

COMP9120

Week 2: Conceptual Database Design

Semester 1, 2025

Remember to form group and put that information in Canvas

47% have already formed a group

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Warming up!

Let's menti!



Acknowledgement of Country

I would like to acknowledge the Traditional Owners of Australia and recognise their continuing connection to land, water and culture. I am currently on the land of the Gadigal people of the Eora nation and pay my respects to their Elders, past, present and emerging.

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› Introduction to Conceptual Database Design

› Entity Relationship Model

- Notation and usage *ER model*
- Entity and Relationship types, attributes
- Key, participation and cardinality constraints
- Weak entities, IsA hierarchies, aggregation

› Purpose of conceptual database design

- Agree on the **structure of database** before deciding on a particular implementation:
Tree swing example:



How the customer explained it

↳ 一張圖片表示 customer
to designer 的意思

1. Requirements Analysis

- Understand...
 - ▶ what data needs to be stored
 - ▶ what applications must be built
 - ▶ what operations are most frequent

2. Conceptual Design

这周的
内容

- Develop...
 - ▶ high-level description of the data closely matching how users think of the data
 - ▶ Works as communication vehicle

Today

3. Logical Design

- Convert...
 - ▶ conceptual design into a logical database schema

4. Schema Refinement

- Refine...
 - ▶ Identify problems in current schema & refine

5. Physical Design

- Convert...
 - ▶ logical schema into a physical schema for a specific DBMS and tuned for app.

6. App & Security Design

- Determine who plays what roles, in what workflows, with security settings ...
 - ▶ What roles are played by different system entities in system processes, and what permissions should be given to these roles?

› What is our goal?

- Specification of the database schema

› **Conceptual Database Design**: A framework for understanding and capturing business information requirements graphically

› It does *not* include how data is implemented, created, modified, used, or deleted.

- Works as communication vehicle between technical people and non-technical people
- Facilitates planning, operation & maintenance of various data resources

› Usually, this is the role of the *System Analyst*

(what)

更关注数据间的关系，而不是
TCE

方法 (How)

- › First designed by **Peter Chen** in 1976
 - Several variations/versions have since appeared
 - The *conceptual database model* we will use in this class: Enhanced or Extended E-R model

EER

- › Definition: A (conceptual) *data modelling* approach is a *visual representation* that depicts the associations among different *categories of data* within a Universe of Discourse – UoD (e.g., enterprise).



~~the associations among different categories of data within a Universe of Discourse – UoD (e.g., enterprise).~~

UoD

- What are the **entities** and **relationships** in the UoD (e.g., enterprise)?
- What information do we need to store in the database about these entities and relationships?
- What are the *business rules* (represented by *integrity constraints*) that should always hold (i.e., be *true*)?

ERD

- › A database ‘schema’ in the ER Model is represented pictorially (**ER Diagrams – ERD** as a shorthand).
 - We can always convert an ER diagram (ERD) into a logical (e.g., relational) schema.

- › **Entity**: represents an *individual object* from the UoD (such as a University): a specific person, place, object, event, etc.
 - it must be distinguishable from other entities
 - Example: *John Doe*, unit *COMP9120*, bank account *4711*

- › **Entity Type** (also called **entity set**): a *collection of entities* that share *common properties* or characteristics

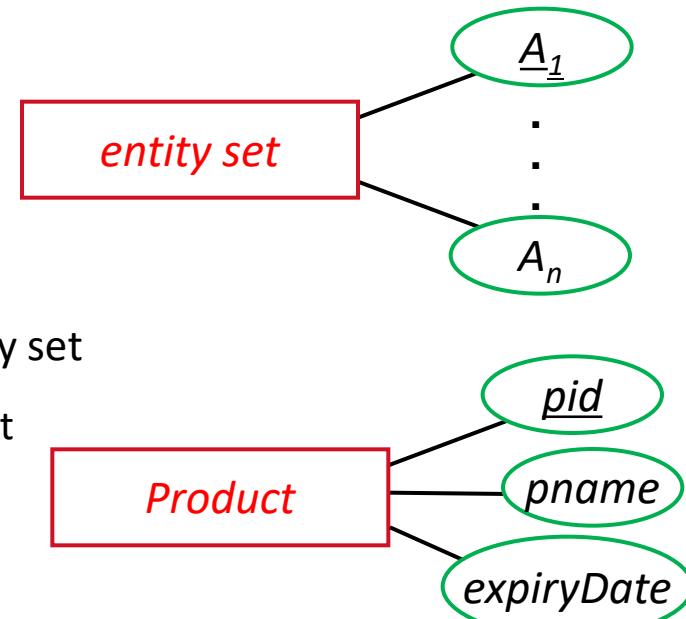
- Example: *students, courses, bank accounts*
- In E-R, a *Rectangle* represents an entity set

- › **Attribute**: describes one *aspect* (i.e., a description) of an entity set

- Descriptive *properties* possessed by *all* members of an entity set
- Example: product have *pid*, *name* and *expiryDate*
- Depicted by an *ellipse*

use

Circle to represent



- › **Domain:** all possible *values* of an attribute

Values may be *complex / set-oriented* which is, as we will see, contrary to the relational model.

- Simple and composite attributes. E.g. (color vs. date)

Single-valued and multi-valued attributes (studentID vs spokenLanguages)

- › **Key:** minimal set of attributes, called a *candidate key*, that uniquely identifies an entity in the set (may have more than one candidate key)

- Example: each student is *uniquely* identified by the student *ID*.
- The selected key among candidate keys is called **Primary Key** (PK) => depicted by underlining the attributes forming the key. Only one primary key at all times!

- › **Entity Schema:** entity set name, attributes, their domains, and PK

Pk is candidate key
candidate key is not a Pk
perhaps

› Which one would you choose as a primary key?

- Staff(staff_id, name, email, phone_number, address, dateOfBirth)

Staff_id

› Which one would you choose as a primary key?

