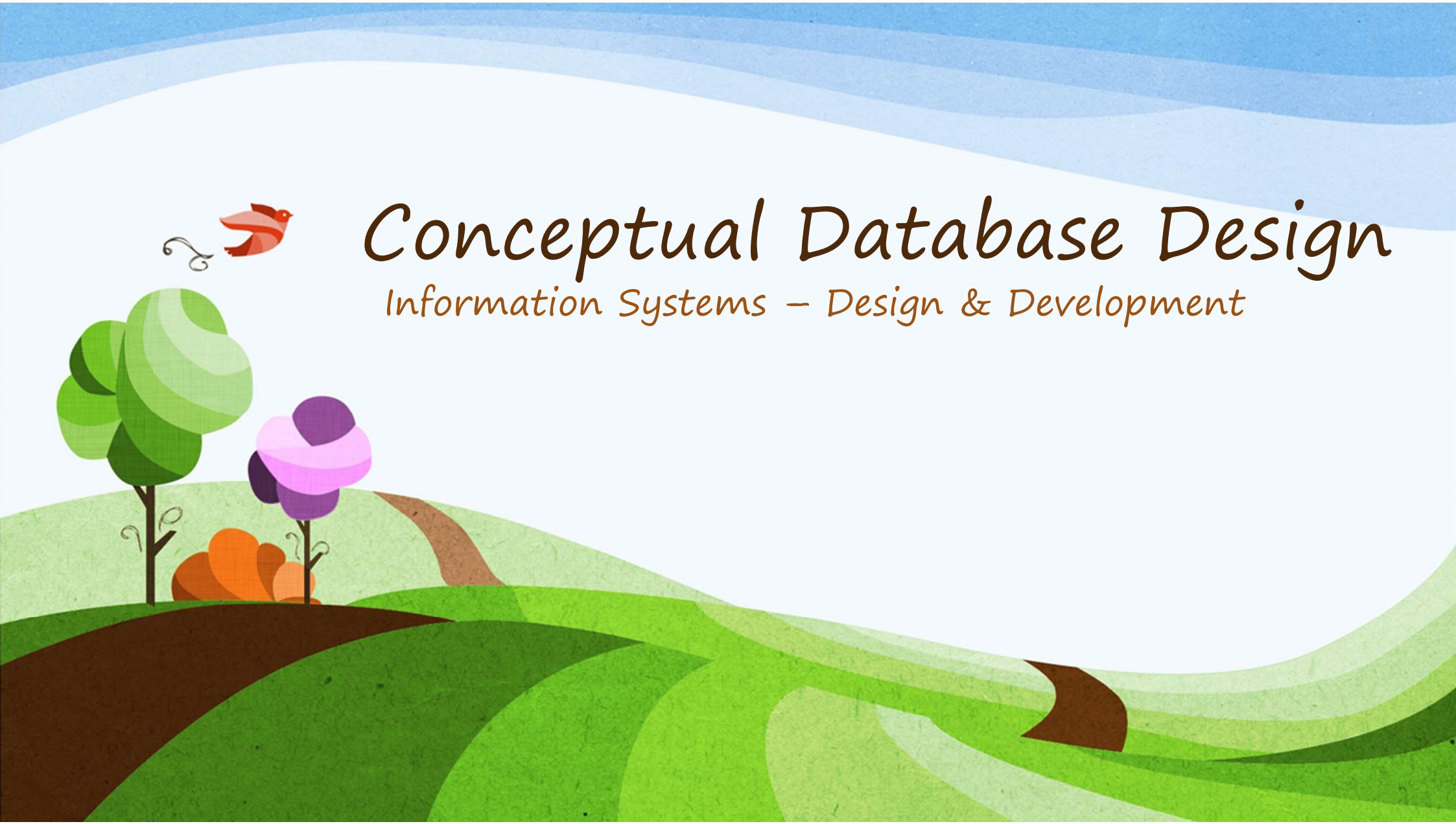

Conceptual Database Design
Information Systems – Design & Development

Conceptual Data Model and Logical Data Model

- Conceptual Data Modeling Elements: Entity-Relationship Model
- The Enhanced Entity Relationship model
- Design Considerations
- Mapping EER model to relations

Imagine you are involved in this database desigh

- Name
- Age

We need to know:

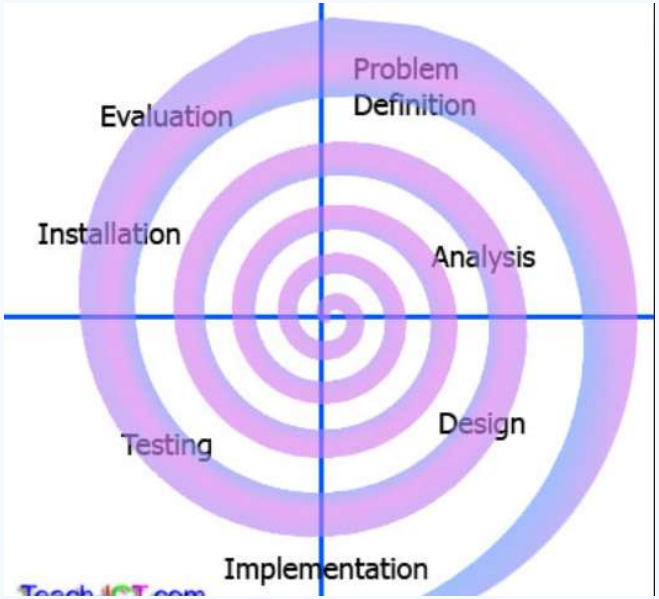
- How Many teachers teach each course?
- How Many students can there be at most in a course?
- Can a student sign up for two courses?

