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Chapter 4. High-Level Database Model

Objectives

- Understand the Database Design Process
- Understand data modeling basing on entity relationship
- Design a suitable database adapted business requirements in reality

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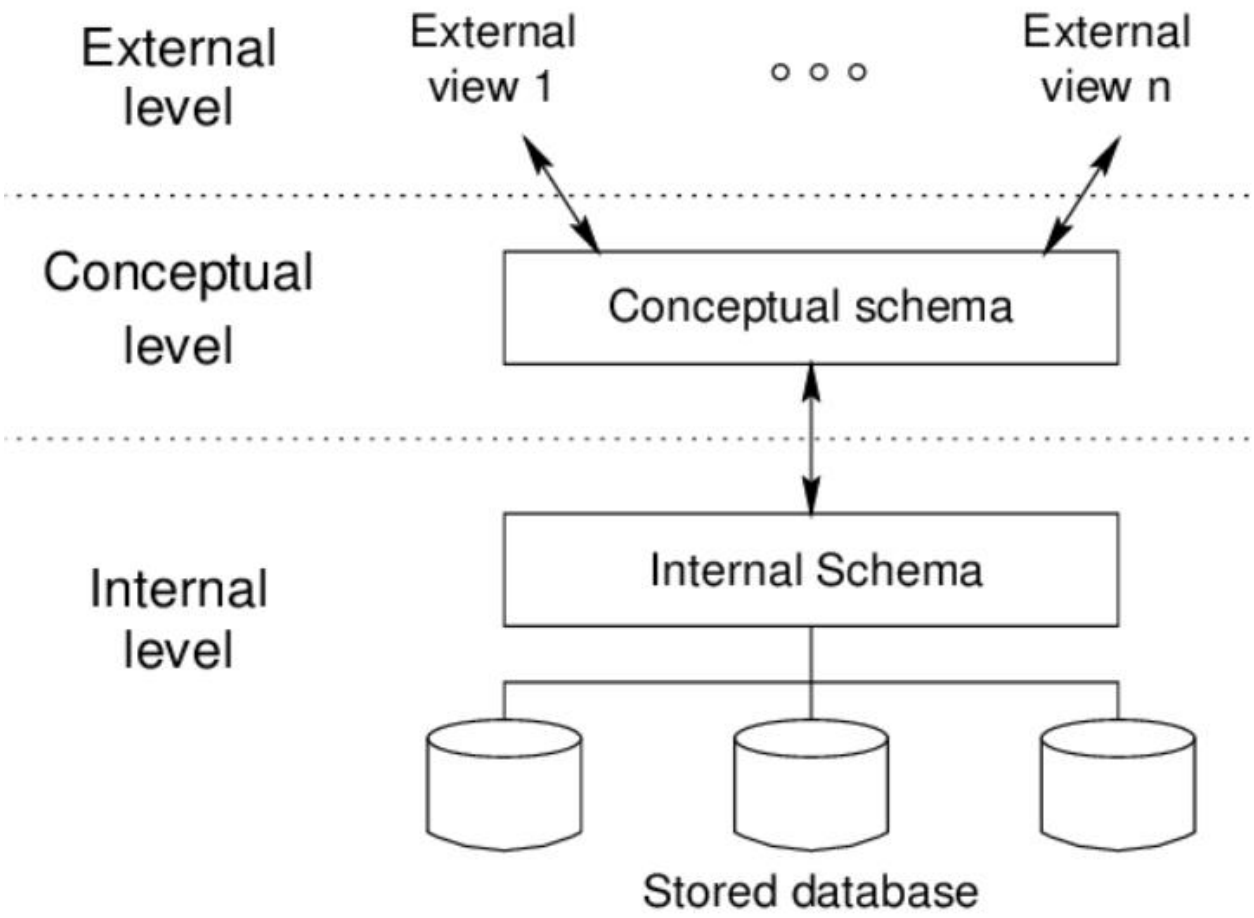
Contents

- Database design process
- Entity relationship model
- What are entity, entity set, attribute, relationship?
- Entity Relationship Diagram (ERD)
- Attributes on Relationships
- Weak Entities
- Sub-class

Data model - Overview



Database modeling and implementation process

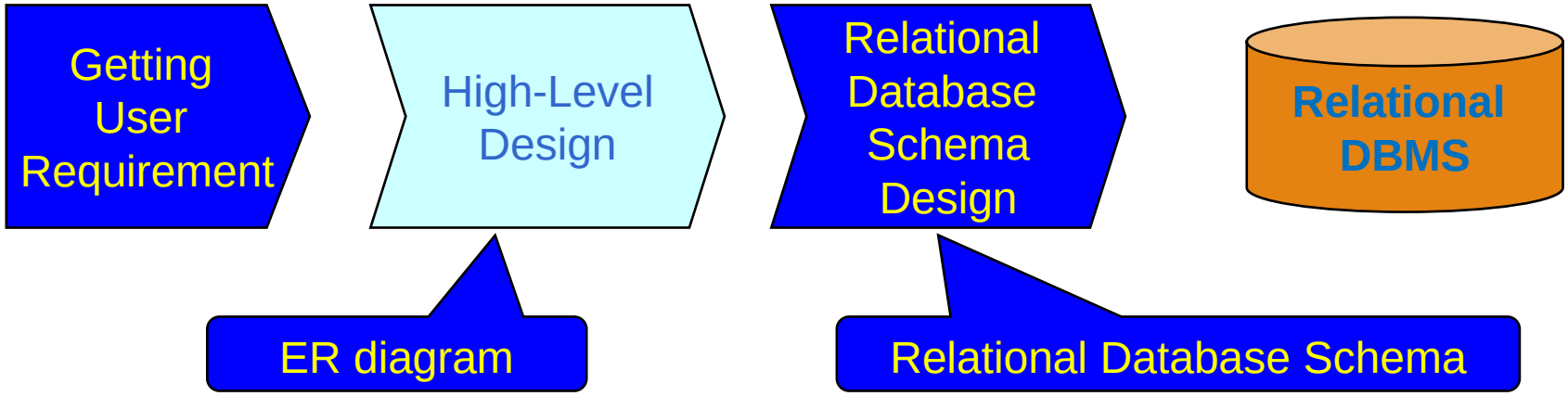


Figure 4.1: The database modeling and implementation process

Steps in Database Design

1. **Requirements Analysis**
   - user needs; what must database do?
2. **Conceptual Design**
   - high level description (Entity Relationship diagram)
3. **Logical Design**
   - translate ERD into DBMS data model
4. **Schema Refinement**
   - consistency, normalization
5. **Physical Design**
   - indexes, disk layout
6. **Security Design**
   - who accesses what, and how

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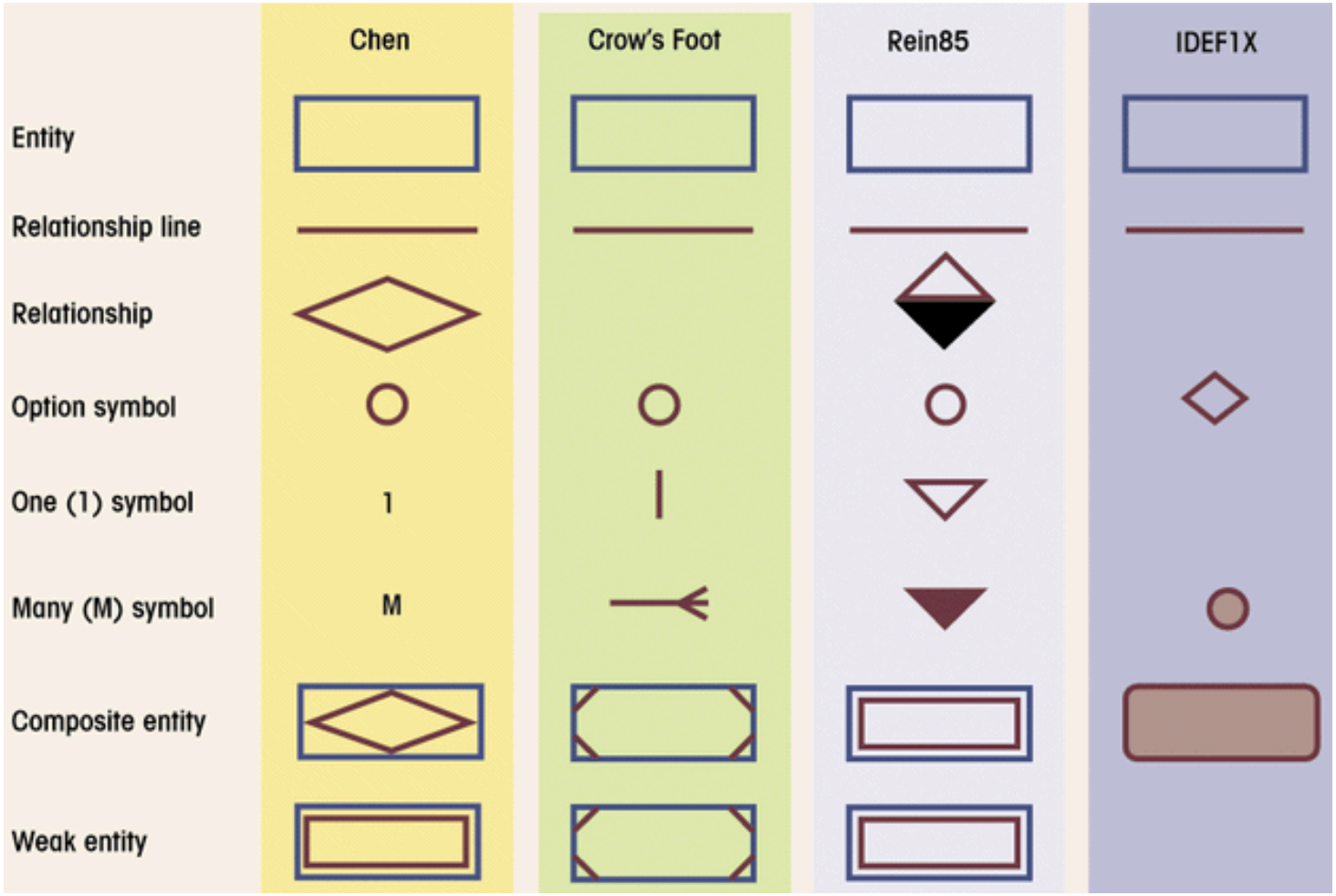
ERD – How to construct

- Gather all the data that needs to be modeled.
- Identify data that can be modeled as real world entities.
- Identify the attributes for each entity.
- Sort entity sets as weak or strong entity sets.
- Sort entity attributes as key attributes, multi-valued attributes, composite attributes, derived attributes.
- Identify the relations between the different entities.
- Using the different symbols draw the entities, their attributes and their relationships. Use appropriate symbols while drawing attributes.