- House(house_number, street_name, city, state, build_in_year, selling_price)

↓
这 4 个 括 号 成 PK

Graphical Representation in E-R Diagram

Symbols:

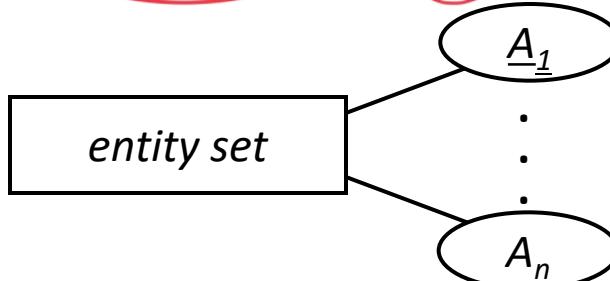
- Entity Sets represented by a rectangle



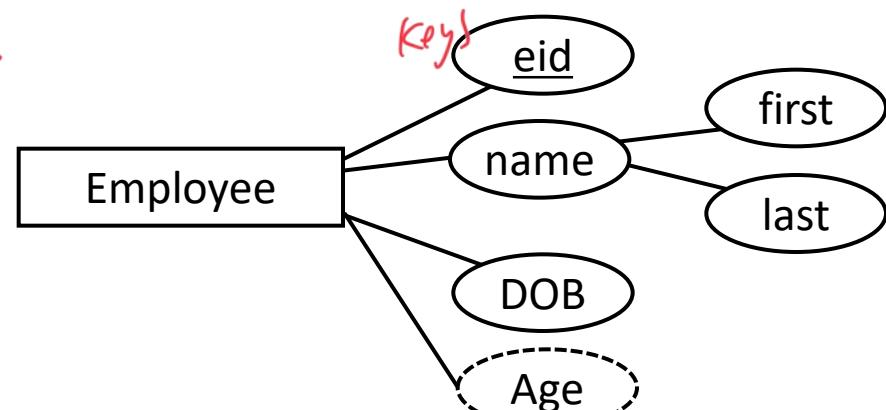
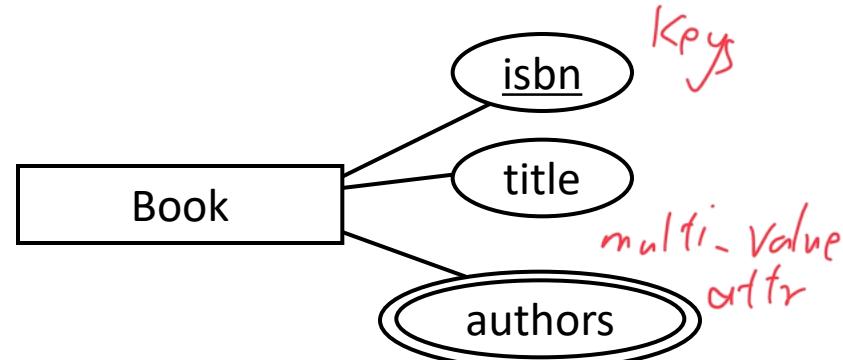
- Attributes depicted by ellipses

Keys are underlined ★

Double ellipses for multi-valued attributes X



Examples:



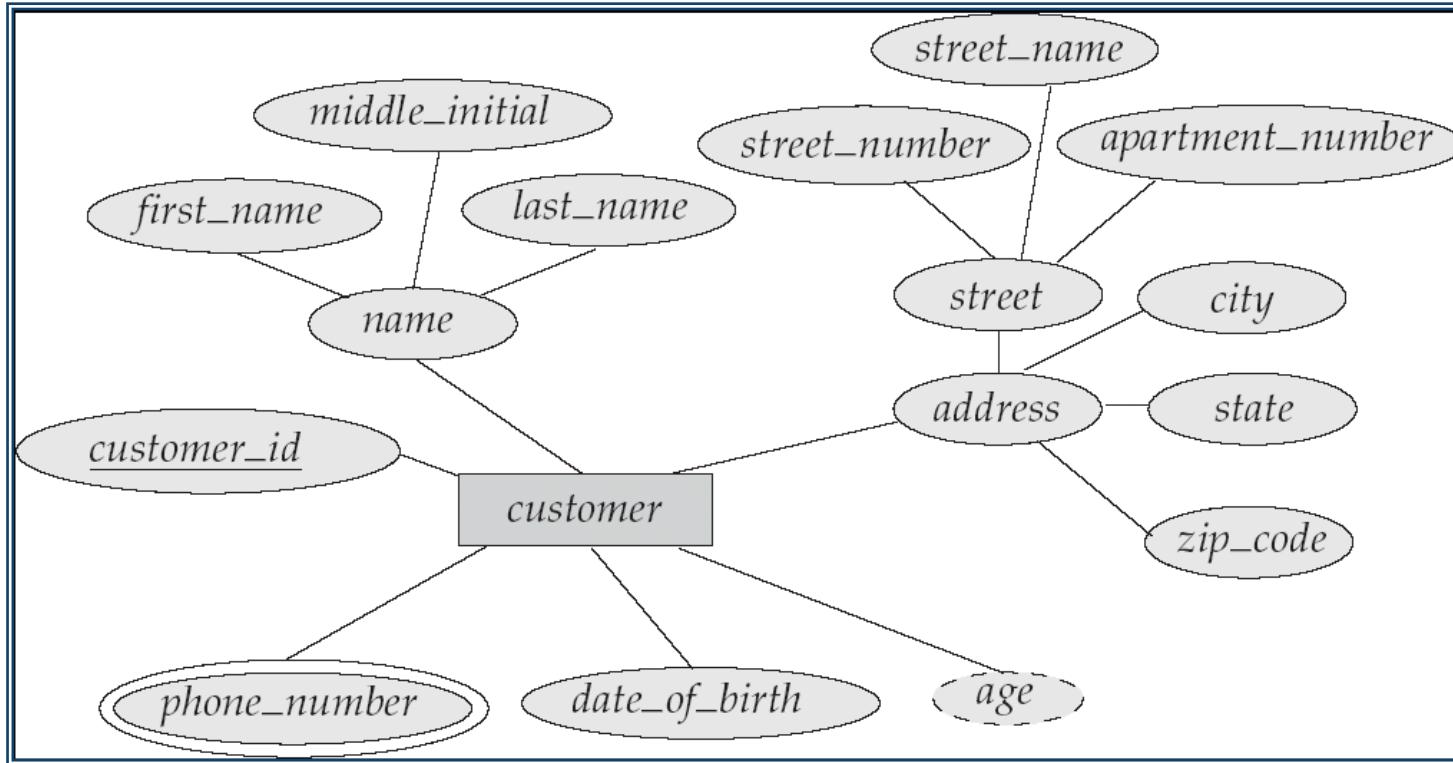
Note:

Book.authors is a *multi-valued attribute*;

Employee.name is a *composite attribute*.