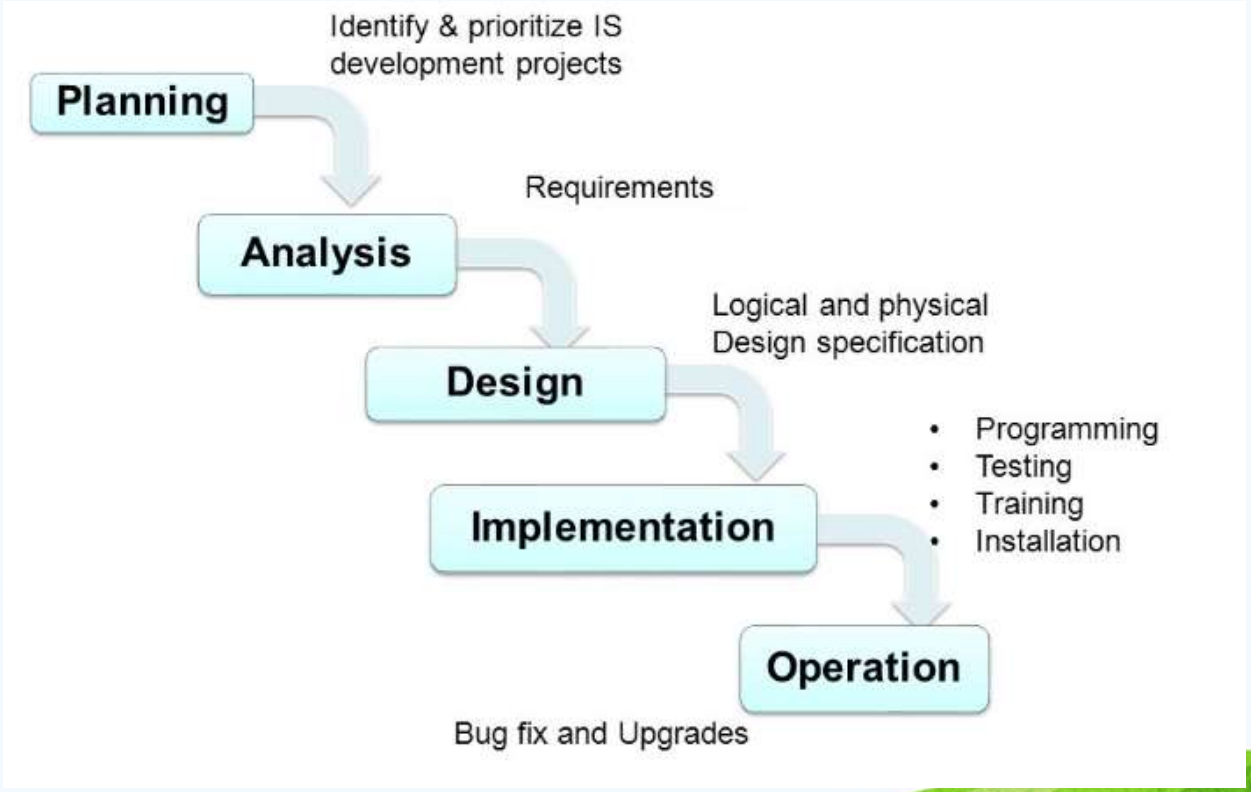
- Name
- Age
- Phone
- Country

- Name
- When?
- Where?
- How long?

How many students are in each course?
The list of students of each course
What teacher teaches each course?

Database life cycle





Critical Success Factors in Database Design

- Work interactively with the users as much as possible.
- Follow a structured methodology throughout the data modeling process.
- Employ a data-driven approach.
- Incorporate structural and integrity considerations into the data models.
- Combine conceptualization, normalization, and transaction validation techniques into the data modeling methodology.
- Use diagrams to represent as much of the data models as possible.
- Use a Database Design Language (DBDL) to represent additional data seMantics that cannot easily be represented in a diagram.
- Build a data dictionary to supplement the data model diagrams and the DBDL.
- Be willing to repeat steps.

These factors are built into the methodology we present for database design.

Why Conceptual Modelling is important?

