E/R Design

CSE462 Database Concepts

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Outline

High-Level Design

Types of questions we must answer during high-level design.

- What information needs to be stored?
- How do information elements relate to each other?
- Which constraints should be assumed?

High-Level Design

Design approach.

- A conceptual model of the data is produced.
- The model is a formal notation.
- Not used directly for database implementation.
- Conceptual models are mapped to logical ones (e.g., logical schema).
- Logical models are mapped to physical ones (e.g., physical schema).

Next...

1. E/R Design
   - Entity/Relationship Model
   - Design Principles
   - Constraints
   - Weak Entity Sets
   - E/R Notation Summary
   - Mapping to Relational Schemas

Entity/Relationship Model

- Entity/Relationship (E/R) is one of many high-level design approaches.
- Others: Unified Modeling Language, Object Definition Language, etc.
- ER has many variants, each with slightly different notation.
- We will follow the one in the book, with a few extensions.
- The structure of the data is represented graphically as an E/R Diagram.
- E/R diagrams consists mainly of: entity sets, attributes, relationships.

Entity and Entity Set

Definition: Entity and Entity Set

An entity is an object of some sort, somewhat similar to objects in an OOPL. A collection of similar entities is an entity set, and its role is analogous to that of classes in an OOPL. Entity sets are usually implemented as relations in the relational model, however, not all relations in the final schema correspond to entity sets.

Attribute

Definition: Attribute

Entity sets have associated attributes, which are the individual properties of every entity in that set. Attribute types can be one of the following:

- primitive (e.g., atomic values such as strings or integers)
- composite (e.g., tuples with primitive components)
- set of values (e.g., set of some primitive or composite)
- derived (e.g., age is derived from date of birth)

Only primitive attributes are allowed in relational schemas. Attributes of an entity usually map to attributes in a relation, but that is not a requirement.

Relationship

Definition: Relationship

A relationship is a connection among entity sets. Binary relationships involve exactly two entity sets and are the most common. In principle, however, a relationship may involve any number of entity sets. Some relationships are implemented as relations, others as attributes.

ER Diagram

Graphical representation: ER Diagrams.

- Entity sets are represented as rectangles.
- Attributes are represented as ovals.
- Relationships are represented as diamonds.
- Edges connect entity sets to their attributes.
- Edges also connect relationships to their entity sets (and attributes).

Example: ER Diagram

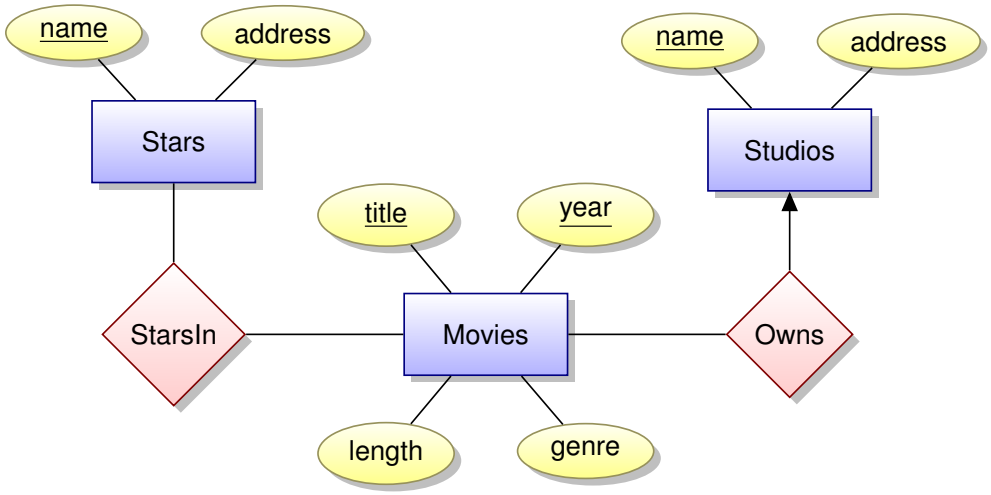


Figure : An ER model for the Movies database represented diagrammatically.