Entity Relationship Diagram - Notations

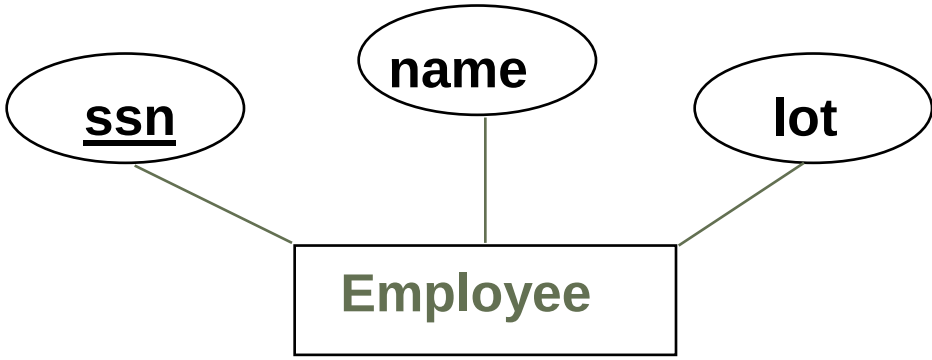
Component	Symbol	Example
Entity	Entity	Student
Weak Entity	Weak Entity	Assignments
Attribute	Attribute	Roll_num
Relationship	Relationship	Saves in
Key Attribute	Attribute	Acct_num

Comparison of E-R Modeling notations



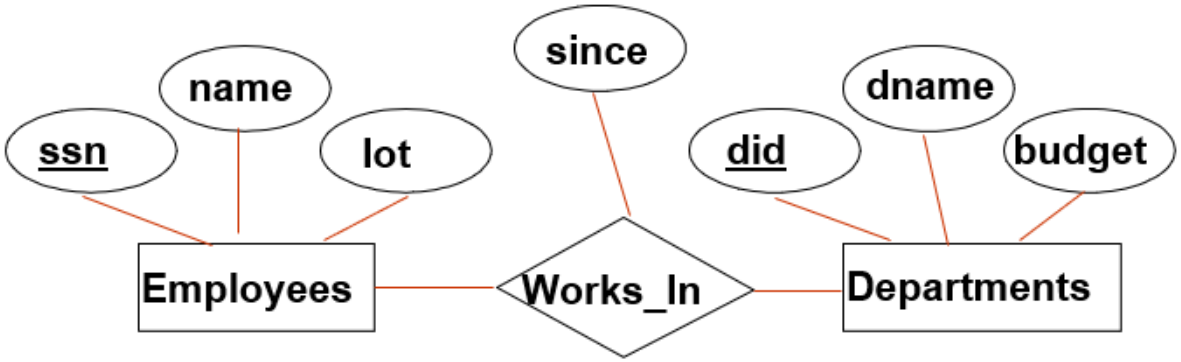
ERD - Entity

- ***Entity:***
  - Real-world thing, distinguishable from other objects.
  - Noun phrase
  - Entity described by set of *attributes*.
- ***Entity Set*: A collection of similar entities. E.g., all employees.**
  - All entities in an entity set have the same set of attributes. (Until we consider hierarchies, anyway!)
  - Each attribute has a domain.



Relationship

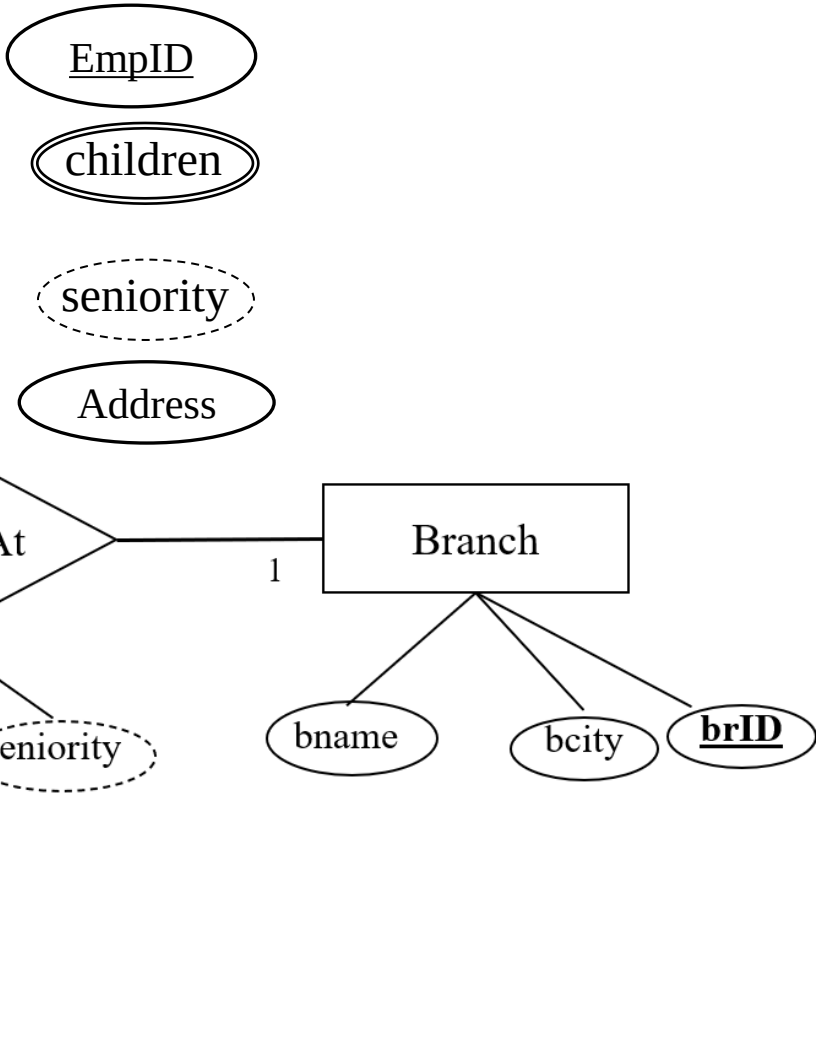
- ***Relationship:*** Association among two or more entities
  - relationships can have their own attributes (descriptive attributes).
  - verb phrases



  - 1-1
  - 1-M/M-1
  - M-M
  - Degree Constraints
  - Recursive relationship
  - Unary, Binary, Ternary relationship
- ***A referential integrity constraints***
  - A value appearing in one context must also appear in another

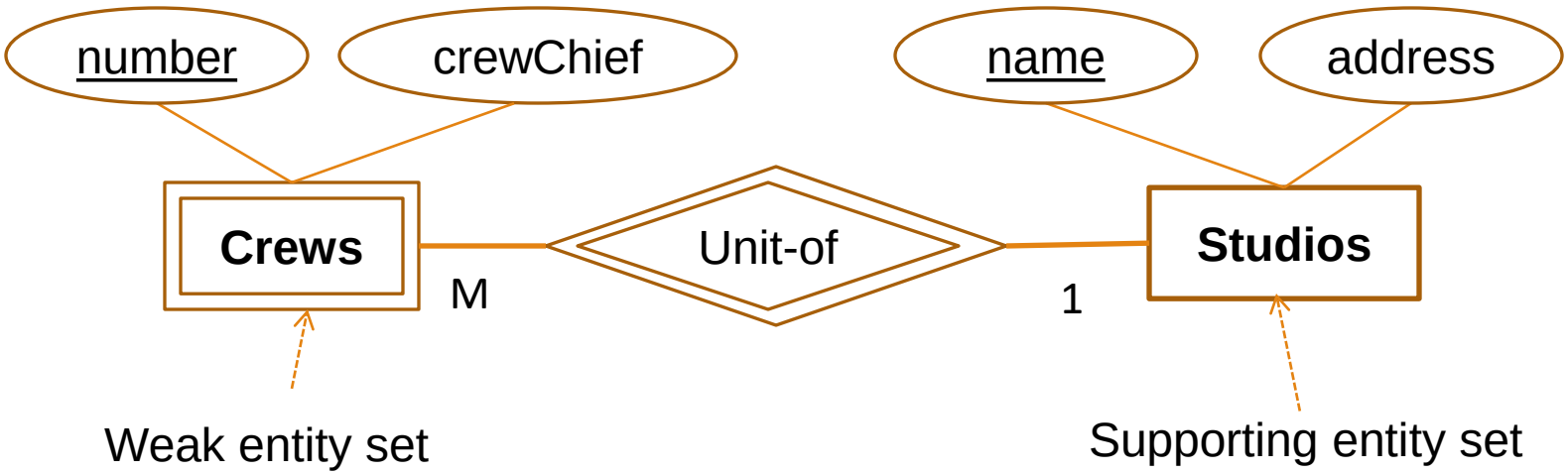
Type of Attributes

- Key attribute
- Multivalued attribute
- Derived attribute
- Composite attribute



Weak Entity Sets

Consider the relationship



- An entity set's key to be composed of attributes, some or all of which belong to another entity set. Such an entity set is called a ***weak entity set***.

Requirements for Weak Entity Sets

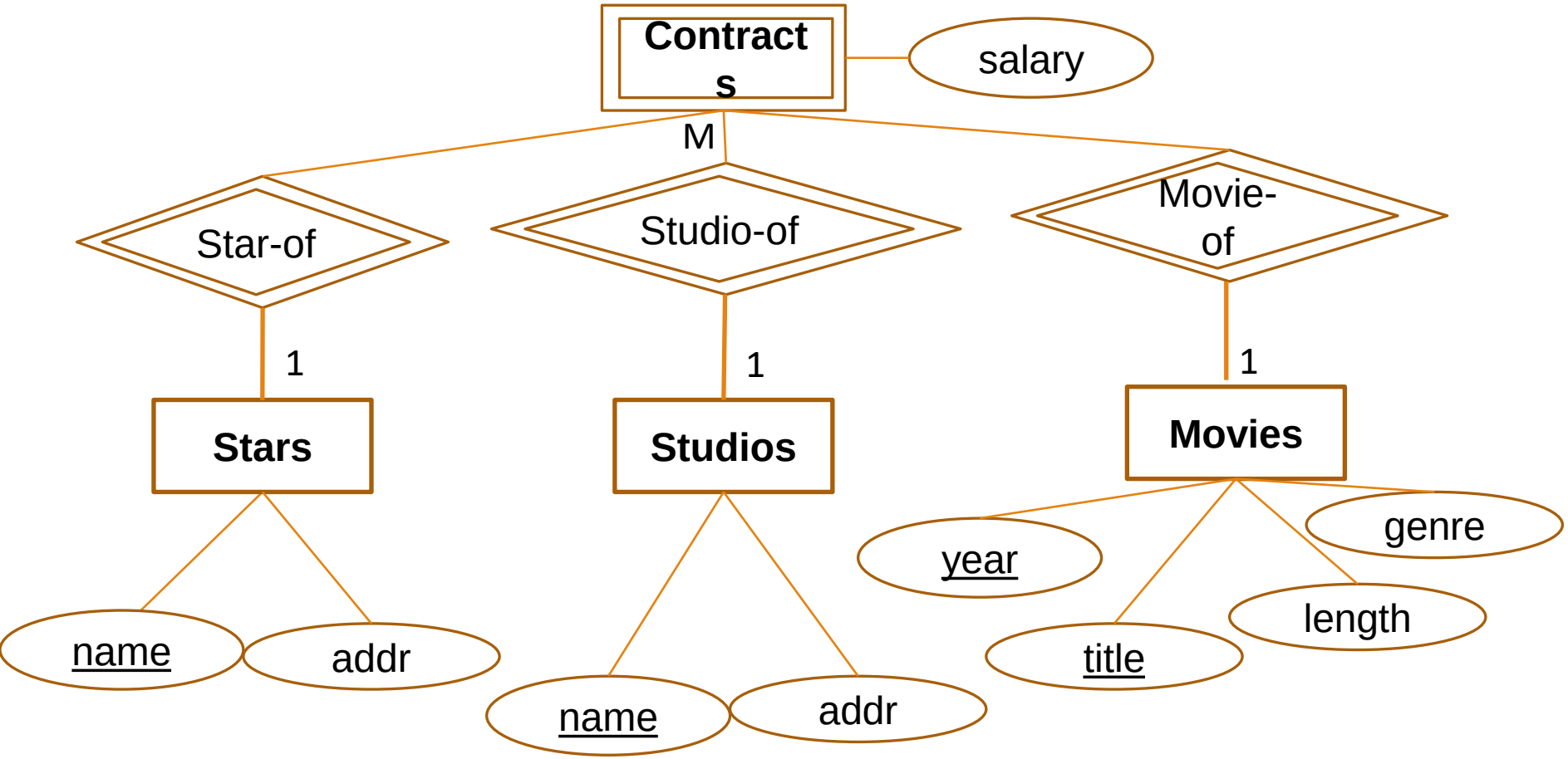
R is a relationship from E to F

R is called *supporting relationship* if

- R must be a binary, many-one relationship from E to F
- R must have referential integrity from E to F
- The attributes that F supplies for the key of E must be key attributes of F