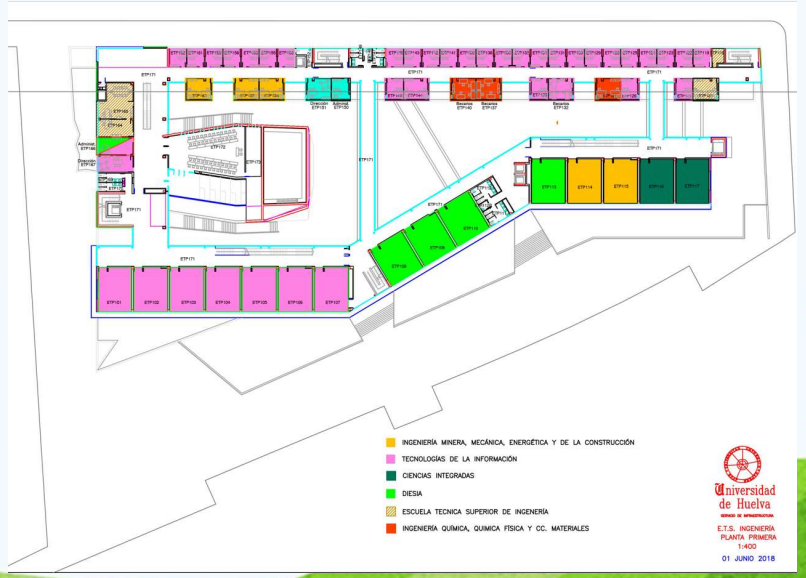
- What is going to be stored?
- How is it going to be used?
- What are we going to do with the data?
- Who should access the data?

A conceptual model is a representation of a system that uses concepts and ideas to form said representation.

Conceptual modeling is used across many fields.

What is Conceptual Design?

- A high-level description of the database
- Sufficiently precise that technical people can understand it
- But, not so precise that non-technical people can't participate



Design Methodology

Step 1. Build conceptual data model

- **Step 1.1** Identify entity types
- **Step 1.2** Identify relationship types
- **Step 1.3** Identify and associate attributes with entity or relationship types
- **Step 1.4** Determine attribute domains
- **Step 1.5** Determine candidate, primary, and alternate key attributes
- **Step 1.6** Consider use of enhanced modeling concepts (optional step)
- **Step 1.7** Check model for redundancy
- **Step 1.8** Validate conceptual model against user transactions
- **Step 1.9** Review conceptual data model with user

Step 2 Build and validate logical data model

- **Step 2.1** Derive relations for logical data model
- **Step 2.2** Validate relations using normalization
- **Step 2.3** Validate relations against user transactions
- **Step 2.4** Check integrity constraints
- **Step 2.5** Review logical data model with user
- **Step 2.6** Merge logical data models into global model (optional step)
- **Step 2.7** Check for future growth

Design Methodology

Step 3 Translate logical data model for target DBMS

- Step 3.1 Design base relations
- Step 3.2 Design representation of derived data
- Step 3.3 Design general constraints

Step 4 Design file organizations and indexes

- Step 4.1 Analyze transactions
- Step 4.2 Choose file organizations
- Step 4.3 Choose indexes
- Step 4.4 Estimate disk space requirements

Step 5 Design user views

Step 6 Design security mechanisms

Step 7 Consider the introduction of controlled redundancy

Step 8 Monitor and tune the operational system

Building our Conceptual Data Model

- **Entity-Relationship (ER)** model, proposed by Peter Chen in 19976, is a popular high-level conceptual data model.
- Object modeling methodologies such as the **Unified Modeling Language (UML)** are becoming increasingly popular in both database and software design.

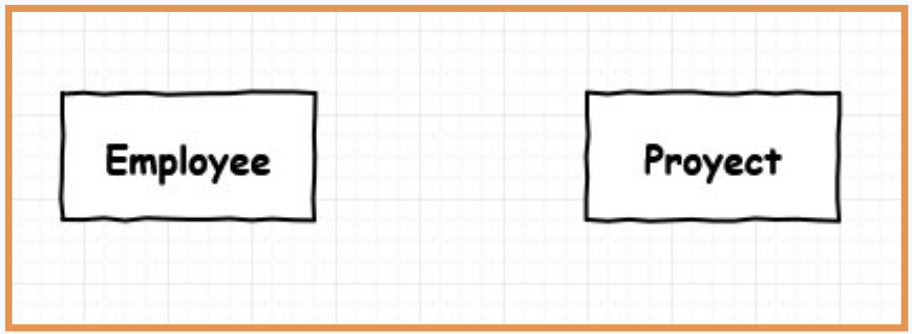
Building our Conceptual Data Model

- A conceptual model comprises:
  - entity sets;
  - relationship sets;
  - attributes and attribute domains;
  - primary keys and alternate keys;
  - integrity constraints.