Example: ER Diagram

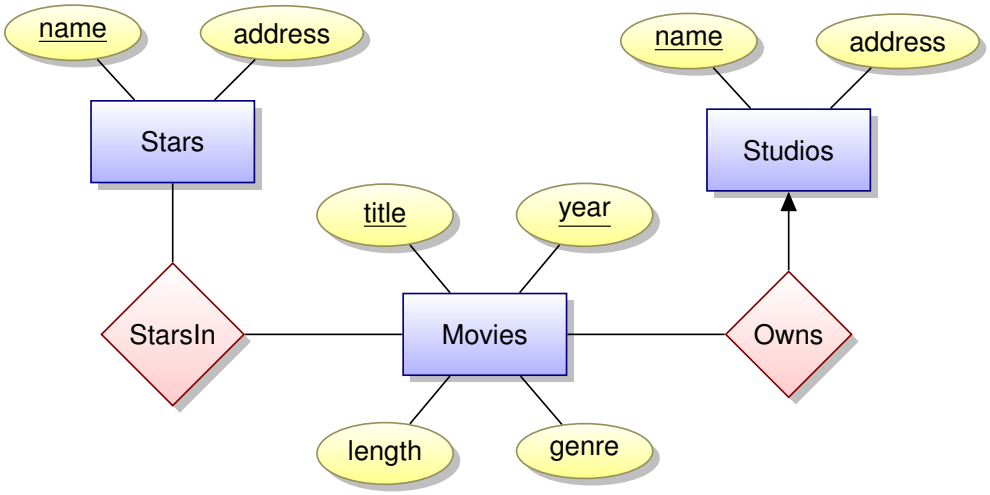
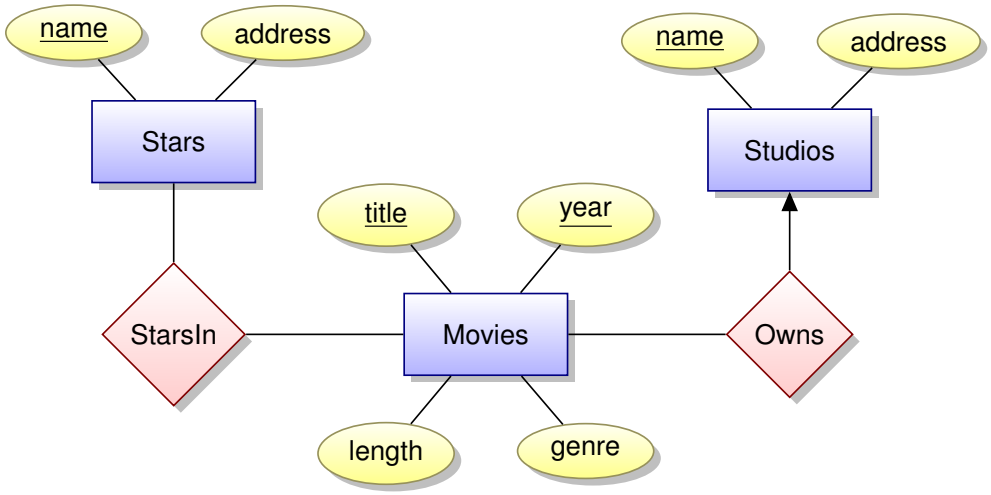


Figure : An ER model for the Movies database represented diagrammatically.

- What are the entities, attributes, and relationships of this model?

Example: ER Diagram



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- What does the relationship *StarsIn* model?

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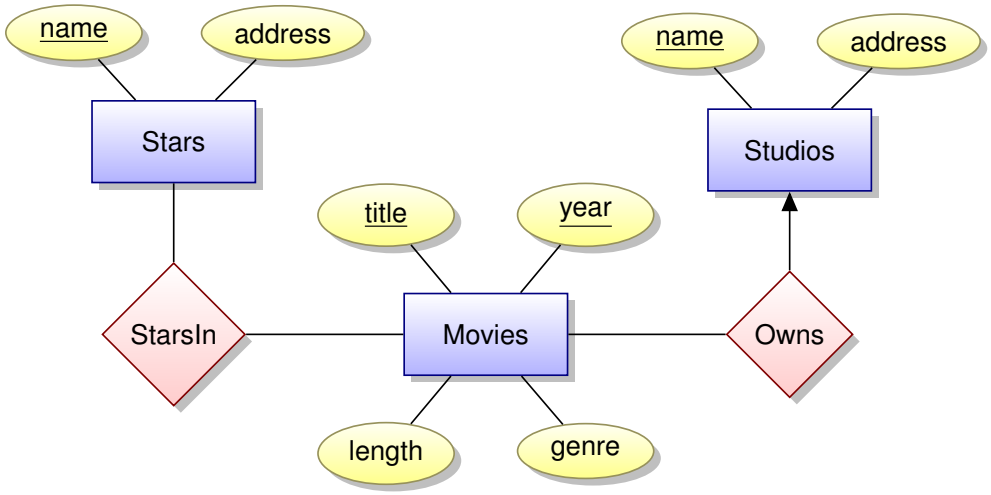

Figure : An ER model for the Movies database represented diagrammatically.

