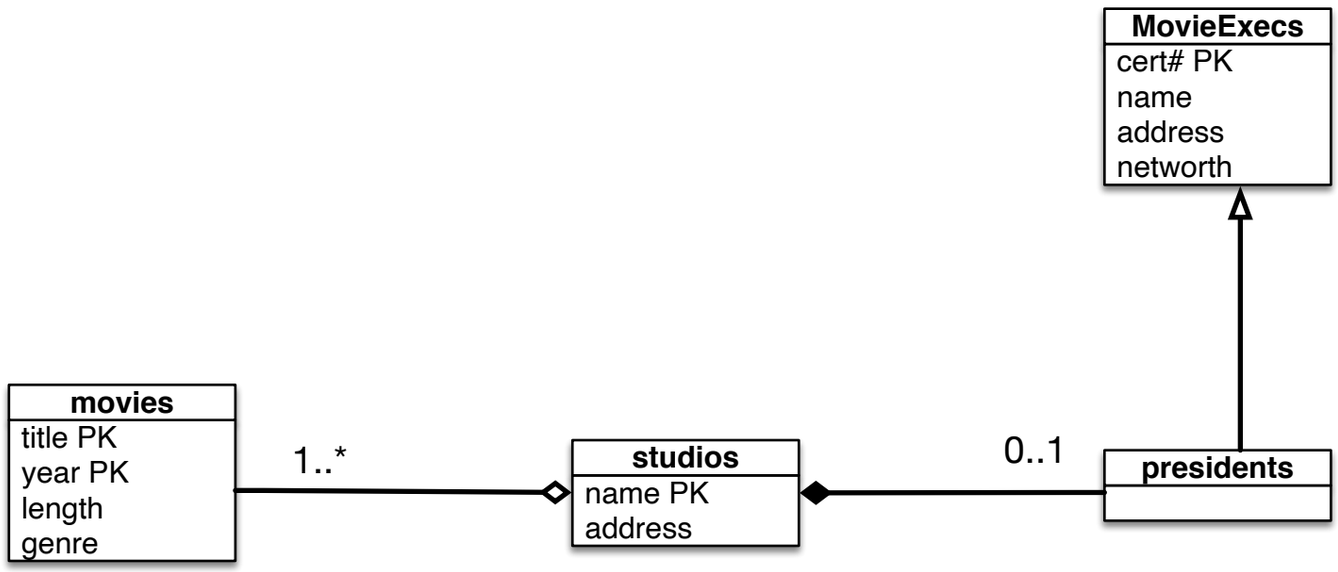
Unified Modeling Language



Unified Modeling Language

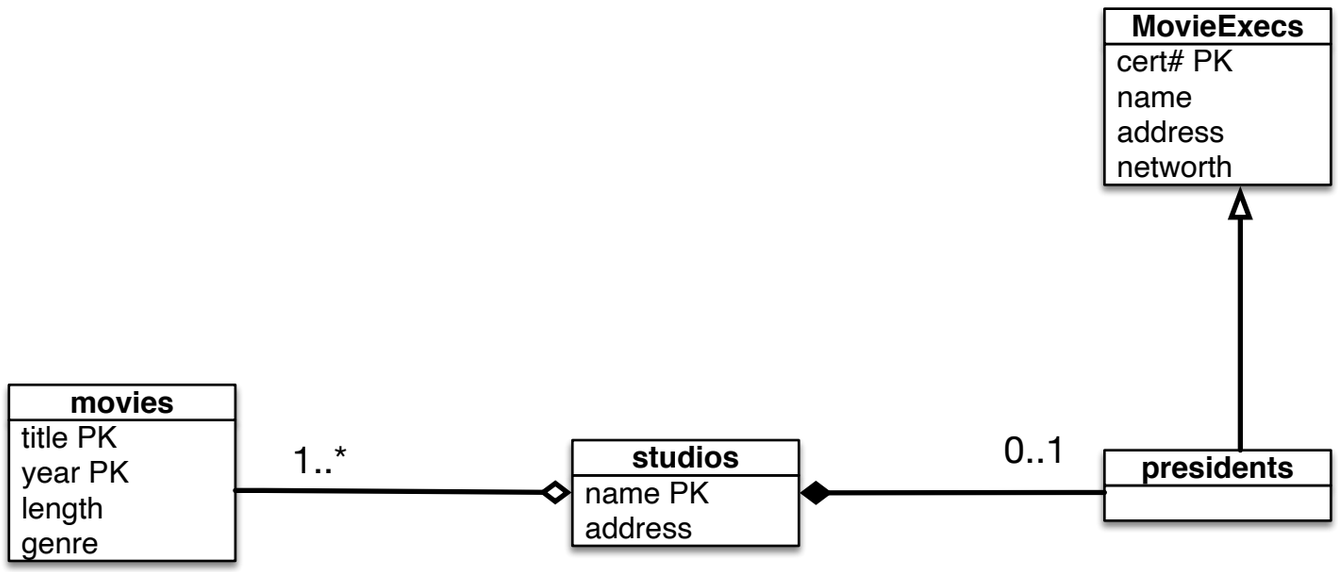
- Subclasses
  - Same possibilities as before:
    - Entity/Relationship approach
    - OO approach
    - Null values