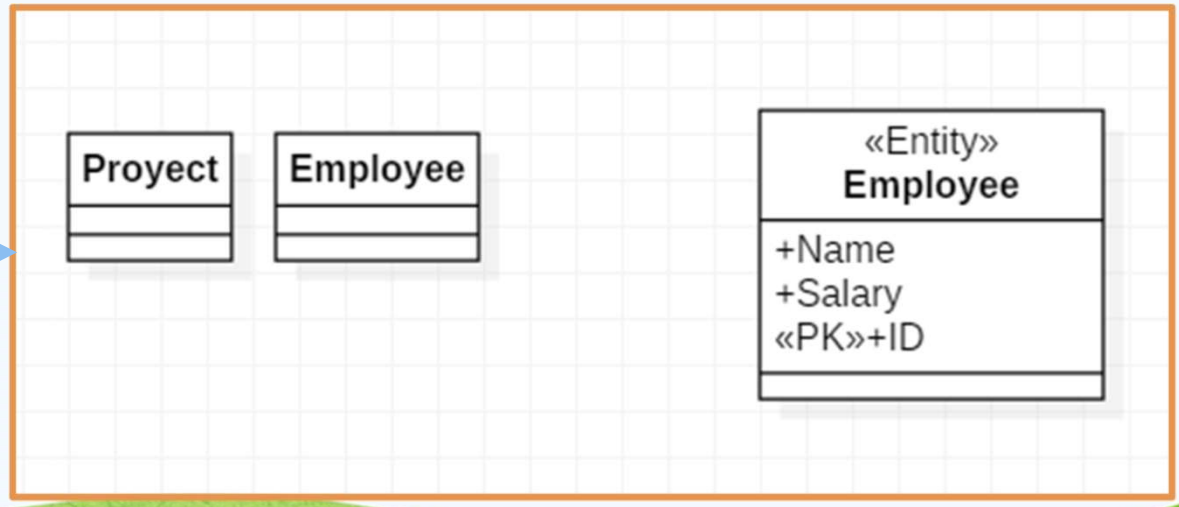
Entities and Entity Set

- **Entities** & **entity sets** are the primitive unit of the E/R model
  - Entities are the individual objects, which are members of entity sets
    - Ex: A specific person or product
  - Entity sets are the *classes* or *types* of objects in our model
    - Ex: Person, Product
    - *These are what is shown in E/R diagrams – as rectangles*
    - *Entity sets represent the sets of all possible entities*

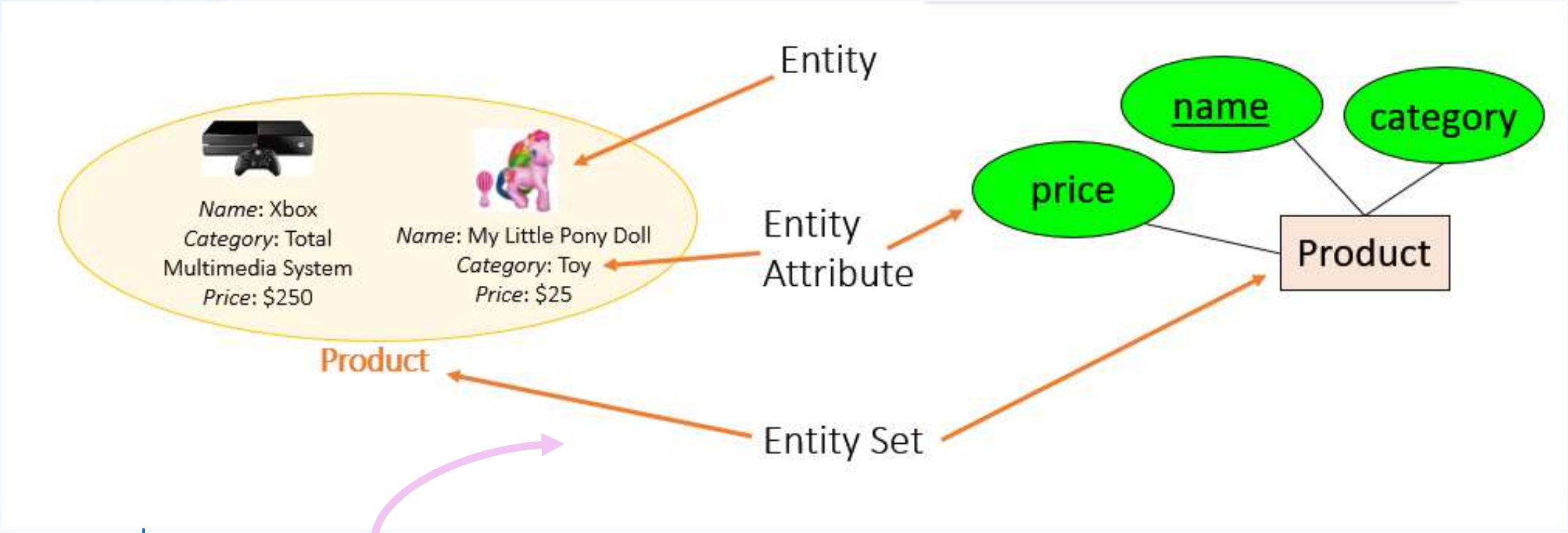
Notation (Chen)



Notation (UML)