- What are the entities, attributes, and relationships of this model?
- What does the relationship *StarsIn* model?
- What does the relationship *Owns* model?

Relationship Multiplicity

Suppose a relationship `R` connects entity sets `E` and `F`. Then,

- `R` is many-one from `E` to `F` if each entity in `E` can be connected to at most one entity in `F`.
- `R` is one-one if it is many-one from both `E` to `F` and `F` to `E`.
- `R` is many-many if it is not many-one from either `E` to `F` or `F` to `E`.

Relationship Multiplicity

Entity sets are connected to relationship diamonds as follows:

- Let `R` be a many-one relationship from `E` to `F`. `R`'s diamond is connected to `F`'s rectangle with an arrow pointing to `F` and to `E`'s rectangle with a simple edge.

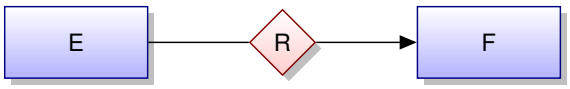

Figure : Many-one relationship `R` from `E` to `F`.

- Let `R` be a one-one relationship between `E` and `F`. `R`'s diamond is connected to both `F`'s and `E`'s rectangles with arrows pointing to each of the rectangles.

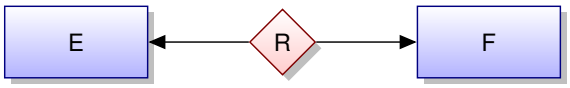

Figure : One-one relationship `R` between `E` and `F`.

Example: Relationship Multiplicity

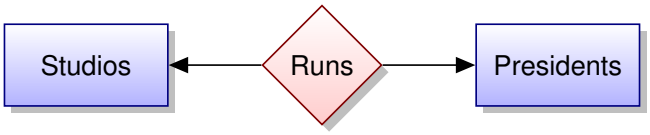

Figure : A one-one relationship.

Example: Relationship Multiplicity

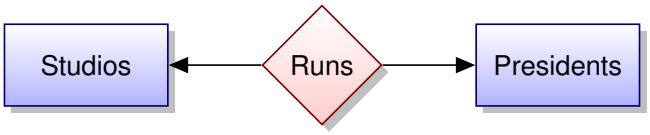

Figure : A one-one relationship.

- How would you interpret the *Runs* relationship?

Multiway Relationship

- The E/R model also supports multiway relationships.
- The multiway relationship diamond connects all involved entities.
- An arrow pointing to an entity set `E` in a multiway relationship indicates that if we pick one entity from each of the other participating entity sets, they are associated to at most one `E` entity.

Example: Multiway Relationship

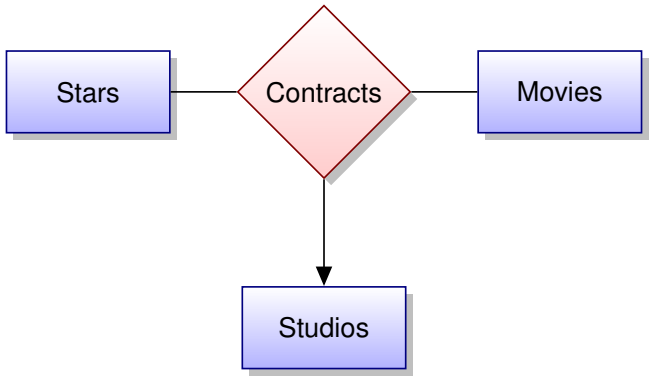

Figure : A three-way relationship.

Example: Multiway Relationship

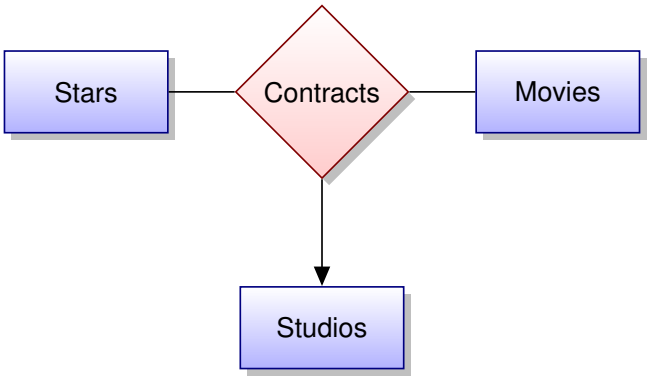

Figure : A three-way relationship.