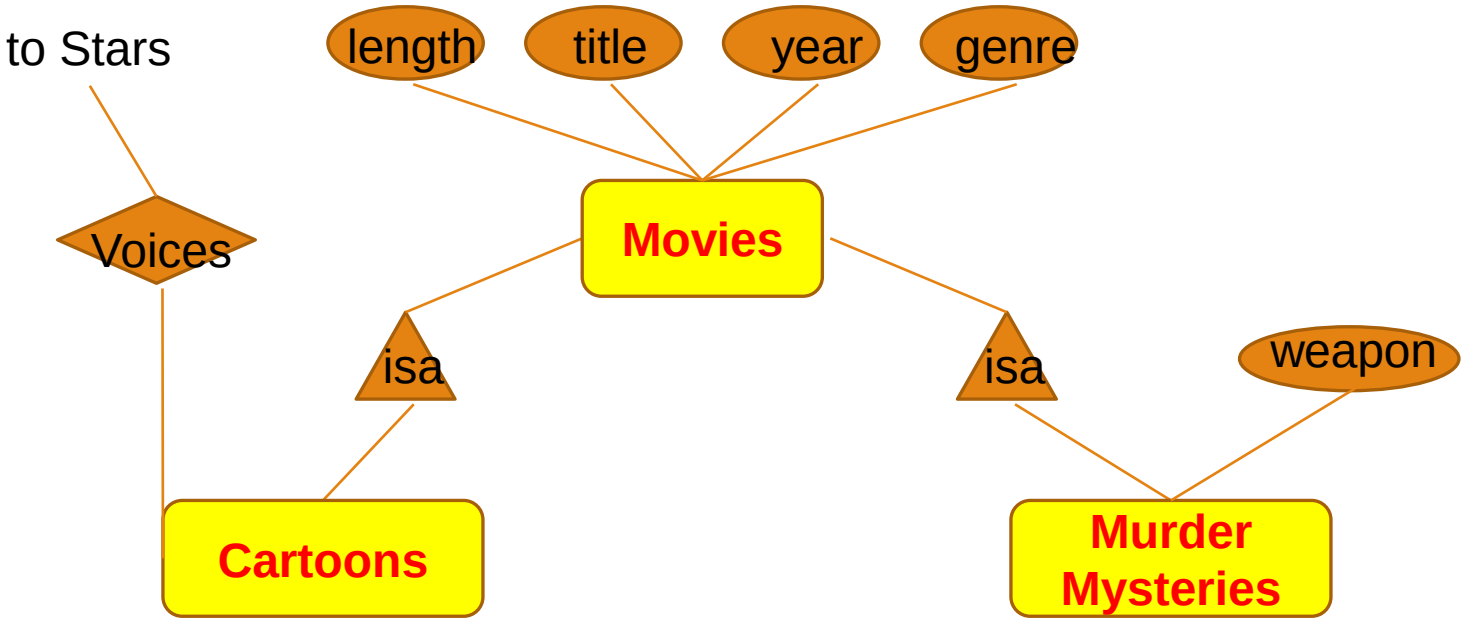
Weak Entity Sets

Example weak entity set



Subclasses in E/R Model

Consider Cartoons and Murder Mysteries are the special kinds of movies, with some special properties



Example COMPANY Database – Construct ERD

Requirements of the Company (oversimplified for illustrative purposes)

- The company is organized into DEPARTMENTs. Each department has a name, number and an employee who *manages* the department. We keep track of the start date of the department manager.
- Each department *controls* a number of PROJECTs. Each project has a name, number and is located at a single location.

Example COMPANY Database (Cont.)

- We store each EMPLOYEE's social security number, address, salary, sex, and birthdate. Each employee *works for* one department but may *work on* several projects. We keep track of the number of hours per week that an employee currently works on each project. We also keep track of the *direct supervisor* of each employee.
- Each employee may *have* a number of DEPENDENTs. For each dependent, we keep track of their name, sex, birthdate, and relationship to employee.

From ER Diagram to Relational Model

- Overview:
  - 1 entity = 1 relation
  - attributes of entity ~ attributes of relation
  - key of entity ~ key of relation
- Convert 1-1 relationship
- Convert 1-M relationship
  - Put key attribute of one-side to M-side
- Convert M-M relationship
  - Generate 1 relation, Primary key of this relation combined from two relations. Attributes of new relation ~ attributes of relationship (if have)

From ER Diagram to Relational Model
Convert 1-1 relationship

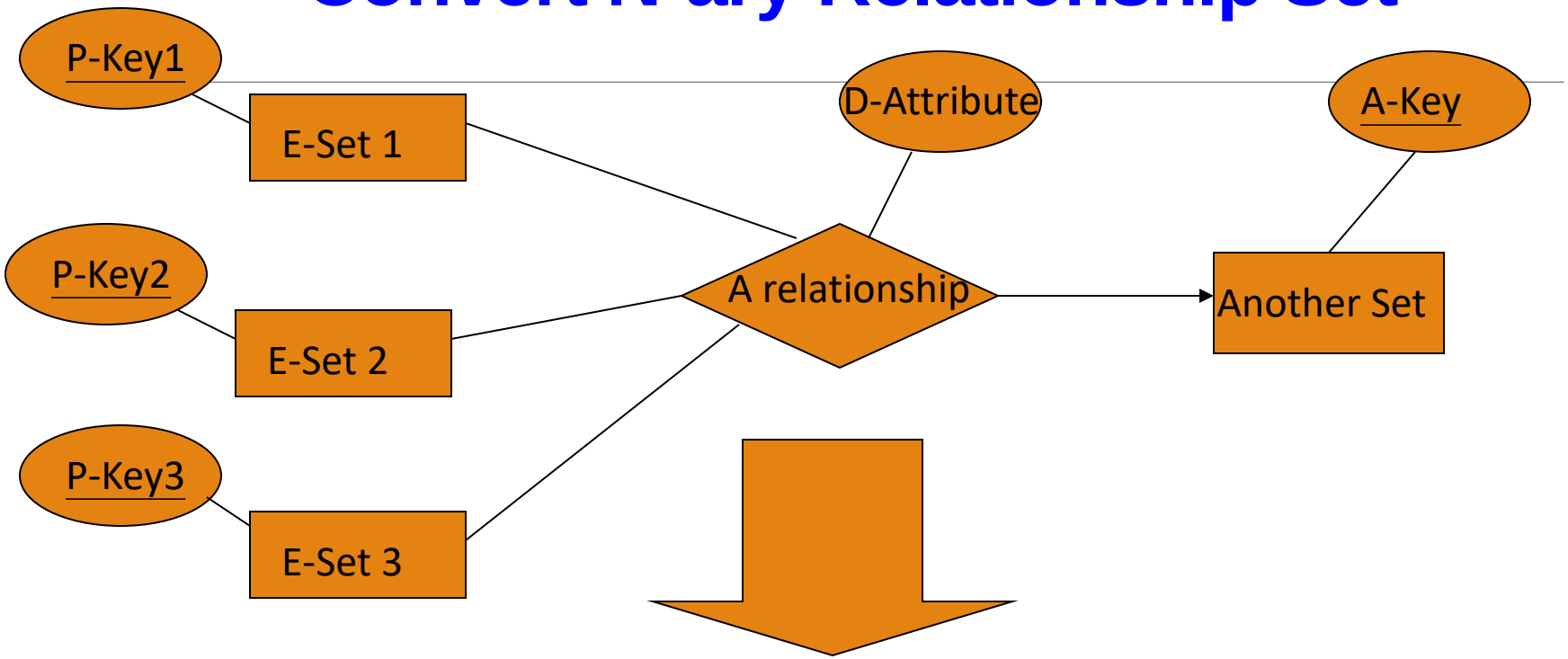
For one-to-one relationship w/out total participation

- Build a table with two columns, one column for each participating entity set's primary key. Add successive columns, one for each descriptive attributes of the relationship set (if any).

For one-to-one relationship with one entity set having total participation

- Augment one extra column on the right side of the table of the entity set with total participation, put in there the primary key of the entity set without complete participation as per to the relationship.

Convert N-ary Relationship Set



P-Key1	P-Key2	P-Key3	A-Key	D-Attribute
9999	8888	7777	6666	Yes
1234	5678	9012	3456	No

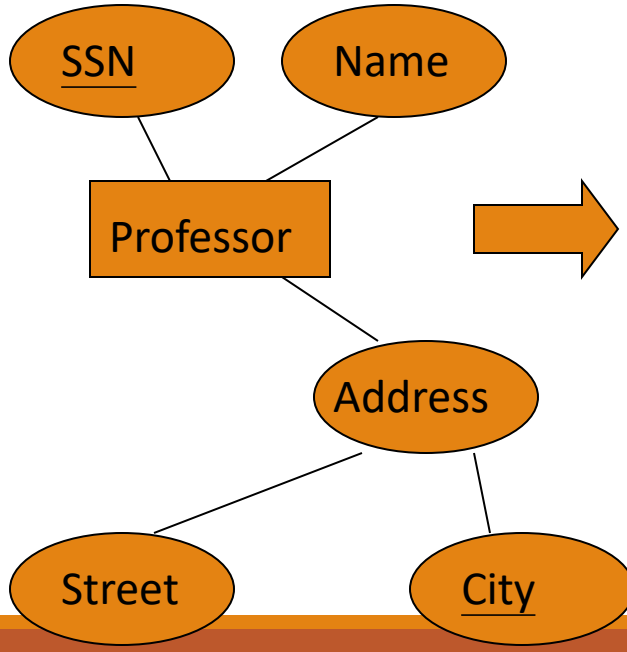
* Primary key of this table is *P-Key1 + P-Key2 + P-Key3*

Representing Composite Attribute

Relational Model Indivisibility Rule Applies

One column for each component attribute

NO column for the composite attribute itself



SSN	Name	Street	City
9999	Dr. Smith	50 1st St.	Fake City
8888	Dr. Lee	1 B St.	San Jose

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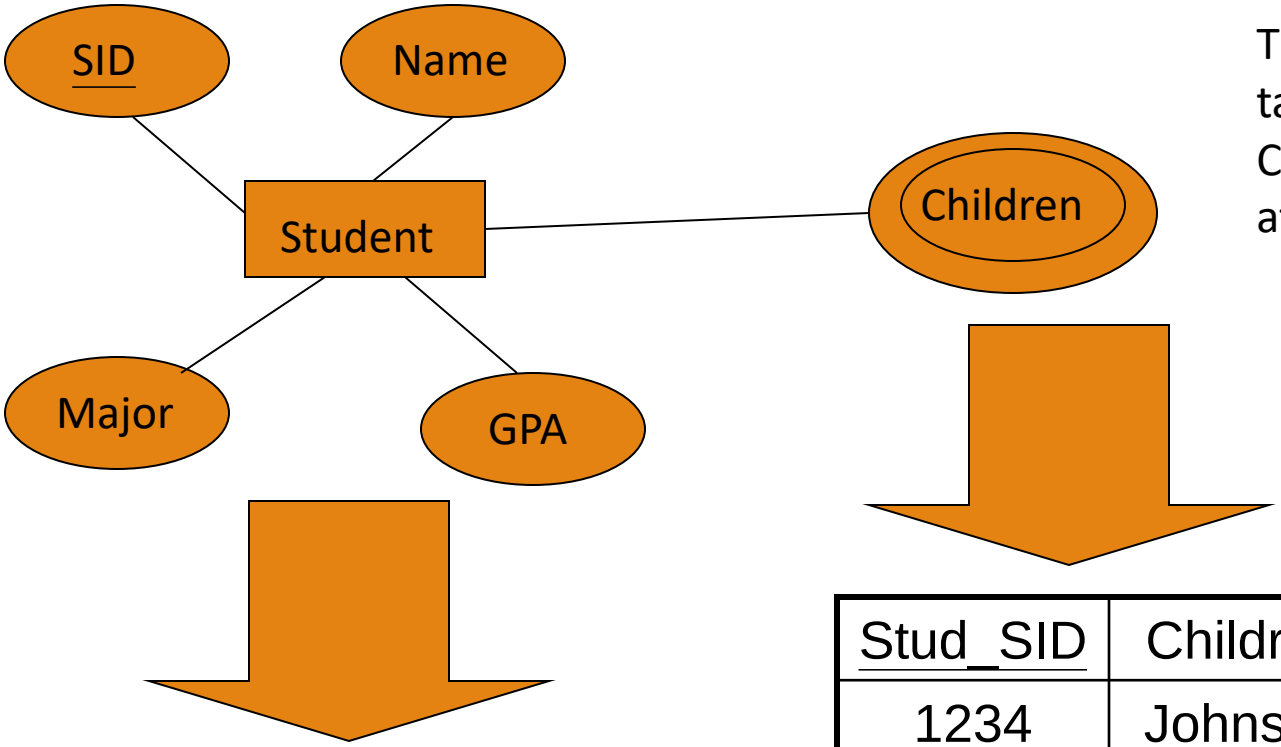
Representing Multivalue Attribute