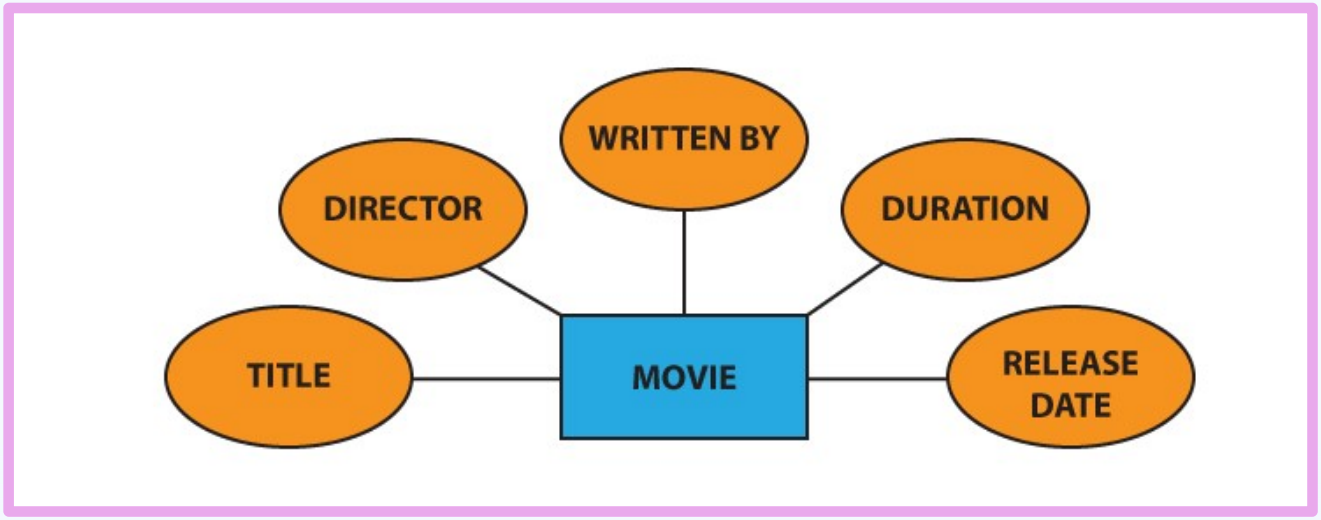
Attributes



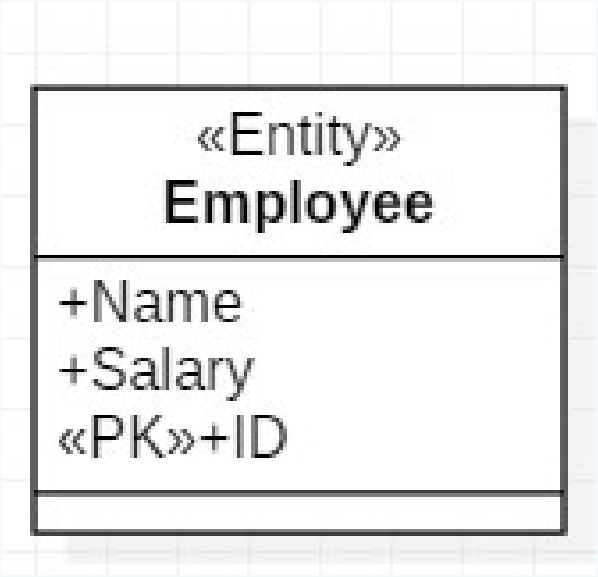
Example

Attributes

In the Chen notation, each attribute is represented by an **oval** containing atributte's name