Employee.Age is a *derived attribute*

★ T1: LK Date-Birth 教員, staff is fully derived



- › **Relationship**: relates *two or more* entities

- Example: John *is enrolled in* COMP9120

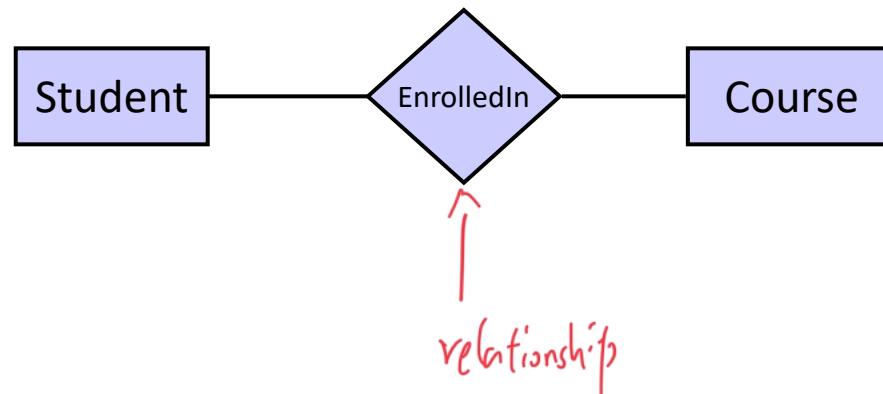
Diamond means relationship

- › **Relationship Type** (also called **Relationship Set**): set of similar relationships

- Formally: a relation among $n \geq 2$ entities, each entity from an entity set is defined as:

$$\{(e_1, e_2, \dots, e_n) \mid e_1 \in E_1, e_2 \in E_2, \dots, e_n \in E_n\}$$

- Example: **Student** (entity set) is related to **Course** (entity set) by **EnrolledIn** (relationship type).
- *Diamond shape represents the relationship type*

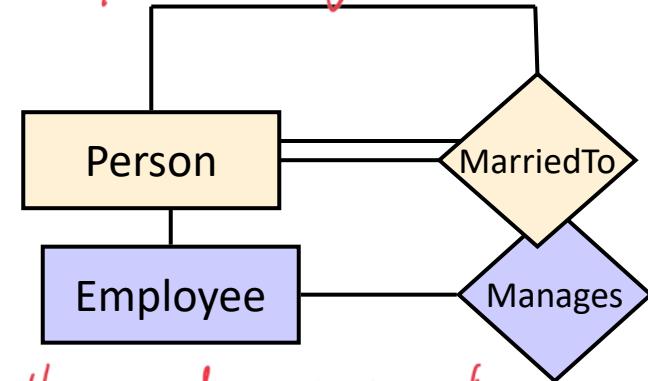


Relationship Degree

A person marry to another person

- Degree of a Relationship: number of entity types involved

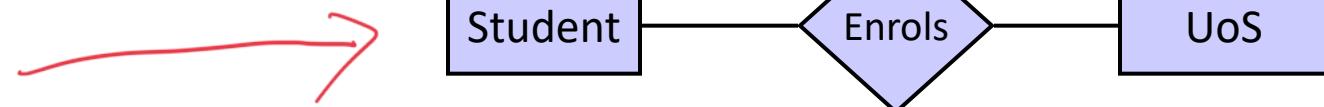
≥ 2



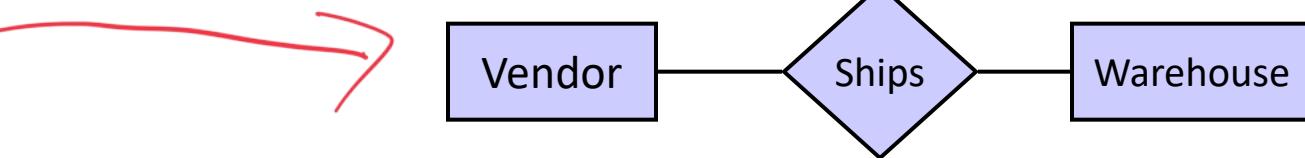
- (1) Unary Relationship (Recursive)



- (2) Binary Relationship

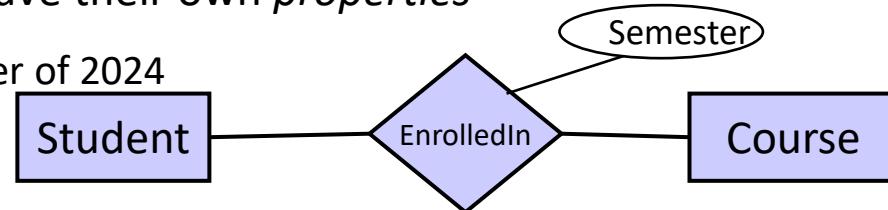


- (3) Ternary Relationship



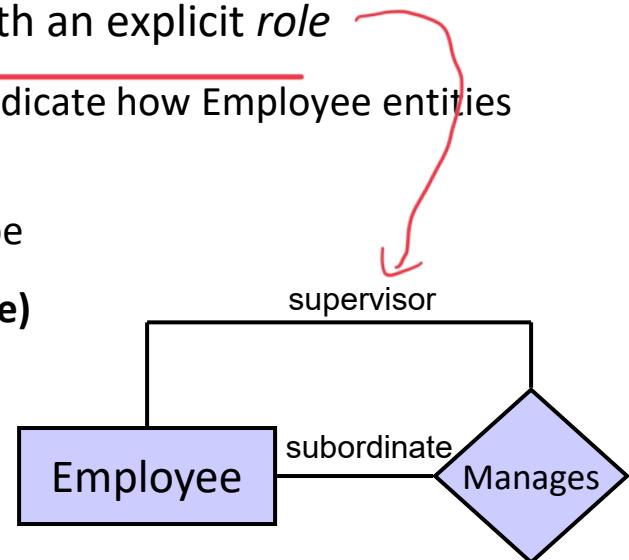
Relationship Attributes: Relationships can also have their own *properties*

- E.g., John enrols in COMP9120 *in* the second semester of 2024
- John and COMP9120 are related *for a limited time*
- 2024sem2 describes this *temporal* relationship - value of the *Semester* attribute of the **EnrolledIn** relationship set



Relationship Role: Each participating entity can be named with an explicit *role*

- The “supervisor” and “subordinate” labels are called *roles*. They indicate how *Employee* entities interact via the *Manages* relationship
- Useful for relationships that relate elements of the same entity type
- Example: **Manages(Employee: supervisor, Employee: subordinate)**