For each multivalue attribute in an entity set/relationship set

- Build a new relation schema with two columns
- One column for the primary keys of the entity set/relationship set that has the multivalue attribute
- Another column for the multivalue attributes. Each cell of this column holds only one value. So each value is represented as an unique tuple
- Primary key for this schema is the union of all attributes

Example – Multivalue attribute



The primary key for this table is Student_SID + Children, the union of all attributes

SID	Name	Major	GPA
1234	John	CS	2.8
5678	Homer	EE	3.6

Stud_SID	Children
1234	Johnson
1234	Mary
5678	Bart
5678	Lisa
5678	Maggie

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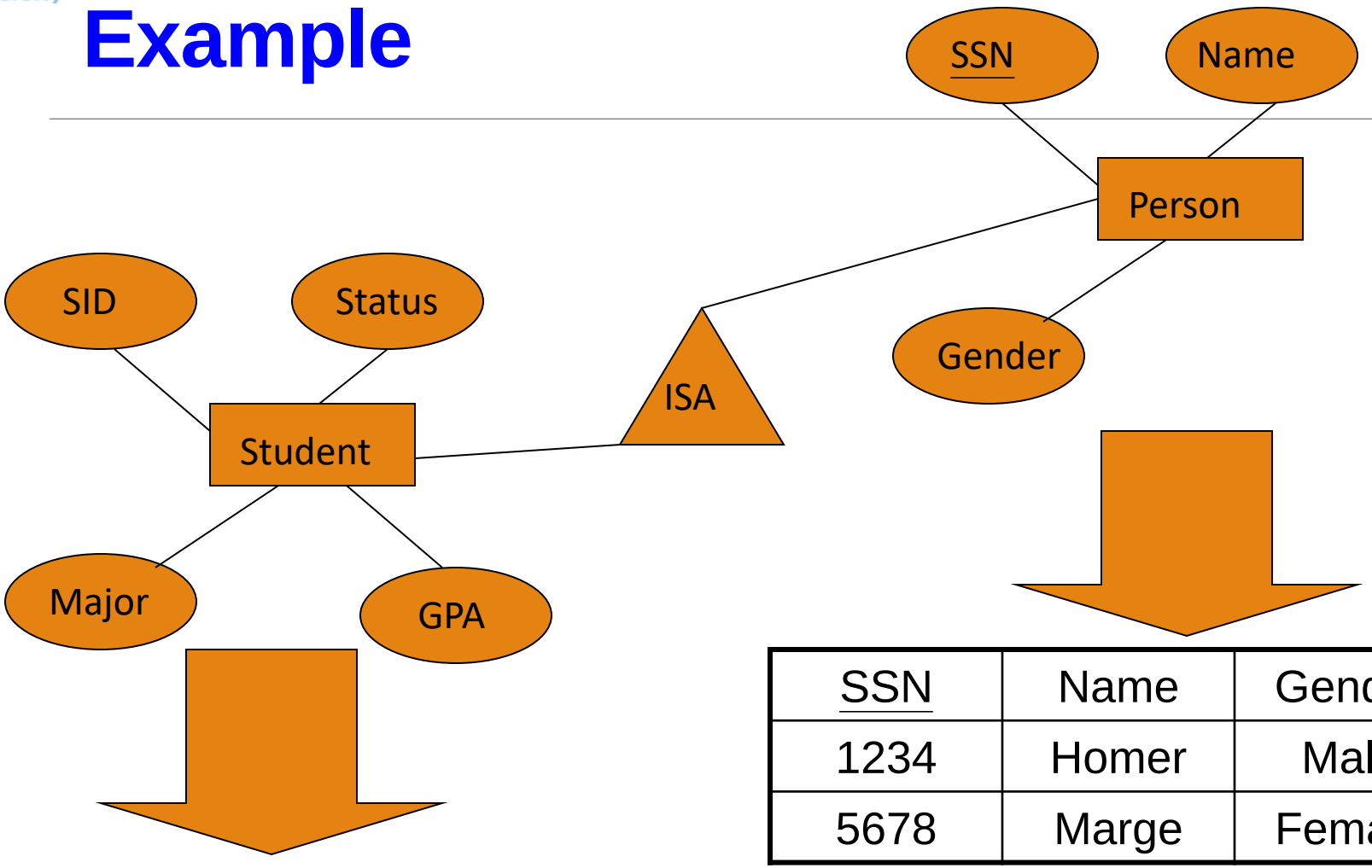
Representing Class Hierarchy

Two general approaches depending on disjointness and completeness

- For non-disjoint and/or non-complete class hierarchy:
  - create a table for each super class entity set according to normal entity set translation method.
  - Create a table for each subclass entity set with a column for each of the attributes of that entity set plus one for each attributes of the primary key of the super class entity set
  - This primary key from super class entity set is also used as the primary key for this new table

Example



SSN	Name	Gender
1234	Homer	Male
5678	Marge	Female

SSN	SID	Status	Major	GPA
1234	9999	Full	CS	2.8
5678	8888	Part	EE	3.6

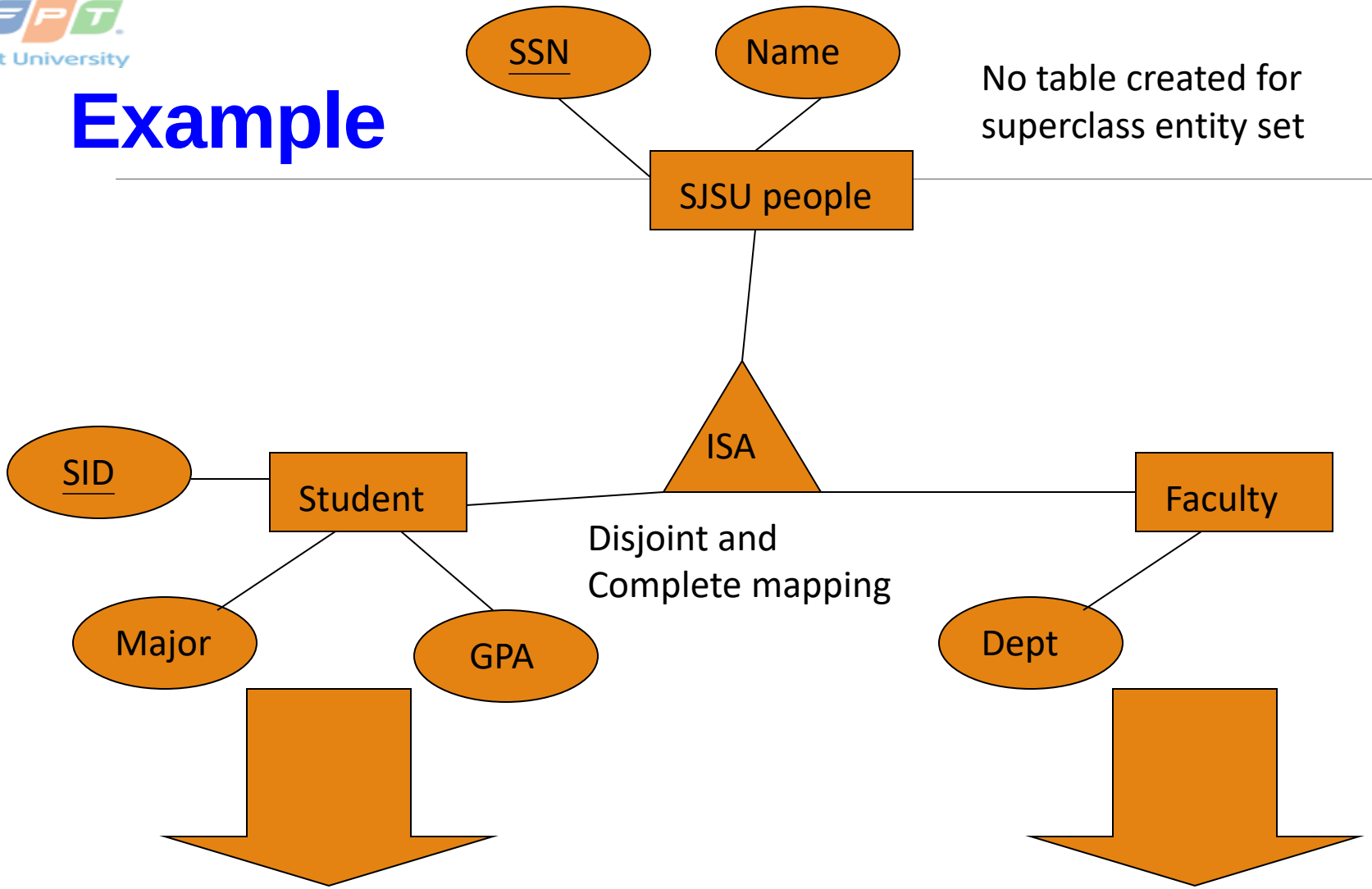
Representing Class Hierarchy

Two general approaches depending on disjointness and completeness

- For disjoint **AND** complete mapping class hierarchy:
- DO NOT create a table for the super class entity set
- Create a table for each subclass entity set include all attributes of that subclass entity set and attributes of the superclass entity set

◦ Simple and Intuitive enough, need example?