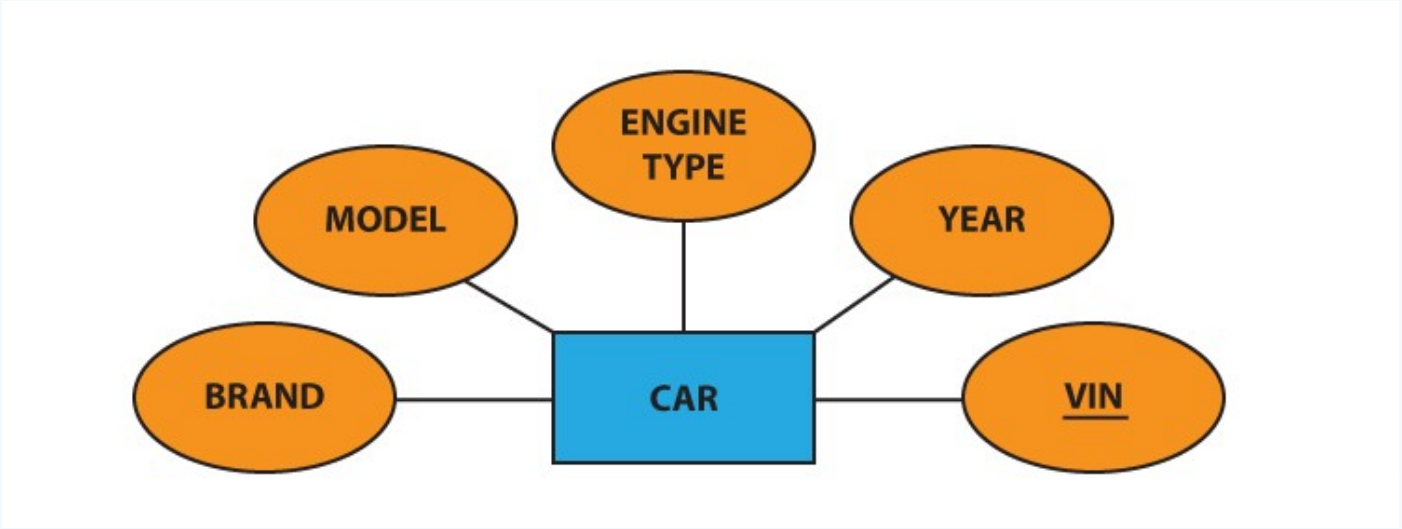
UML notation

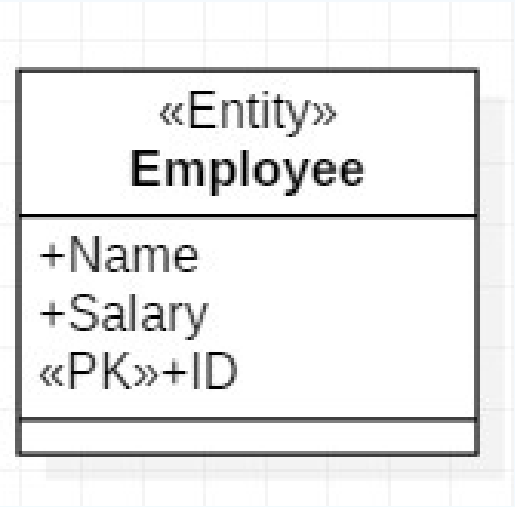


Domain: set of possible values for an attribute – Attributes may share a domain

Key attribute

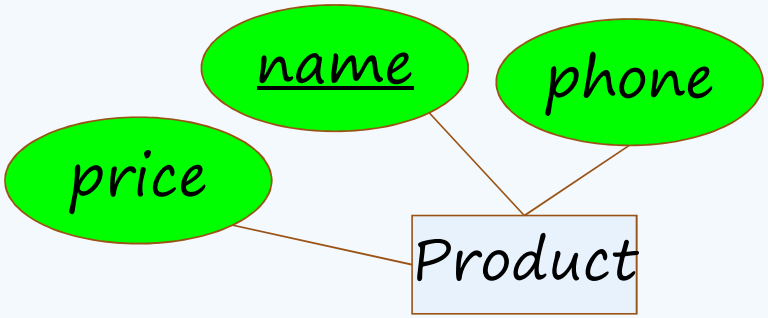
- **key attribute** – an attribute that uniquely identifies a particular entity.
- The name of a key attribute is underscored (Chen Notation).





Key Attribute(s)

- A *key* is a **minimal** set of attributes that uniquely identifies an entity.

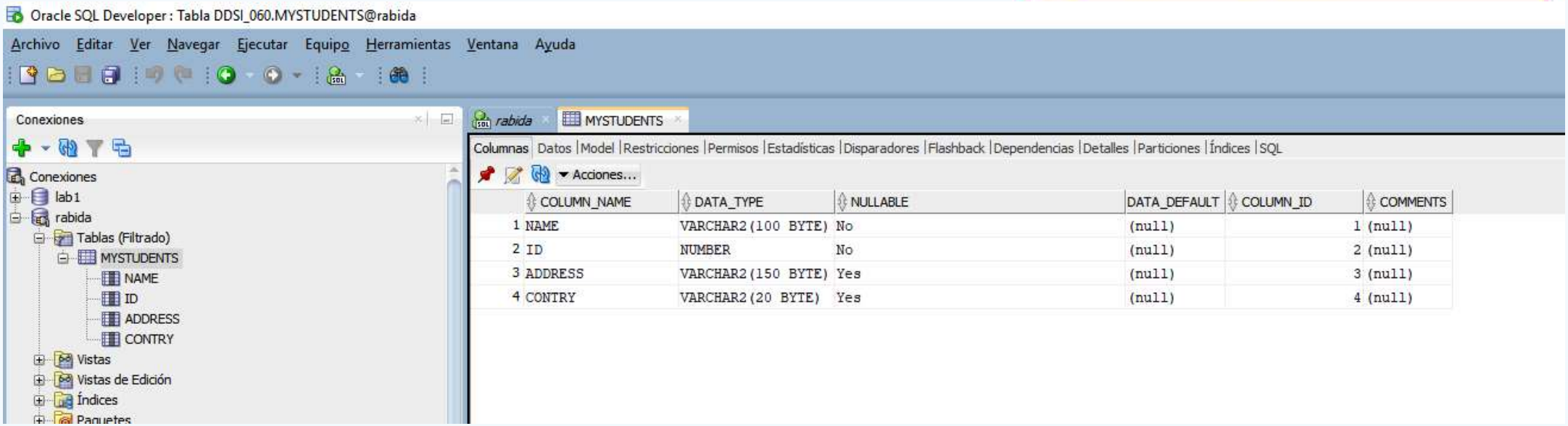


Here, {name, phone} is **not** a key (it is not minimal).
If it were, what would it mean?