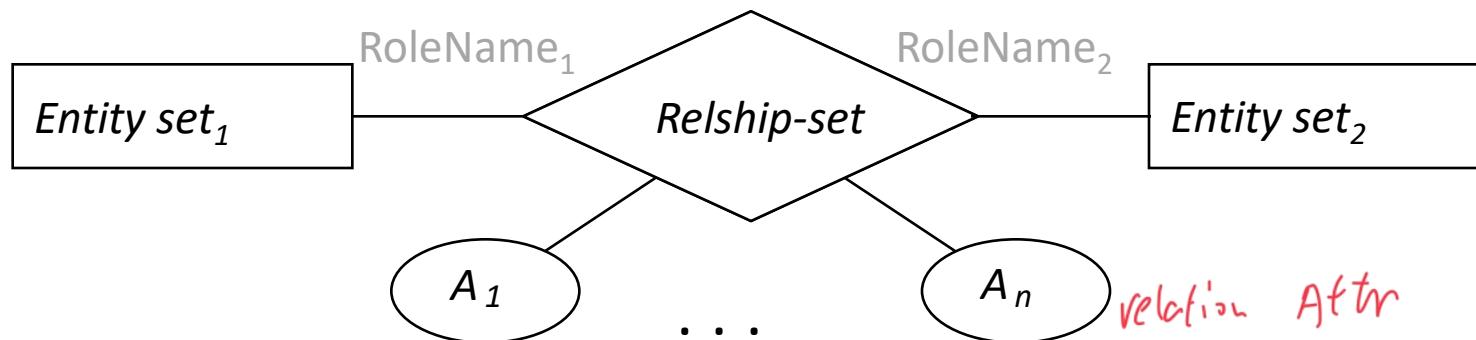


Relationship Type Schema:

- Relationship name
- Role names (or names of participating entity sets) – this is optional
- Relationship attributes and their domains

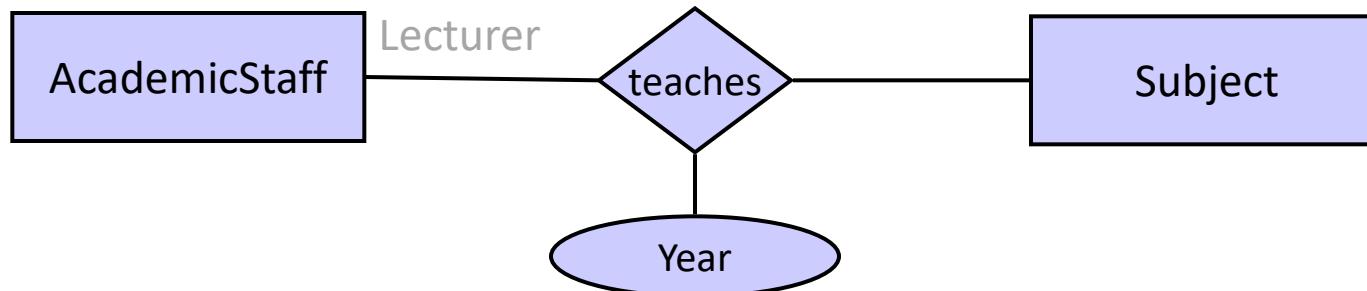
Graphical Representation of Relationships in ERD

Symbol:

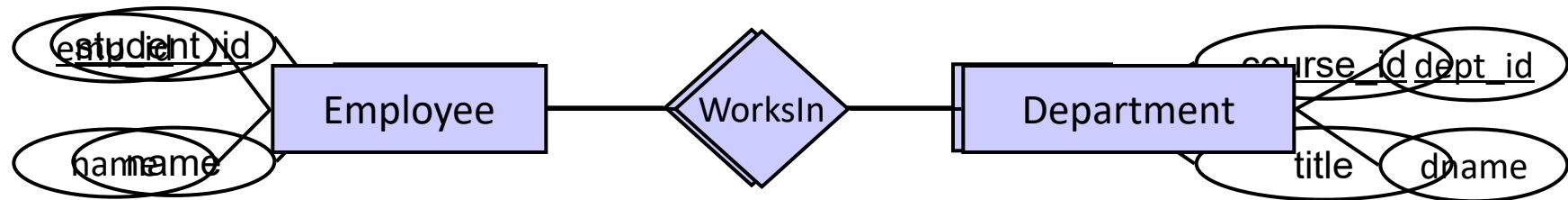


- ▶ Diamonds represent relationship set
- ▶ Lines link attributes to entity/relationship sets and entity sets to relationship set.
- ▶ Roles are labels over edges (lines), labelled with role names

Example



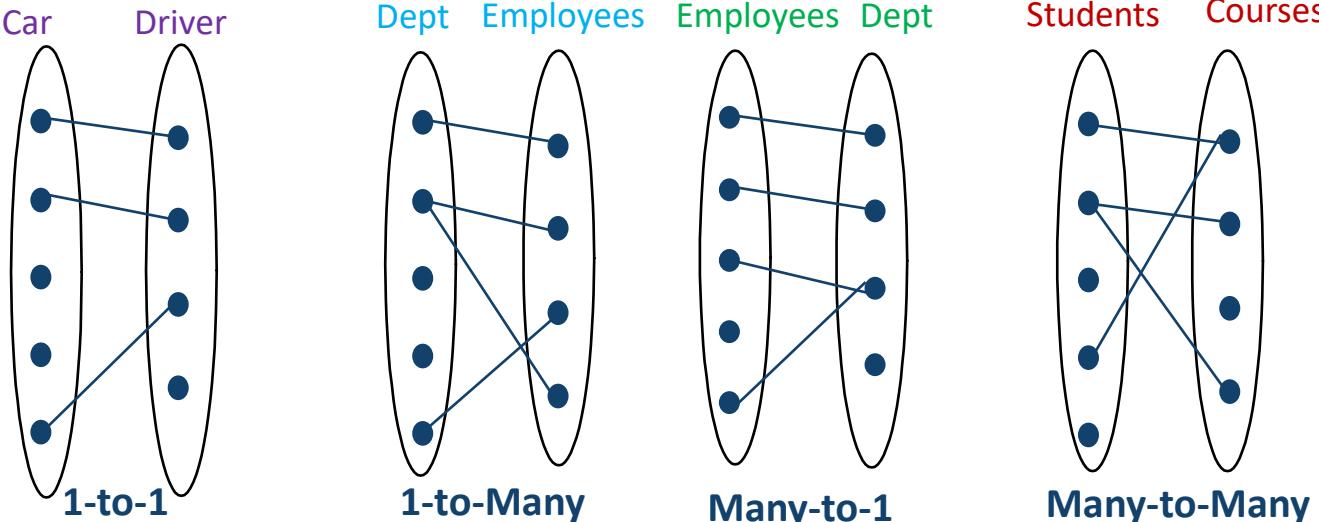
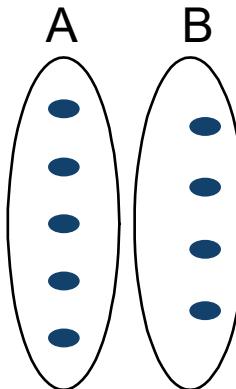
- › The combination of the primary keys of the participating entity sets forms a **superkey** (superset of a key) of an (entity) relationship.
 - Example: (student_id, course_id) is the superkey of *Enrols*