- How would you interpret the *Contracts* relationship?

Roles in Relationships

- What if an entity set `E` appears more than once in a relationship?
- How can we distinguish amongst the different participations of `E`?

Roles in Relationships

- What if an entity set `E` appears more than once in a relationship?
- How can we distinguish amongst the different participations of `E`?
- For each line connecting `E` to the relationship, label the role of `E`.

Example: Roles in Relationships

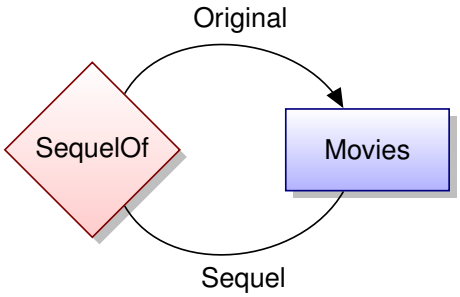

Figure : A relationship with roles.

Example: Roles in Relationships

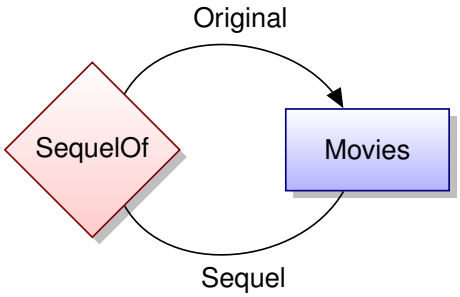

Figure : A relationship with roles.

- How would you interpret the *SequelOf* relationship?

Relationship Attributes

- Sometimes we must associate information with a relationship.
- The information does not naturally belong to any involved entity set.
- We model the information as attributes of the relationship.
- Use the same graphical notation as for entity set attributes.

Example: Relationship Attributes

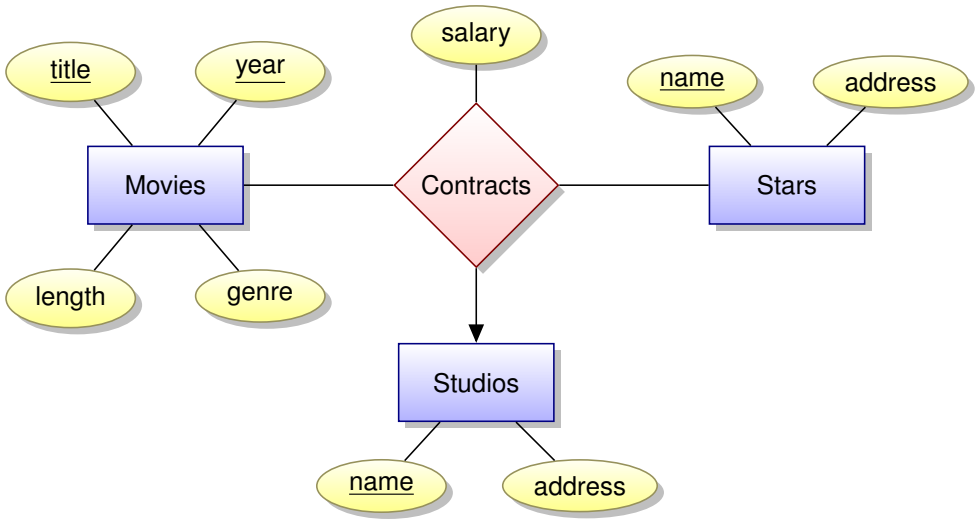

Figure : A relationship with an attribute.