The E/R model forces us to designate a single **primary** key, though there may be multiple candidate keys

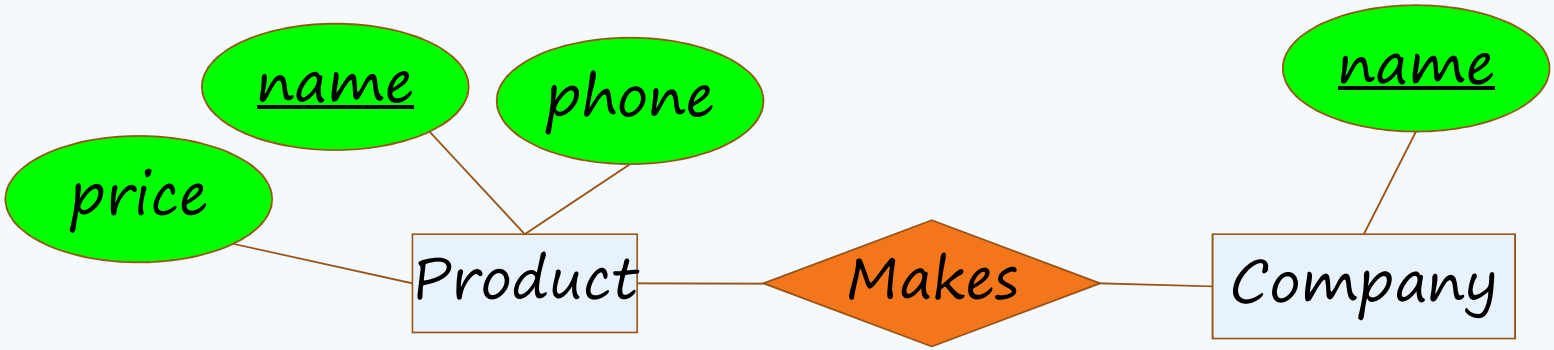
What an entity really means?

DDSI_060.MYSTUDENTS		
	* NAME	VARCHAR2 (100 BYTE)
P	* ID	NUMBER
	ADDRESS	VARCHAR2 (150 BYTE)
	CONTRY	VARCHAR2 (20 BYTE)
MYSTUDENTS_PK (ID)		
MYSTUDENTS_PK (ID)		



Relationships

- A relationship is between two (or more) entities



Association or corrjobTitleondence between entity instances

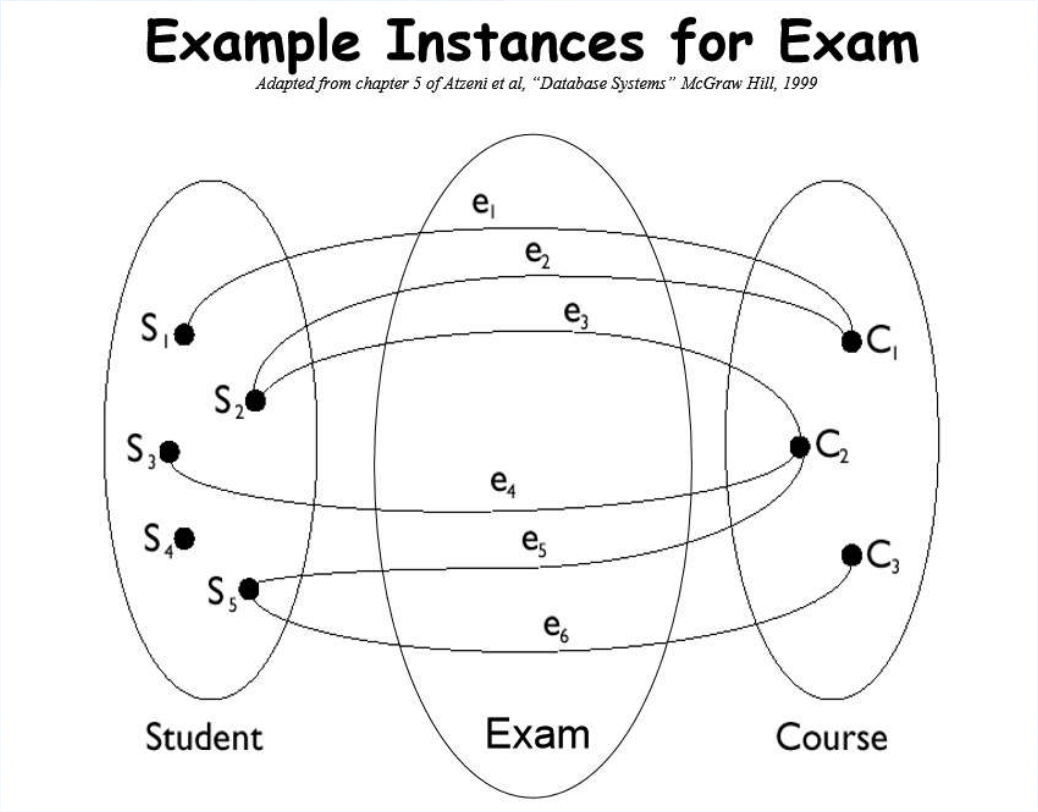
Example: Corresondence between the author of a book with the book he has written

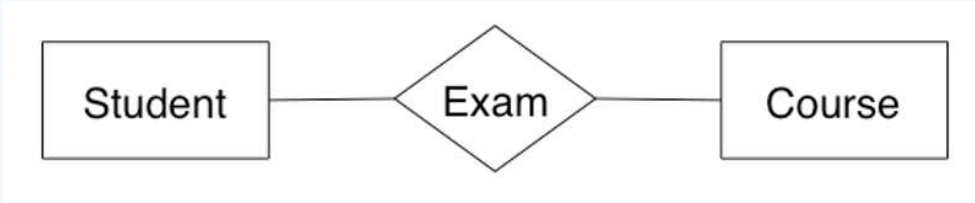
A type of relationship is the set of relationships of the same type.