- We must consider the ***mapping cardinality of the relationship*** when deciding what the ***candidate key*** (*minimal set of attributes*) is:
 - Consider **WorksIn**: An *employee* can work in *many* departments; a *department* can have *many* employees.
 - In contrast, *each department* has at *most one* manager
- We do **not** represent the ***keys of the relationship set*** in E-R diagram

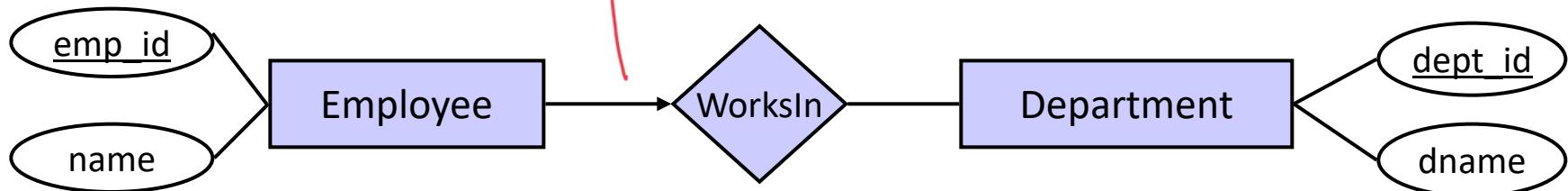
Mapping Cardinality of Relationships

- › We present examples of each style of relationship.
 - Given a relationship between two entity sets **A** and **B**, we need to consider *both directions* of the relationship:
 - How many instances of **B** can a given instance of **A** be related to?
 - How many instances of **A** can a given instance of **B** be related to?
- › Answer: **1 to 1, 1 to N, N to 1, N to M** are the possible **cardinalities** of a relationship between entities
- › Beware: the natural language formulation may confuse you!
 - **Many-to-1** means each instance of **A** is related to *at most 1* instance of **B**



Cardinalities are depicted in E-R diagrams (**ERD**) as **constraints**.

- › If for a particular entity set, each entity participates in at most one instance of a relationship, the *key* of the entity set is the (candidate) key of the relationship type
 - E.g., *Employee* key (*emp_id*) is also unique in *WorksIn*
 - called: **many-to-one**, also denoted **N:1 relationship**
- › Representation in E-R diagram: **arrow** 
- › Example: An *employee* works in *at most one* department.



- If every entity of an entity type participates in at least one instance of a relationship, a **participation constraint** holds, i.e., it is true:

 - also called a **total participation** of entity E in R

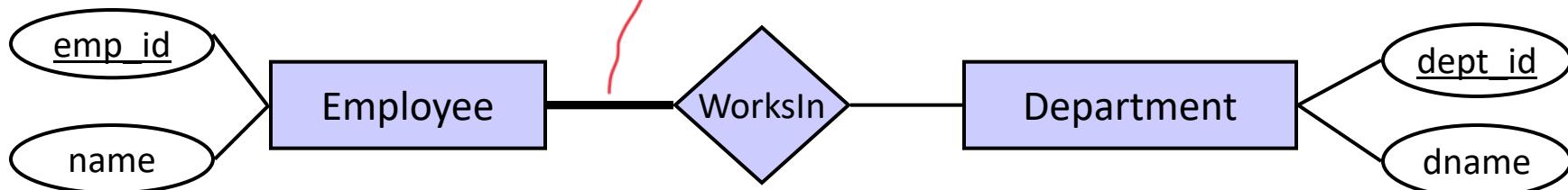
 - A participation that is *not total* is said to be **partial**

1 - to - N ? No

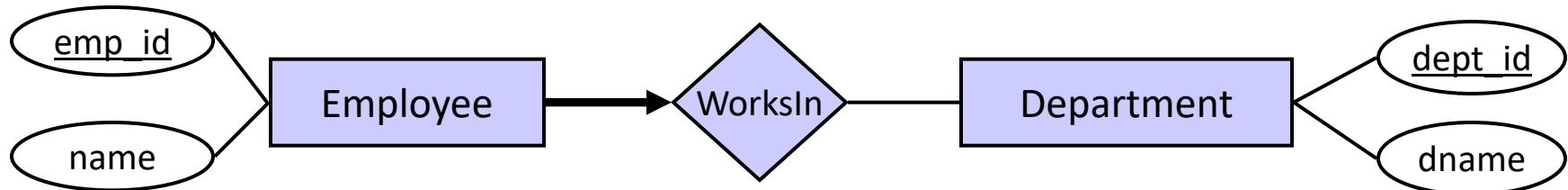
即普通线

- Representation in E-R diagram: ***thick line***

- Example: Every employee works in at *least* one department



- › If every entity participates in *exactly one* relationship, then both a **participation** and a **key constraint** hold.
 - › Representation in E-R diagrams: **thick arrow**
 - › Example: Every employee works in exactly one department
 - Again: N:1 relationship
- at least + at most
 ||
 exactly one

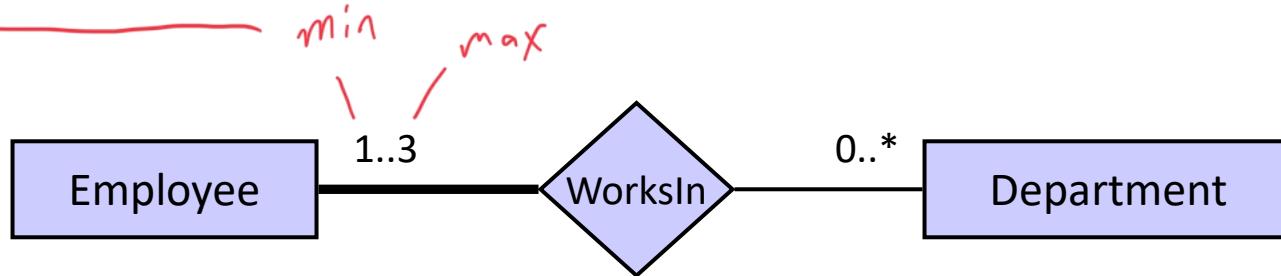


- › ***Generalisation*** of ***key*** and ***participation*** constraints

- › A **cardinality constraint** for the participation of an entity set E in a relationship R specifies **how often** an entity of set E participates in R: **at least** (*minimum cardinality*) and **at most** (*maximum cardinality*).