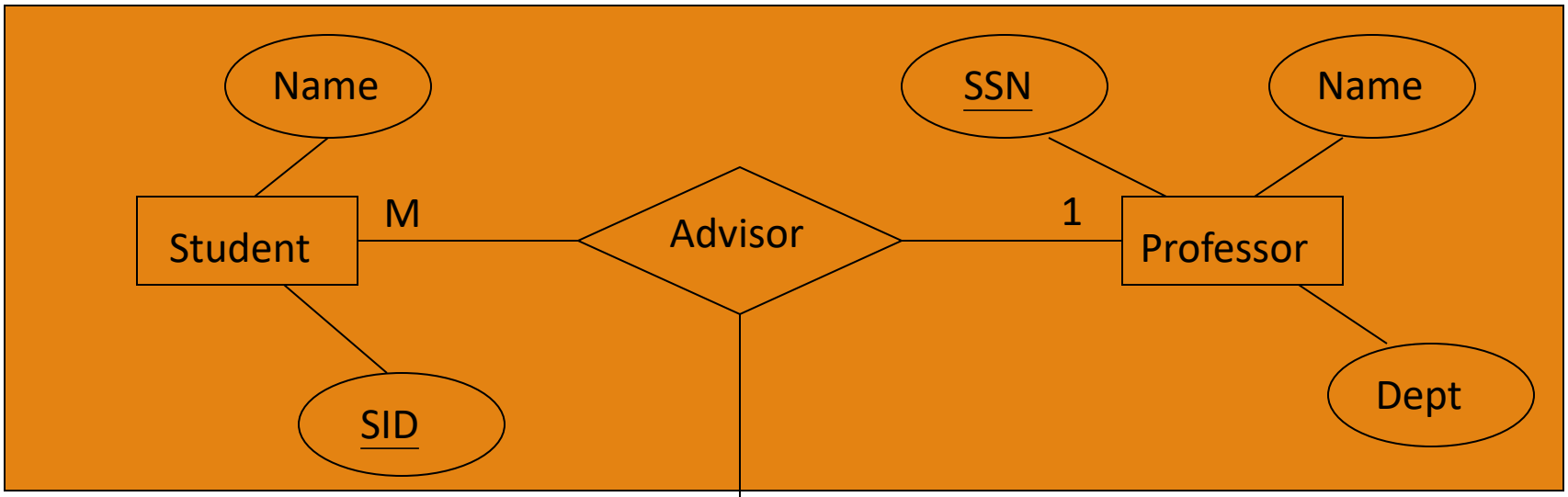
Example

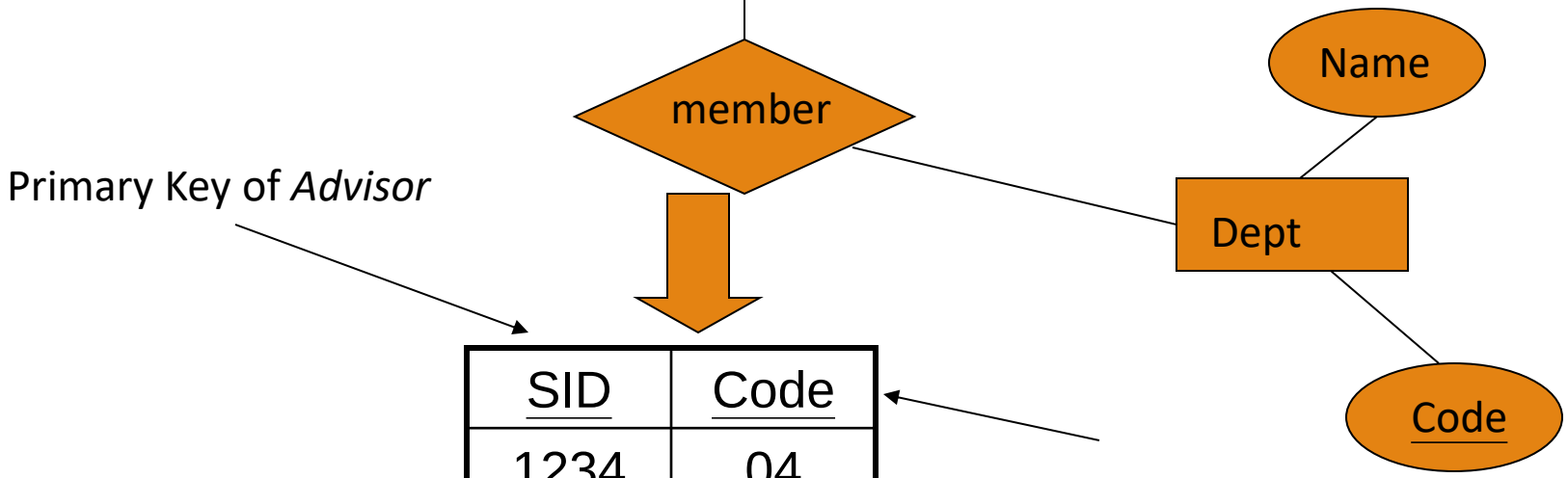


SSN	Name	SID	Major	GPA
1234	John	9999	CS	2.8
5678	Mary	8888	EE	3.6

SSN	Name	Dept
1234	Homer	C.S.
5678	Marge	Math

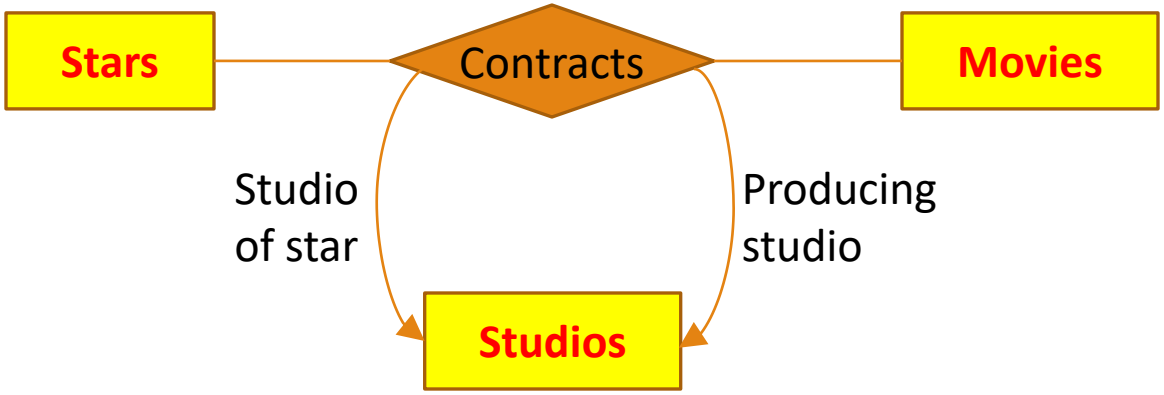
Representing Aggregation





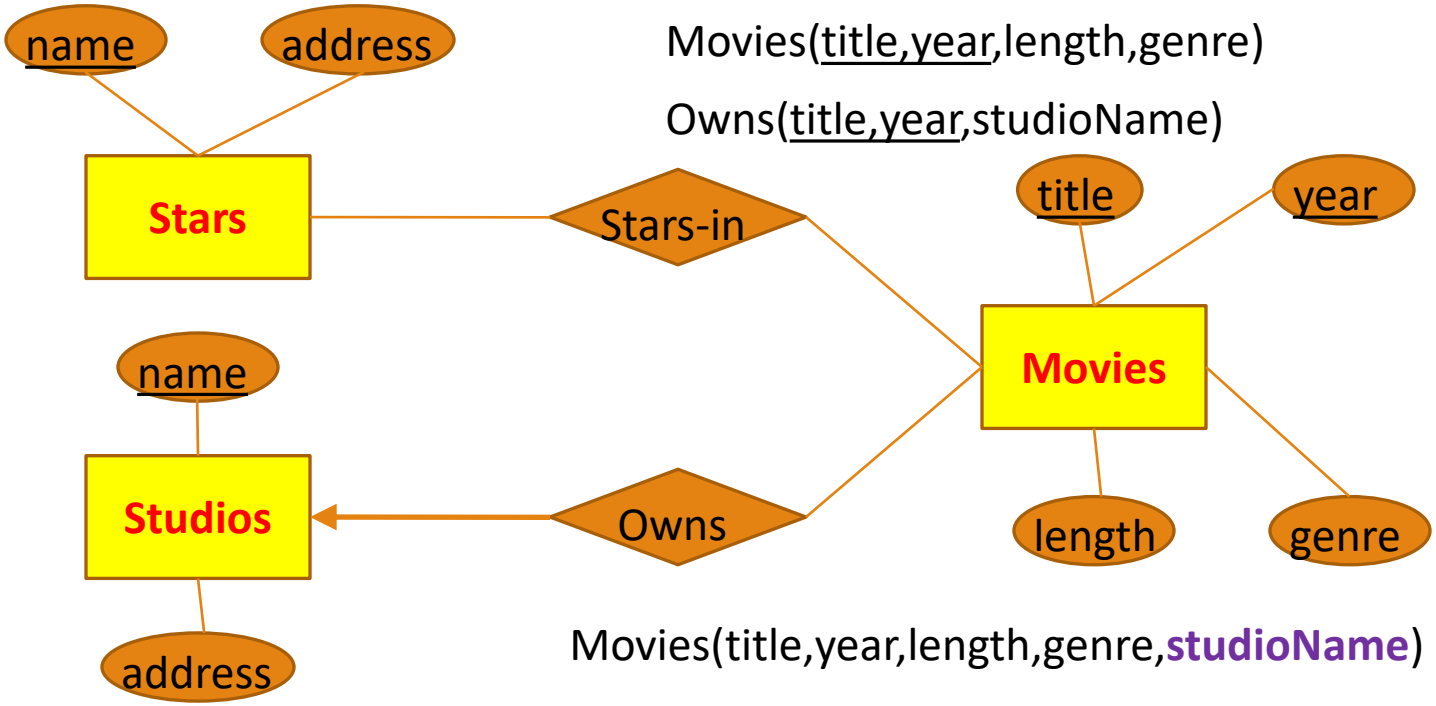
SID	Code
1234	04
5678	08

From E/R Relationship to Relations



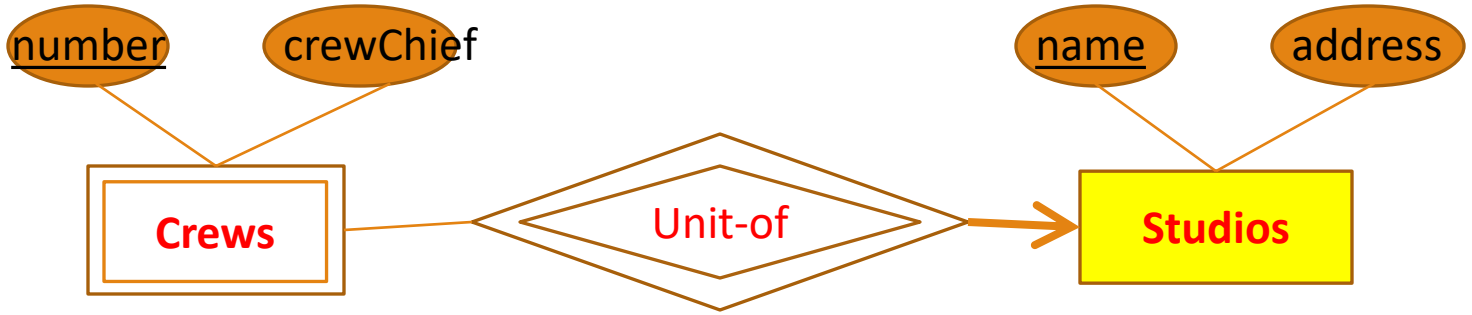
Contracts(starName, title,year, studioOfStar_name, producingStudio_name)

Combining Relations



- Suppose an entity set E and a many-one relationship R from E to F. We can combine two relations E and R into one relation with a schema consisting of:
  - All attributes of E,
  - The key attributes of F, and all own attributes belonging to relationship R

Handling Weak Entity Sets



Studios(name,address)
Crews(number,crewChief,studioName)

If W is a weak entity set, construct for W a relation whose schema consists of:

- All attributes of W
- All own attributes of supporting relationships for W
- For each supporting relationship for W, say a many-one relationship from W to entity set E, all the key attributes of E