Example: Relationship Attributes

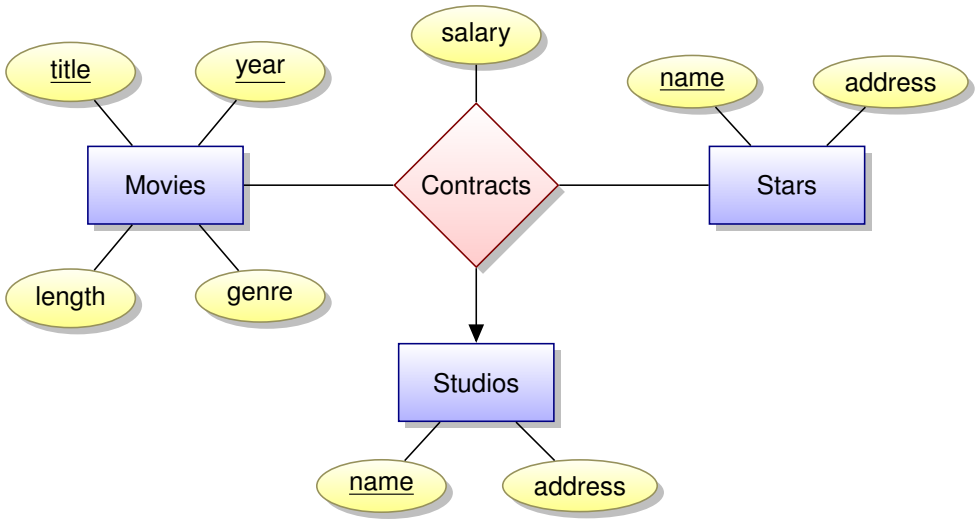

Figure : A relationship with an attribute.

- We can always factor out relationship attributes. (How?)

Example: Relationship Attributes

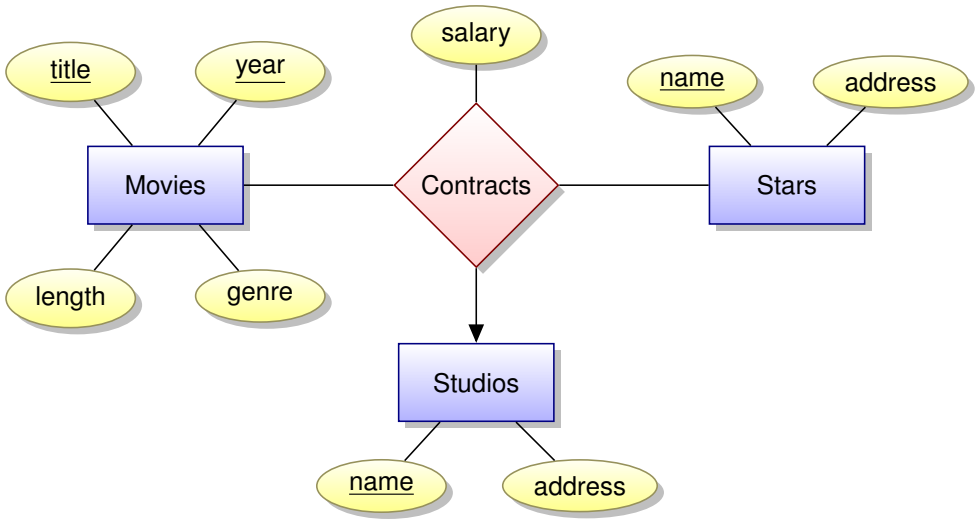

Figure : A relationship with an attribute.

- We can always factor out relationship attributes. (How?)
- Create a new entity set to hold the attributes. Include the new entity set in the relationship.

Simplifying Multiway Relationships

- Multiway relationships may be converted to a collection of binary ones.
- Create a connecting entity set to replace the multiway relationship.
- Create a many-one relationship from the connecting entity set to each of the participating entity sets (or roles).

Subclass Relationship

- Sometimes a subset `F` of a given entity set `E` has special properties (not present in `E`) associated to all its entities.
- We say `F` is a subclass of `E` (and `E` a superclass of `F`).
- An isa relationship connects an entity set with its subclasses.
- An entity may have representatives in a tree of entity sets, related by isa relationships (resembling inheritance relationships in OOPLs).
- In the ER diagram, isa relationships are represented as triangles.
- The subclass connects to one side of the triangle while the superclass connects to opposite point.
- isa relationships are one-one, but no arrows are drawn.

Example: Subclass Relationship

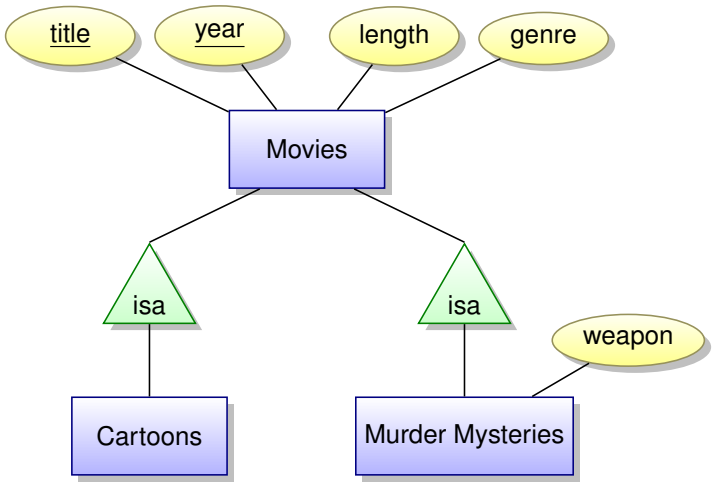

Figure : Subclass (isa) relationships.