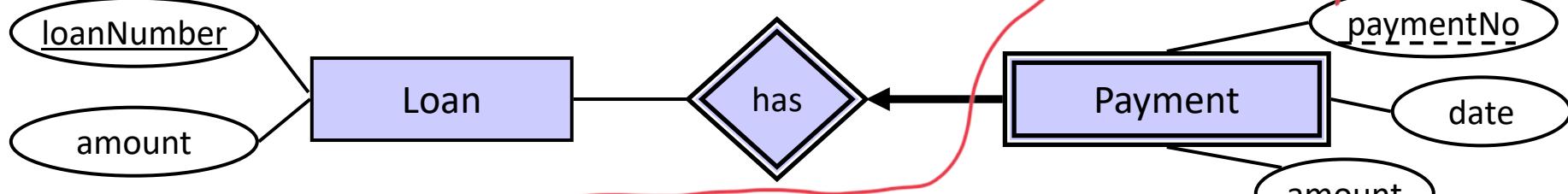
- In an ER-diagram, we annotate the edge between an entity set E and relationship R with min..max, where *min* is the minimum cardinality and *max* the maximum cardinality. If no maximal cardinality is specified, we set '*' as *max* number ("don't care" or no upper limit).

Example: Every employee works in *at least* 1 department and *at most* 3 departments.



› **Weak entity type:** An entity type that does not have a self-contained *primary key*.

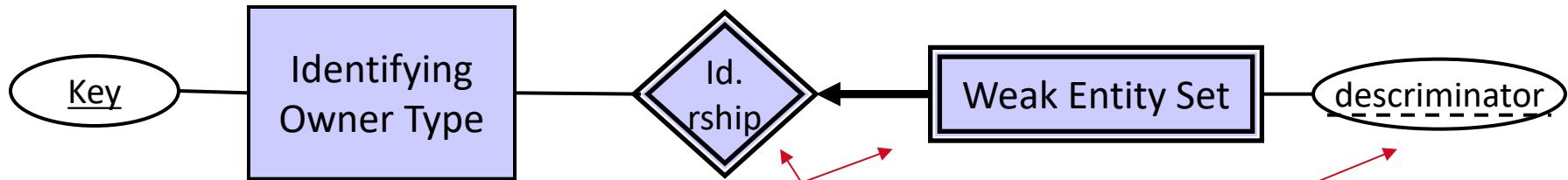
- Its existence **depends** on the existence of an *identifying owner* entity
- The weak entity must:
 - relate to the identifying owner entity set via a one-to-many *identifying relationship type* from the *identifying owner* entity set to the *weak entity* set
 - have total participation in the identifying relationship type
 - Can be seen as an **exclusive 'part-of'** relationship
 - Example: *payment* of a *loan*



- › The **discriminator** (or **partial key**) of a weak entity type is the set of attributes that distinguishes them among all the entities of a weak entity type related to the *same owning entity*.
- › The primary key of a *weak entity type* is formed by the **primary key** of the strong entity type(s) on which the weak entity type is existence dependent, **plus** the weak entity type's **discriminator**.

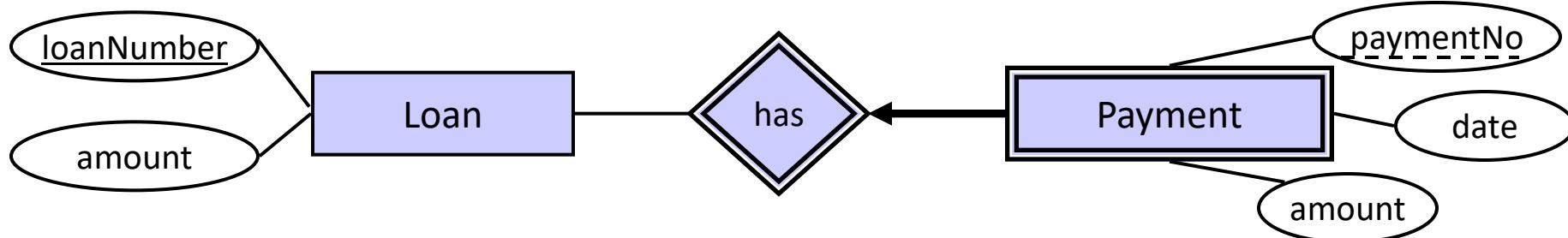
Representation of Weak Entity Types

Symbols:



- We depict a weak entity set by double rectangles.
- Identifying relationship depicted using a double diamond
- underline the discriminator of a weak entity set with a dashed line

Example:



- ▶ paymentNumber: discriminator of the Payment entity set
- ▶ Primary key for Payment: (loanNumber, paymentNumber)

Let's take a break!

It's time to play our menti game!



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- › ER model in its original form did not support
 - SPECIALIZATION/ GENERALIZATION
 - ABSTRACTIONS ('aggregation')
- › This led to the development of an 'Enhanced' ER model:
 - Includes all modelling concepts of basic ER
 - Some additional object-oriented concepts: subclasses/superclasses, specialization/generalization, categories, attribute inheritance
 - The resulting model is called the Enhanced-ER or Extended ER (E2R or EER) model
 - used to model applications more completely and accurately
- › When we talk about E-R model, we always mean EER model

- › Arranging entity sets in a type hierarchy.

- Determine entity sets whose set of *properties* are a **subset** of another entity set