Rename attributes, if necessary, to avoid name conflicts

Do not construct a relation for any supporting relationship for W

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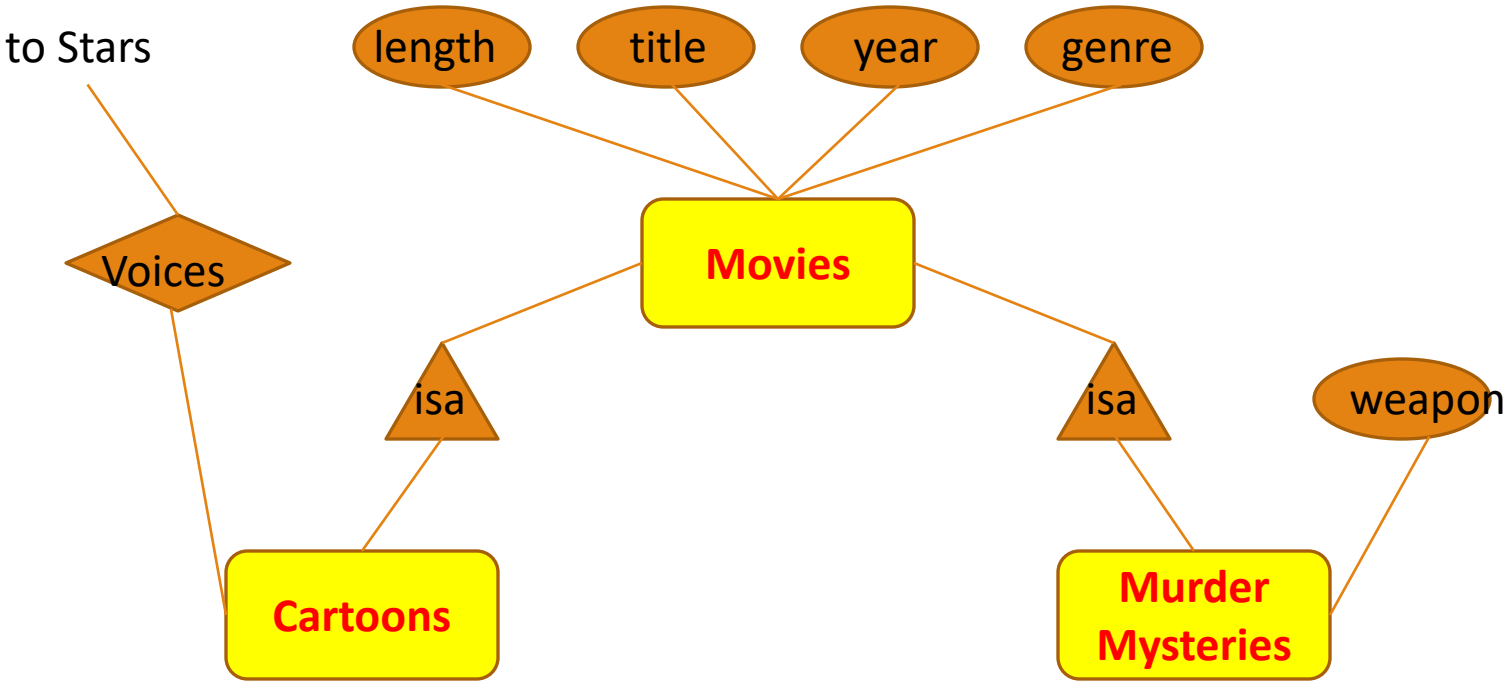
SUBCLASS STRUCTURES TO RELATIONS

Converting Subclass Structures to Relations

How we convert this structure to relations?

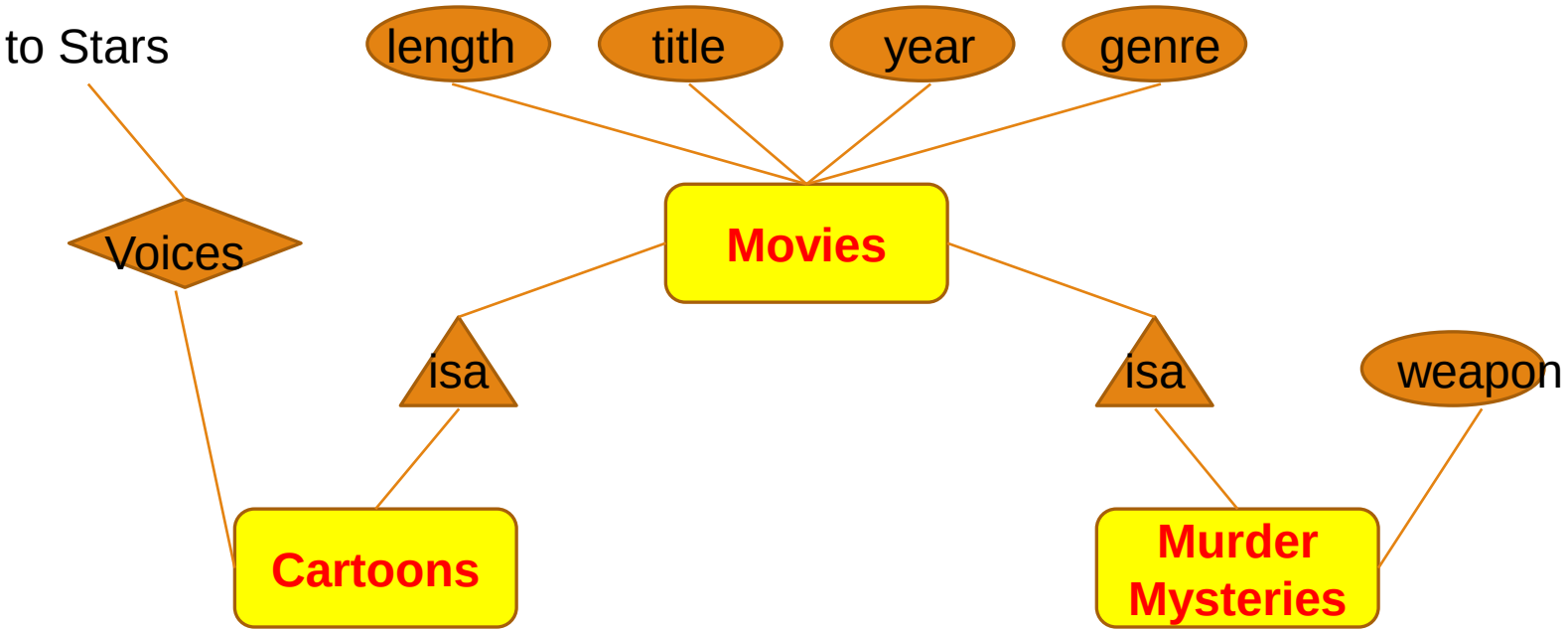


Converting Subclass Structures to Relations

The principal conversion strategies

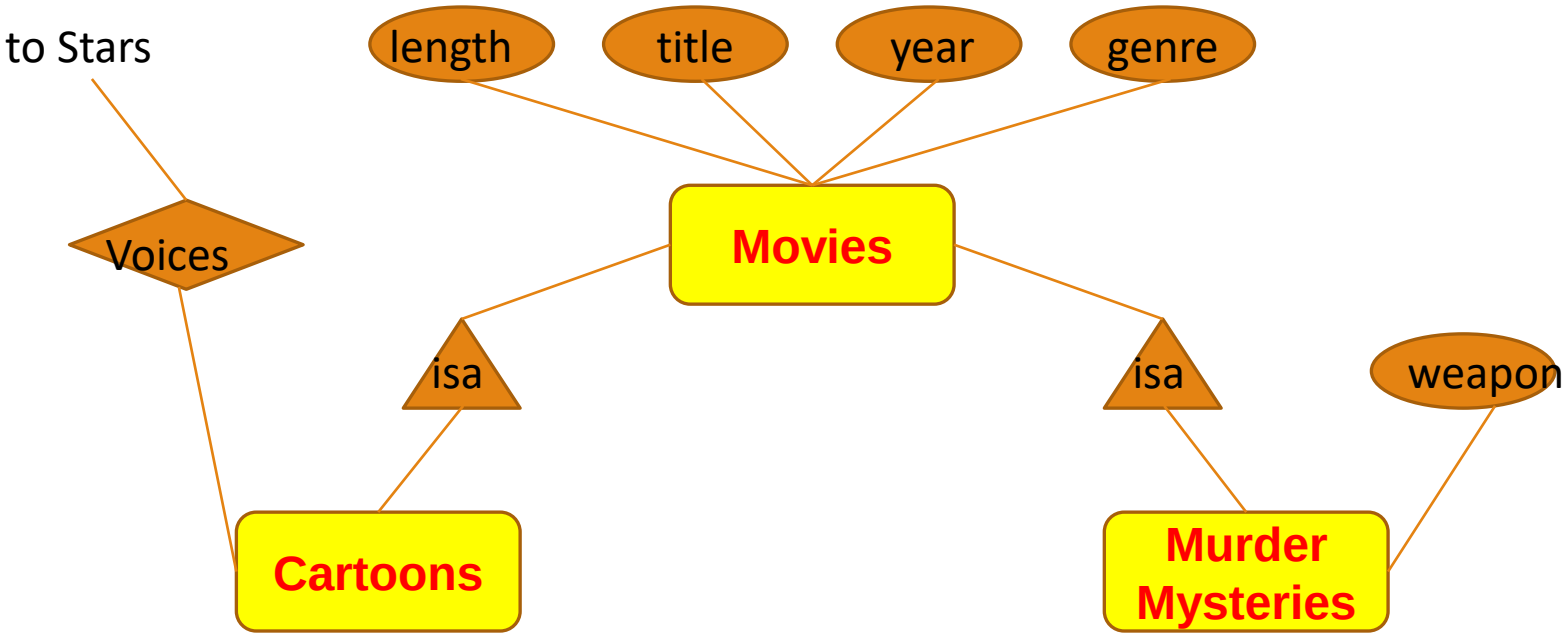
- Follow E/R viewpoint
  - For each entity set E in the hierarchy, create a relation that includes the key attributes from the root and any attributes belong to E
- Treat entities as object-oriented
  - For each possible subtree that includes the root, create one relation, whose schema includes all the attributes of all the entity sets in the subtree
- Use null values
  - Create only one relation with all attributes of all entity sets in the hierarchy. Each entity is represented by one tuple, and that tuple has a NULL value for whatever attributes the entity does not have

E/R Style Conversion



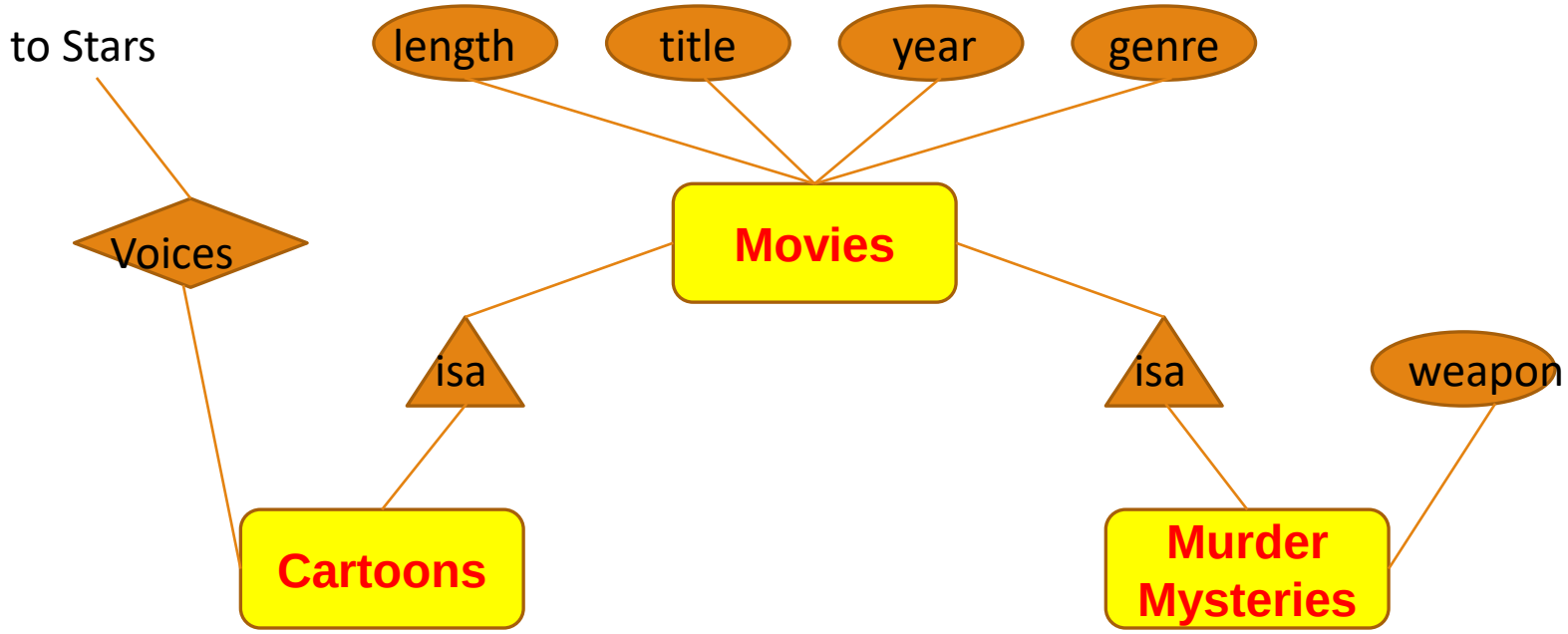
Movies(title,year,length,genre)
MurderMysteries(title,year,weapon)
~~Cartoons(title,year)~~ ← remove
Voices(title,year,starName)