- Murder Mysteries and Cartoons need not be disjoint.
- Some movies are neither Murder Mysteries nor Cartoons.

Example: Subclass Relationship

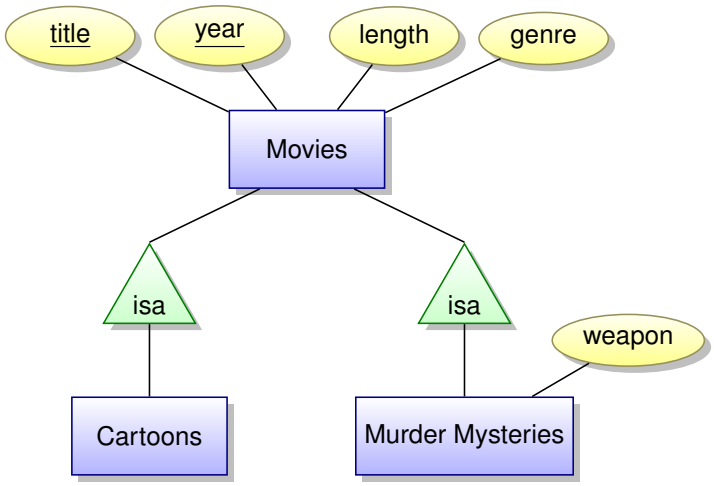

Figure : Subclass (isa) relationships.

- Murder Mysteries and Cartoons need not be disjoint.
- Some movies are neither Murder Mysteries nor Cartoons.
- What attributes and relationships do the involved entities have?

Participation

Consider an entity set E and a relationship R involving E and some other entity sets.

- E's participation in R is either total or optional.
- Optional participation means that entities in E may participate in R.
- Total participation means that every entity in E must participate in R.
- Optional participation is represented using a single line.
- Total participation is represented using a double line.
- Thus, all relationships shown thus far were optional.

To-Do

- Discuss problems 4.1.1-4.1.10.
- On your own: read section 4.1 from chapter #4 in the textbook and go over the remaining problems.

Next...

1. E/R Design
   - Entity/Relationship Model
   - Design Principles
   - Constraints
   - Weak Entity Sets
   - E/R Notation Summary
   - Mapping to Relational Schemas

Design Principles

- Faithfulness to the specifications.
- Avoid redundancy– anomalies creep into databases during design!
- Simplicity: stick to specifications, avoid unnecessary elements.
- Create a new relationship only if it cannot be inferred from existing ones.
- Choose correctly among attributes, entity sets, and relationships.
- Attributes are simple and easy to understand, cannot participate in relationships, and only provide partial information about an entity.
- Entity sets provide information for an entire class of objects.
- Relationships contain information about two or more entity sets.

To-Do

- Go over the examples and problems in this section.
- On your own: read section 4.2 from chapter #4 in the textbook and go over the remaining problems.

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To-Do

- We have seen how to represent keys.
- We will skip referential integrity (4.3.3) and degree constraints (4.3.4).
- On your own: read section 4.3 from chapter #4 in the textbook and go over the problems.

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Weak Entity Sets

- Some entity sets do not carry enough identifying information.
- E.g., as a part-of relationship or a multiway relationship decomposition.
- Entity sets of this type are called weak entity sets.
- They have zero or more attributes of their own, but no key.
- May have a partial key: a set of discriminator attribute(s).
- Identified by combining its partial key and borrowed keys from all identifying relationships it maintains with other entity sets.

Weak Entity Sets

- A weak entity set is represented by a rectangle with a double border.
- Discriminator attributes are underlined using a dashed underline.
- An identifying relationship is represented by a diamond with a double border.

To-Do

- Go over the examples and problems in this section.
- On your own: read section 4.4 from chapter #4 in the textbook and go over the remaining problems.