Employee				
id	name	phone	address	salary

Customer				
id	name	phone	address	credit_rating

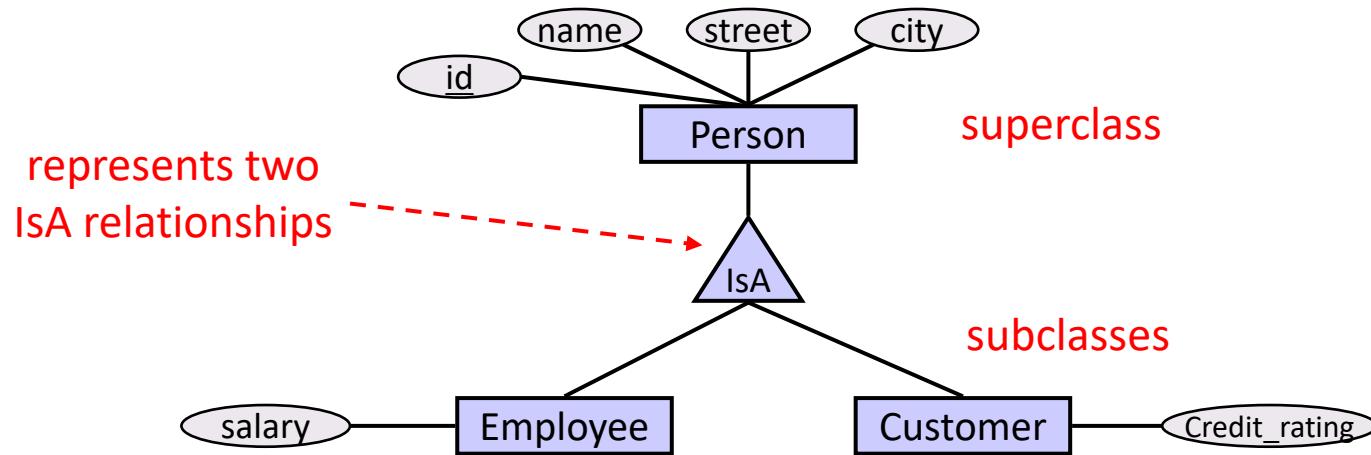
Person			
id	name	phone	address



Employee	
	salary

Customer	
	credit_rating

- › Arranging entity sets in a type hierarchy.
 - Determine entity sets whose set of properties are a subset of another entity set
- › Definition of **Generalisation / Specialisation / Inheritance**:
Two entity types E and F are in an **IsA-relationship** (“ F is a E ”), if
 - (1) the set of attributes of F is a *superset* of the set of attributes of E , and
 - (2) the entity set F is a *subset* of the entity set of E (“each f is an e ”)
- › We say that F is a *specialisation* of E (F is **subclass**) and E is a *generalisation* of F (E is **superclass**).
 - Example: **Student** is a subclass of **Person**
- › **Attribute inheritance** – a lower-level (subclass) entity type *inherits* all the attributes and relationship participations of its supertype.
- › Depicted by a *triangle* component labelled *IsA*



- › Specialisation stems from a single entity set. It emphasizes differences among entities within the set by creating distinct lower-level entities
- › Generalization proceeds from the recognition that a number of entity sets share some common features

- › We can specify *overlap* and *covering* constraints for ISA hierarchies:

- › **Overlap Constraints**

- **Disjoint**



- an entity can belong to only one lower-level entity set

- **Overlapping** (the default - opposite to Ramakrishnan/Gehrke book)

- an entity can belong to more than one lower-level entity set

- › **Covering Constraints**

- **Total**

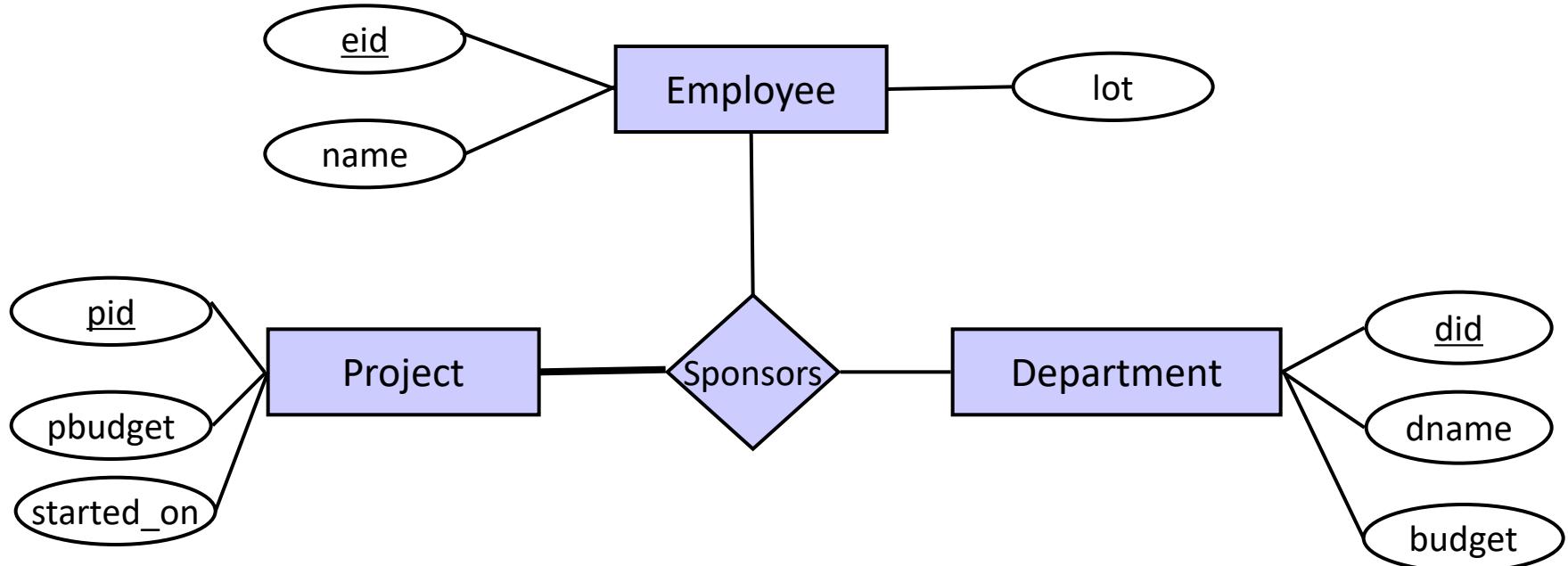
- an entity must belong to one of the lower-level entity sets

- Denoted with a thick line between the IsA-triangle and the superclass

- **Partial** (the default)

- an entity need not belong to one of the lower-level entity sets

- Consider a *ternary relationship* *Sponsors*



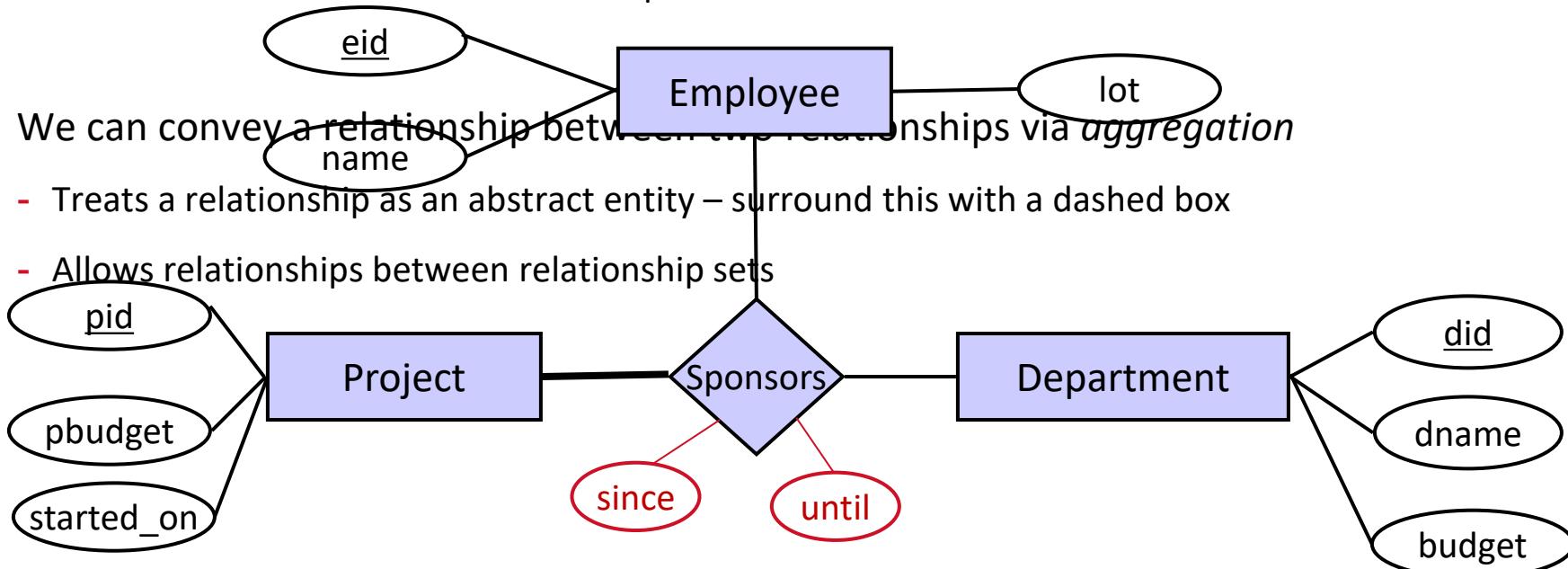
- Each project can be sponsored by one or more departments
- A department can appoint one or more employees to monitor a sponsorship
- What are the issues with this representation?