An Object-Oriented Approach



Movies(title,year,length,genre)
MoviesC(title,year,length,genre)
MoviesMM(title,year,length,genre,weapon)
MoviesCMM(title,year,length,genre,weapon)

Using Null Values



Movie(title,year,length,genre,weapon)

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Unified Modeling Language –self studying

Introduction

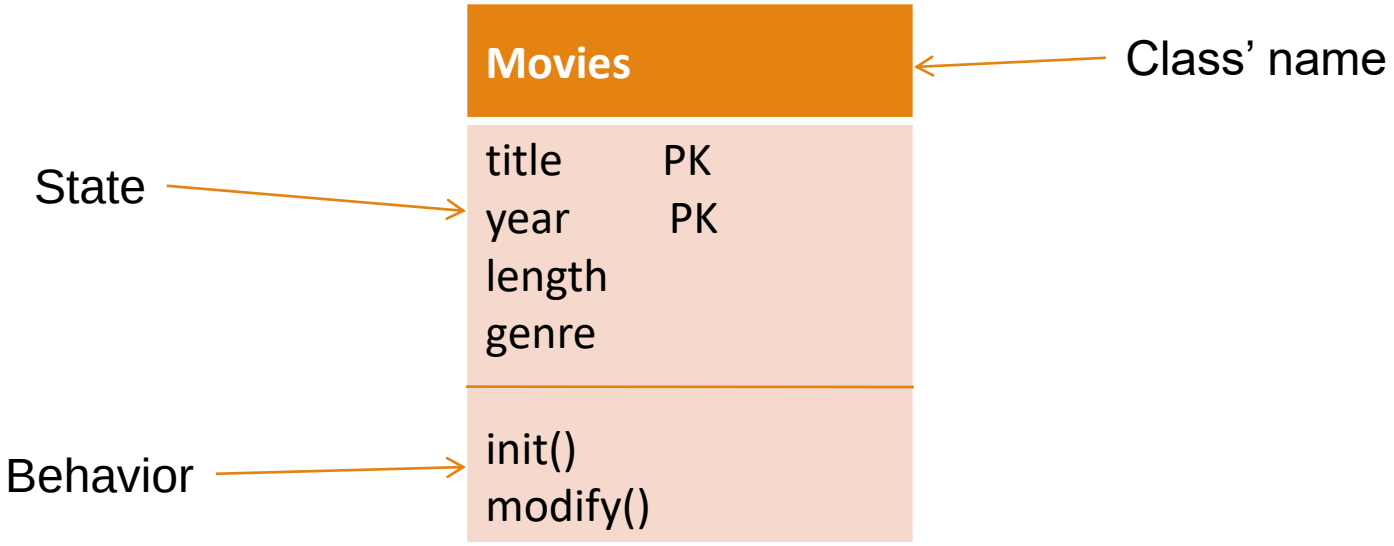
- UML is designed to model software in an object-oriented style, but has been adapted as a database modeling language
- UML offers much the same capabilities as the E/R model, with the exception of multi-way relationships, only binary relationships in UML.

UML vs. E/R Model

UML	E/R Model
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 referential integrity

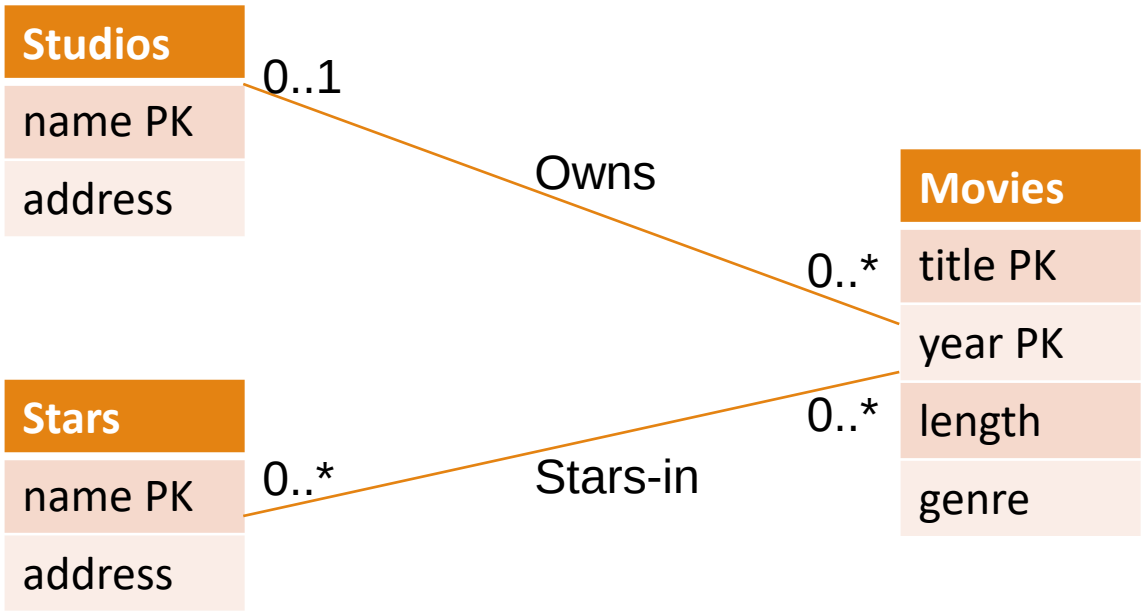
Figure 4.34: Comparison between UML and E/R terminology

UML Classes


Movies
Class' name
State
title PK
year PK
length
genre
Behavior
init()
modify()

Associations

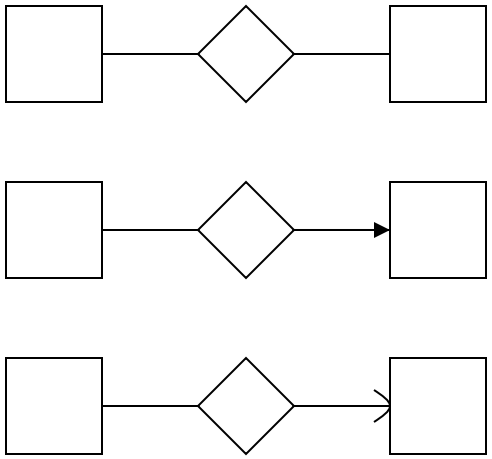
Consider an associations between Movies, Stars, and Studios in UML



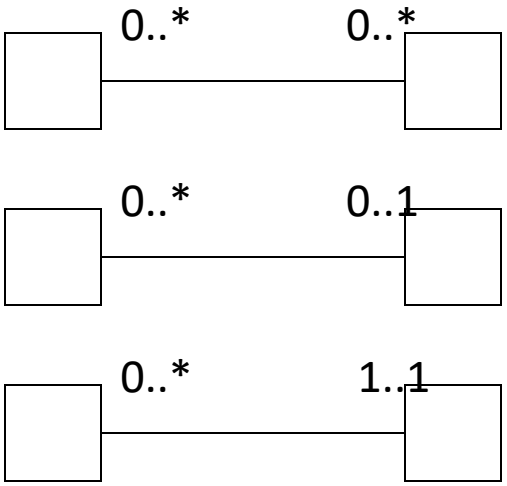
Associations

Comparison with E/R Multiplicities

E/R



UML

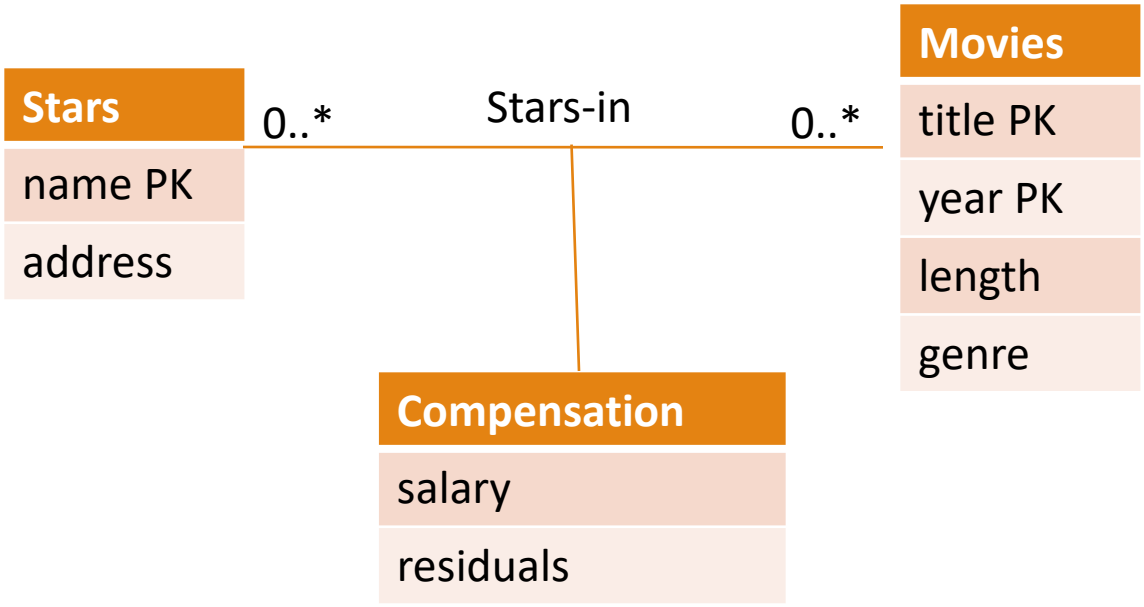


Self-Associations

An association can have both ends at the same class; such an association is called a self-association