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Entity Sets

Figure : Strong

Figure : Weak

Attributes

Figure : Simple

Figure : Derived

Figure : Multivalued

Figure : Key

Figure : Discriminator

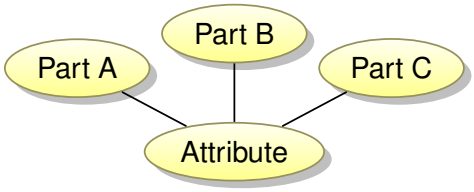

Figure : Composite

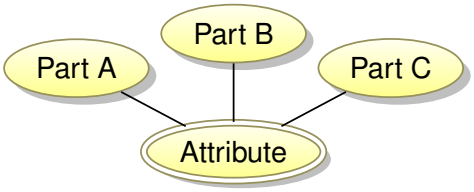

Figure : Multivalued, Composite

Relationships

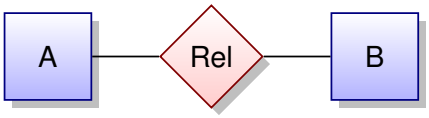

Figure : Binary, Many-Many

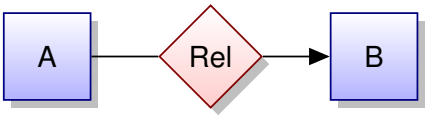

Figure : Binary, Many-One

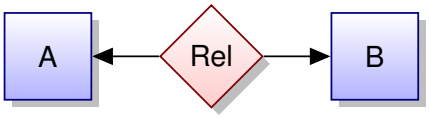

Figure : Binary, One-One

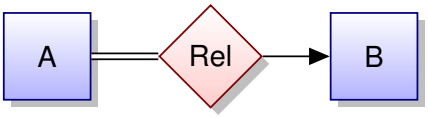

Figure : Binary, Many-One, Total

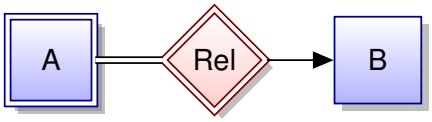

Figure : Binary, Many-One, Identifying, Total

Is-A Relationships

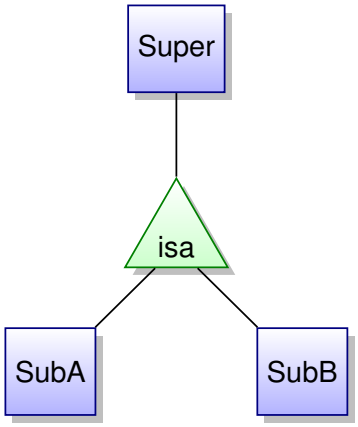

Figure : Simple

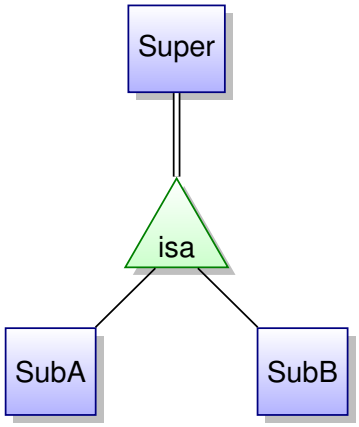

Figure : Total

Is-A Relationships

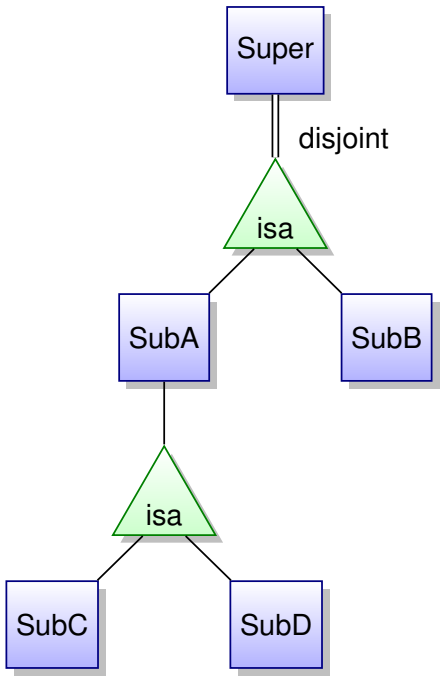

Figure : Two-Level, Total and Disjoint on Super

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Mapping to Relational Schemas

ER Element	Relational Schema Element(s)
Entity Set	Table
Simple Attribute	Attribute
Composite Attribute	One attribute per component
Multivalued Attribute	Table and foreign key
1:1 or 1:N Relationship	Foreign key (or relationship table)
N:M Relationship	Relationship table and two foreign keys
N-ary Relationship	Relationship table and *n* foreign keys

Table : Mapping ER Models to Relational Schemas.