(Example adapted from Ramakrishnan & Gherke, DBMS, 3rd edition)

- › Relationship set *Sponsors* is really trying to model *two relationships*
 - It is trying to model the fact that departments *sponsor* projects, but also these sponsorships are *monitored*.
Sponsor have 2 meanings
 - What if we want to add different attributes for each of these relationships, e.g., attribute “*since*” to the sponsorship and until attribute “*until*” to the monitoring?
 - It would be more meaningful. However, we need to ensure our model adds such required attributes on the correct relationship.

- › We can convey a relationship between two relationships via *aggregation*

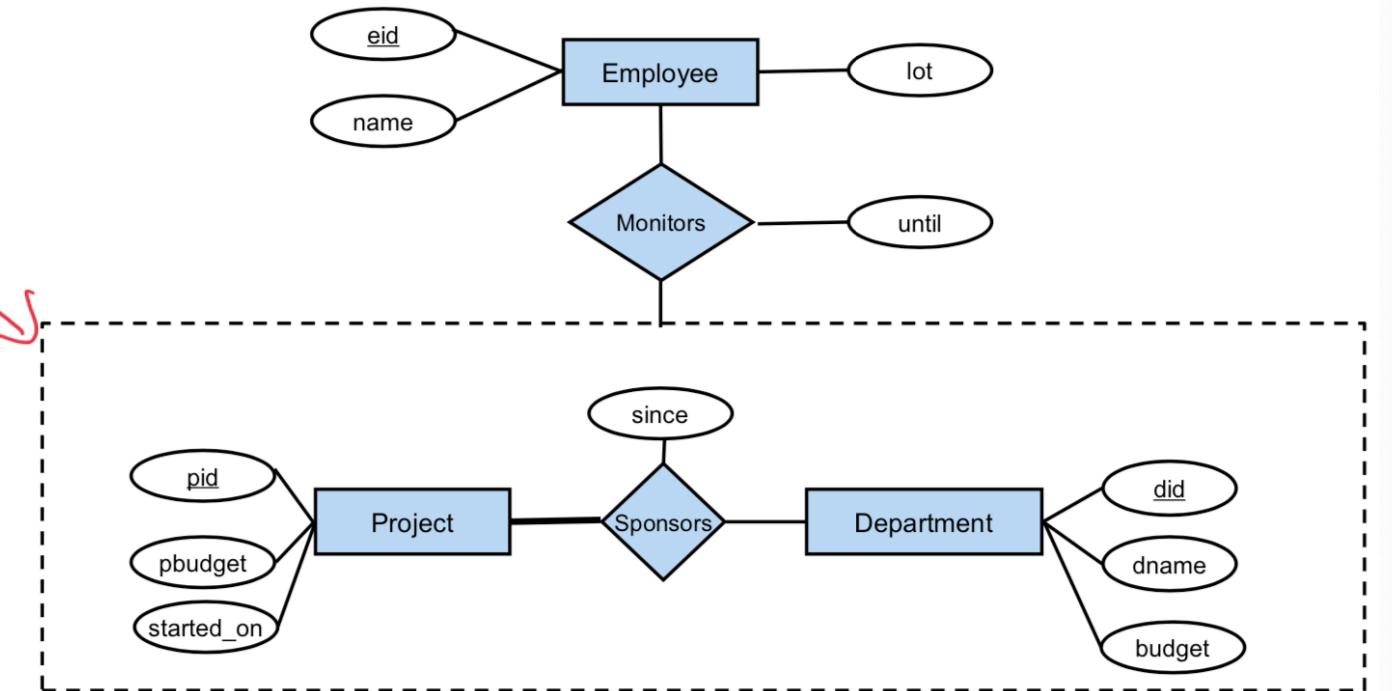
- Treats a relationship as an abstract entity – surround this with a dashed box
- Allows relationships between relationship sets



对 relationship 來說

E-R Diagram With Aggregation

- › **Aggregation:** It conveys a **relationship between two relationships**: in our example, it conveys a relationship between the *sponsors* relationship type and the Employee entity type: we introduce aggregation via a *Monitors* relationship type.
 - Allows us to model that *sponsorships* start at a given time and that employees are assigned to *monitor* a *sponsorship* until a given time.



(Example from Ramakrishnan & Gherke, DBMS, 3rd edition)

› Conceptual database design using the E-R Model

- Understanding and experience with conceptual database design using the entity-relationship model:
- Basic Constructs: Entity, Attributes (single, composite, multivalued, derived), Relationships, Cardinality Constraints
- Advanced Concepts: Weak Entities, Inheritance, Aggregation



- › Many variations of ER diagrams are in use, and there is no widely accepted standard.
 - › **Which notation should I use for assessments like quiz, final exam etc?**
 - Must use the notation just outlined in this lecture
-

- › Ramakrishnan/Gehrke (3rd edition)
 - **Chapter 2**
- › Kifer/Bernstein/Lewis (2nd edition)
 - Chapter 4
- › Ullman/Widom (3rd edition)
 - Chapter 4
- › Silberschatz/Korth/Sudarshan (5th edition - ‘sailing boat’)
 - Chapter 6
- › Elmasri/Navathe (5th edition)
 - Chapters 3 and 4

› Readings:

- **Ramakrishnan/Gehrke, Chapter 3 plus Chapter 1.5**
- Kifer/Bernstein/Lewis, Chapter 3
- Ullman/Widom, Chapter 2.1 - 2.3, Section 7.1 and Chapter 8.1-8.2

See you next week!

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