Example

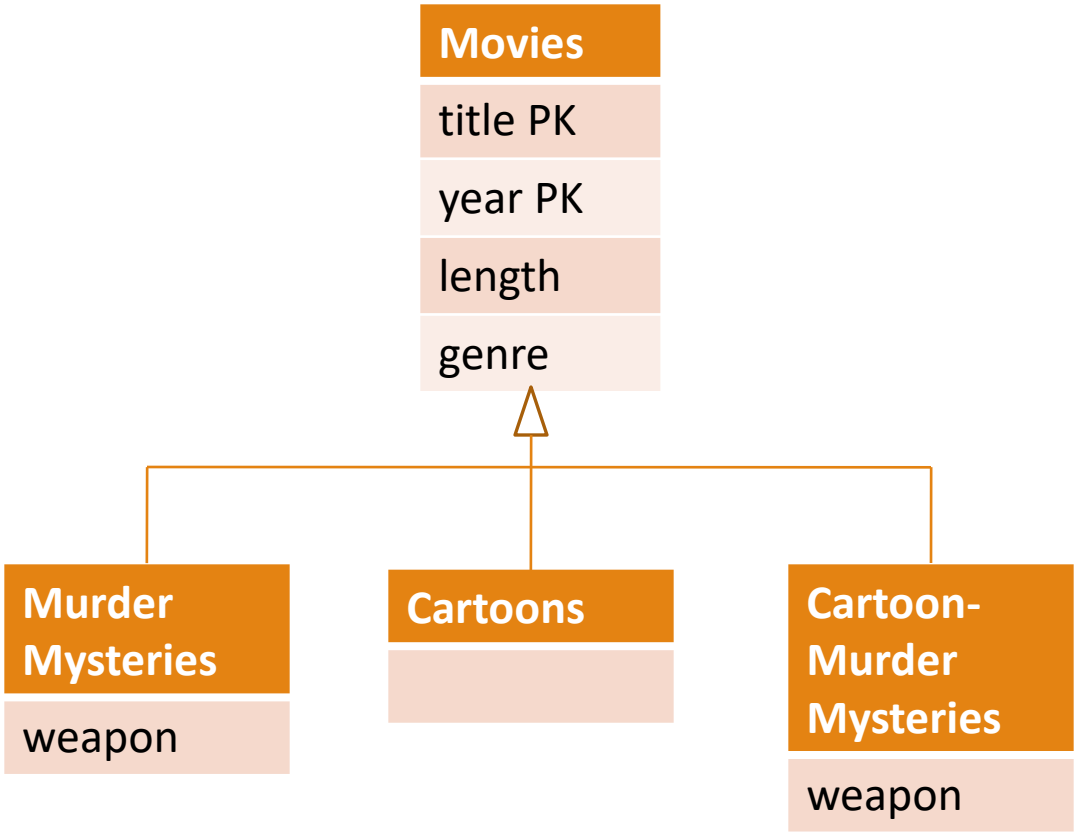
Association Classes



Subclasses in UML

Consider Movies and its three subclasses

Figure 4.40: Cartoons and murder mysteries as disjoint subclasses of movies



Aggregations and Compositions

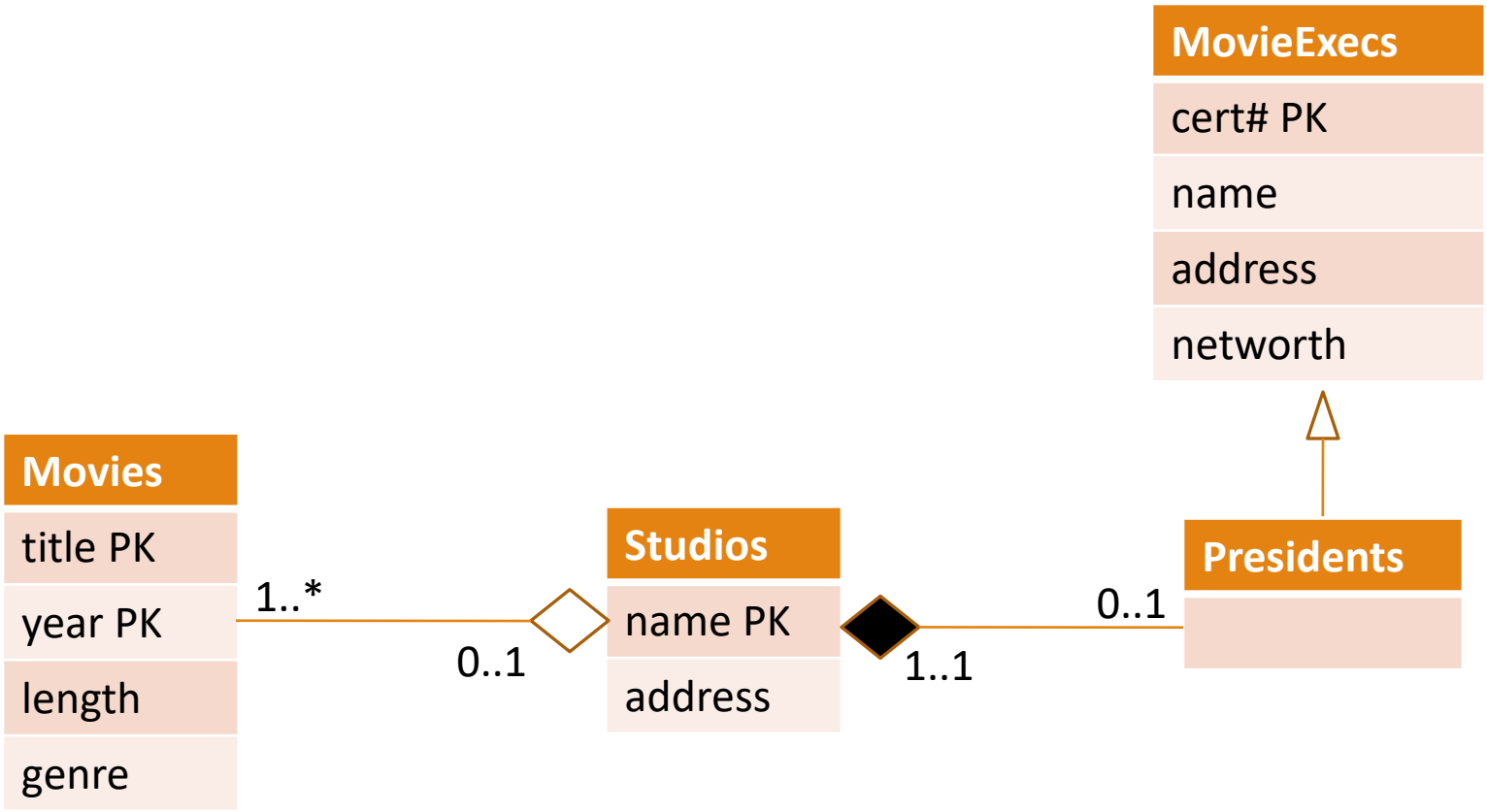


Figure 4.41: An aggregation from Movies to Studios and a composition from Presidents to Studios

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UML-to-Relations Basics

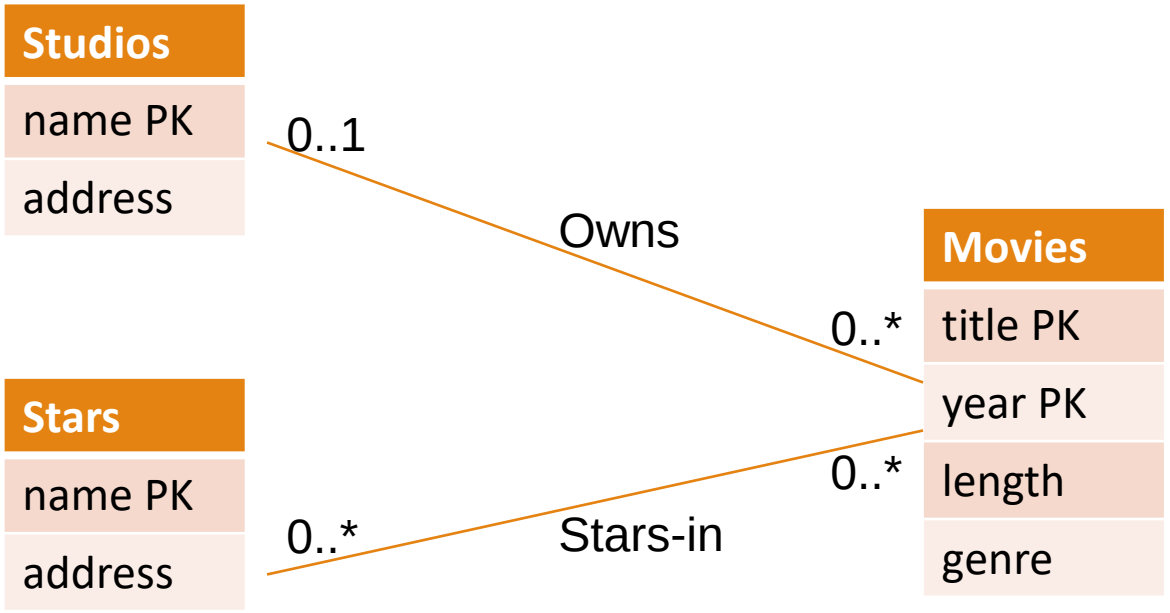
Classes to Relations

- For each class, create a relation
  - name is the name of the class
  - attributes are the attributes of the class

Associations to Relations

- For each association, create a relation
  - name is the name of that association
  - attributes are the key attributes of the two connected classes

UML-to-Relations Basics



Movies(title,year,length,genre)
Stars(name,address)
Studios(name,address)

Stars-In(movieTitle,movieYear,starName)
Owns(movieTitle,movieYear,studioName)

From UML Subclasses to Relations

We can use any of the three strategies outlined for E/R to convert a class and its subclasses to relations

- E/R-style: each subclass' relation stores only its own attributes, plus key
- OO-style: relations store attributes of subclass and all super-classes
- Nulls: One relation, with NULL's as needed

From Aggregations and Composition to Relation

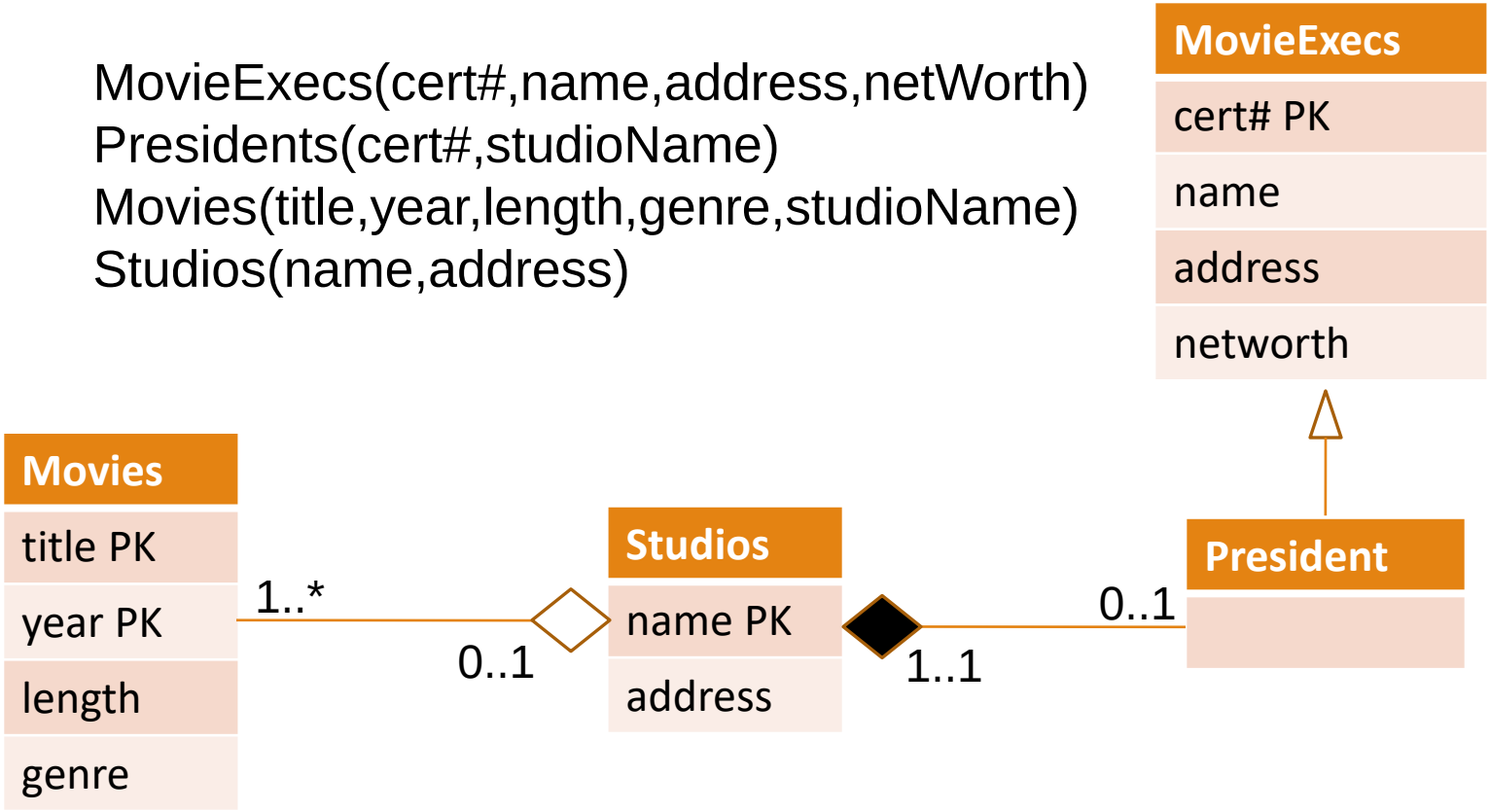
No relation for the aggregation or composition

Add to the relation for the class at the non-diamond end the key attribute(s) of the class at the diamond end

- In the case of an aggregation, it is possible that these attributes can be null

From Aggregations and Composition to Relation

MovieExecs(cert#,name,address,netWorth)
Presidents(cert#,studioName)
Movies(title,year,length,genre,studioName)
Studios(name,address)



The UML Analog of Weak Entity Sets

We use the composition, which goes from the weak class to the supporting class, for a weak entity set

Example:

Studios(name,address)
Crews(number,crewChief,studioName)