Mapping to Relational Schemas

1. Attributes
   - Assume $\mathtt{A}$ is an attribute of entity set $\mathtt{E}$.
   - $\mathtt{A}$ is a simple attribute $\rightarrow$ single table field.
   - $\mathtt{A}$ is a composite attribute $\rightarrow$ list of table fields, one per $\mathtt{A}$ component.
   - $\mathtt{A}$ is a multivalued attribute $\rightarrow$
     - Define a separate table $\mathtt{R_A}$ for the multivalued attribute.
     - Schema($\mathtt{R_A}$) = Key($\mathtt{E}$) $\bigcup$ $\mathtt{A}$.
     - Key($\mathtt{R_A}$) = Key($\mathtt{E}$) $\bigcup$ $\mathtt{A}$.
     - Note: if $\mathtt{A}$ is a multivalued composite, adapt accordingly.

Mapping to Relational Schemas

2. Entity Sets
   - Assume E is a strong entity set.
   - Table($\mathtt{E}$) = $\mathtt{R_E}$.
   - Schema($\mathtt{R_E}$) = Attrs($\mathtt{E}$).
   - Key($\mathtt{R_E}$) = Key($\mathtt{E}$).

Mapping to Relational Schemas

3. Weak Entity Sets

- Assume W is a weak entity set identified by $E_1, \ldots, E_n$.
- Table($\mathtt{W}$) = $\mathtt{R_W}$.
- Schema($\mathtt{R_W}$) = $\bigcup_i$ Key($\mathtt{E_i}$) $\bigcup$ Attrs($\mathtt{W}$).
- Key($\mathtt{R_W}$) = $\bigcup_i$ Key($\mathtt{E_i}$) $\bigcup$ Discriminator($\mathtt{W}$).
- Foreign keys of $\mathtt{R_W}$: one for each Key($\mathtt{E_1}$), ..., Key($\mathtt{E_n}$).

Mapping to Relational Schemas

4. IsA Relationships
   - Assume F is a subclass of B.
   - Table(F) = R_F.
   - Schema(R_F) = Key(B) $\bigcup$ Attrs(F).
   - Key(R_F) = Key(B).
   - Foreign keys of R_F: one for Key(B).
   - Can you think of other strategies?

Mapping to Relational Schemas

5. Binary Relationships

- Assume *S* is a relationship involving entity sets E_1, E_2.
- Table(S) = R_S.
- Schema(R_S) = Key(E_1) $\bigcup$ Key(E_2) $\bigcup$ Attrs(S).
- Key(R_S) =
  - if S is many-many: Key(E_1) $\bigcup$ Key(E_2);
  - if S is many-one: Key(E_1);
  - if S is one-many: Key(E_2);
  - if S is one-one: choose Key(E_1) or Key(E_2).
- Foreign keys of R_S: one for Key(E_1) and one for Key(E_2).
- For each E_i with total participation in S, add a `NOT NULL` constraint to the definition of each of the attributes in Key(E_i).

Mapping to Relational Schemas

6. N-Ary Relationships

- Assume S is a relationship involving entity sets $E_1, \ldots, E_n$.
- Table(S) = R_S.
- Schema(R_S) = $\bigcup_i$ Key(E_i) $\bigcup$ Attrs(S).
- Key(R_S) = $\bigcup_i$ Key(E_i) for each E_i participating in S with cardinality "many".
- Foreign keys of R_S: one for Key(E_1), ..., Key(E_n).
- For each E_i with total participation in S, add a `NOT NULL` constraint to the definition of each of the attributes in Key(E_i).

Mapping to Relational Schemas

7. Optimization

- Let R_1 and R_2 be relations obtained from the mapping.
- R_1 and R_2 may be combined into a new relation R_3 if:
  - R_1 and R_2 must come from the same entity set.
  - Key(R_1) = Key(R_2).
- Schema(R_3) = Attrs(R_1) $\bigcup$ Attrs(R_2).
- Key(R_3) = Key(R_1) = Key(R_2).
- Foreign keys of R_3: the union of the foreign keys of R_1 and R_2, except those of R_1 referring to R_2 and vice-versa.

Mapping to Relational Schemas

8. DDL Generation
   - Generate a `CREATE TABLE` DDL statement for each table.
   - Define reasonable data types for each attribute.
   - Define `NOT NULL` constraints for mandatory attributes.
   - Define `NOT NULL` constraints for total participation in relationships.
   - Define check constraints for attributes, if necessary.
   - Define primary keys, unique keys, and foreign keys.
   - Create views for relations corresponding to entity sets with derived attributes.

To-Do

- Go over the examples and problems in this section.
- On your own: read section 4.5 from chapter #4 in the textbook and go over the remaining problems.