Unified Modeling Language



Use E/R approach

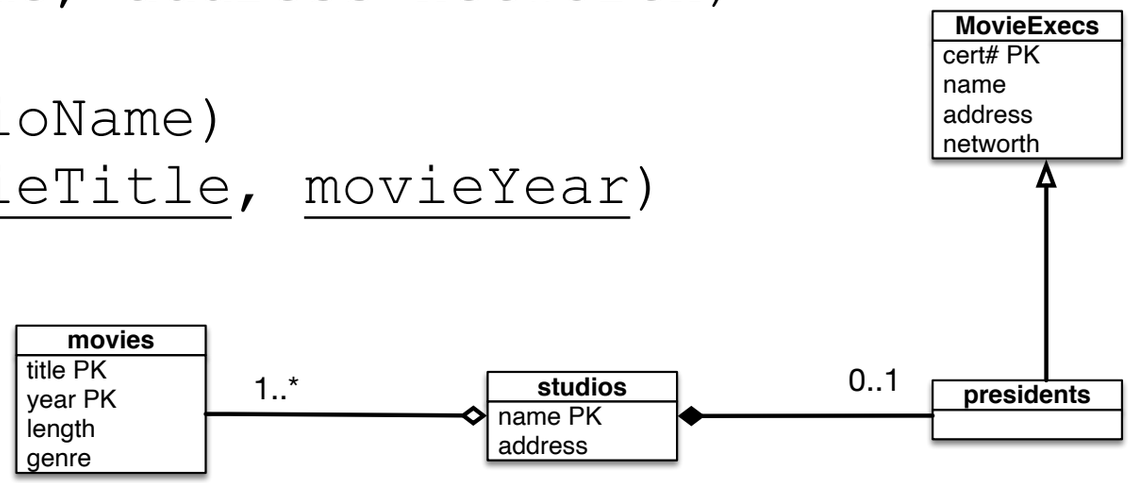
Unified Modeling Language




```
movies(title, year, length, genre)
studios(name, address)
movieExecs(cert#, name, address networth)
presidents(cert#)
presides(cert#, studioName)
owns(studioName, movieTitle, movieYear)
```

Unified Modeling Language

movies(<u>title</u>, <u>year</u>, length, genre)
studios(<u>name</u>, address)
movieExecs(<u>cert#</u>, name, address networth)
presidents(cert#)
presides(cert#, studioName)
owns(<u>studioName</u>, <u>movieTitle</u>, <u>movieYear</u>)



- Obviously, the presidents relation is superfluous
- What about owns?

Unified Modeling Language

- Dealing with compositions and associations:
  - They are many-to-one relationships
    - Incorporate the target relation into the other
    - If an aggregation, there might be no additional attributes

Unified Modeling Language

- This leads to a simpler database scheme

```
movies(title, year, length, genre, studioName)
studios(name, address)
movieExecs(cert#, name, address, netWorth)
presides(cert#, studioName)
```