Example: A type of relationship WRITES relates the types of entities BOOK and AUTHOR

In the same way as with entities, we will simply call the relationship type the relationship

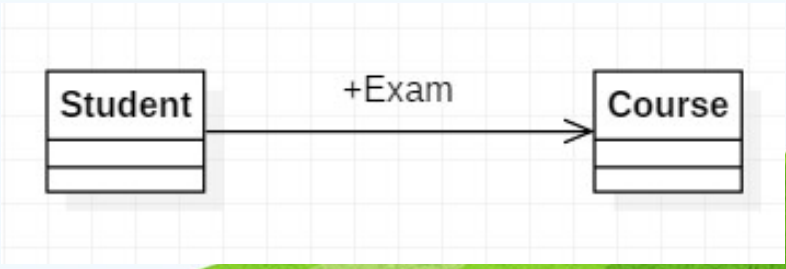
But what does a relationship really mean?





Student and Course are entities
- Their instances are particular students (eg S1) and particular courses (eg C1)

Exam is a relationship
- Its instances describes particular exams (eg e1)
- Each exam has exactily one associated student and course



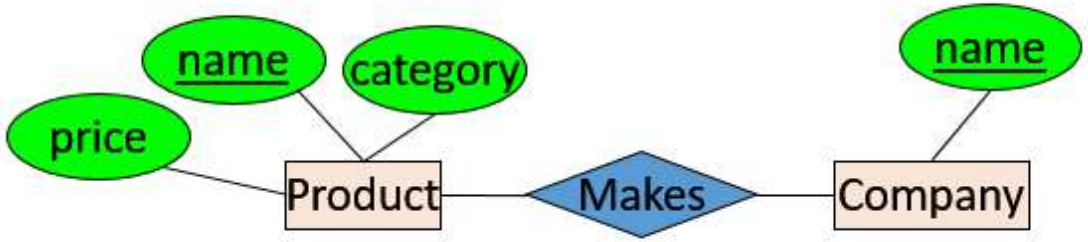
But what does a relationship really mean?

Company

name
GizmoWorks
GadgetCorp

Product

name	category	price
Gizmo	Electronics	$9.99
GizmoLite	Electronics	$7.50
Gadget	Toys	$5.50



Makes

C.name	P.name
GizmoWorks	Gizmo
GizmoWorks	GizmoLite
GadgetCorp	Gadget

How can we identify entities?

Sometimes it is difficult to decide if a certain object or concept can be modeled as an entity

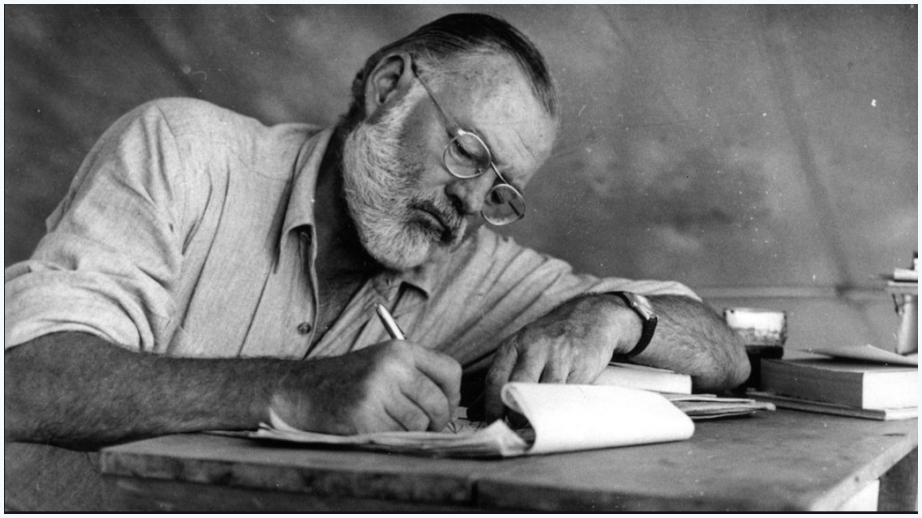
Example: color is usually a property of an entity (the color of a car), but in a paint factory it would probably be appropriate to model "color" as an entity with its own properties

Some authors have tried to specify the concept of entity

TARDIEU et al. (1979) propose three general rules that an entity must comply with:

- it has to have its own existence
- each copy of a type of entity must be distinguishable from the others
- all instances of an entity type must have the same properties

Easy example



Writers (id, name, age) create novels (id, title, date)

Two or more novels can't have the same title

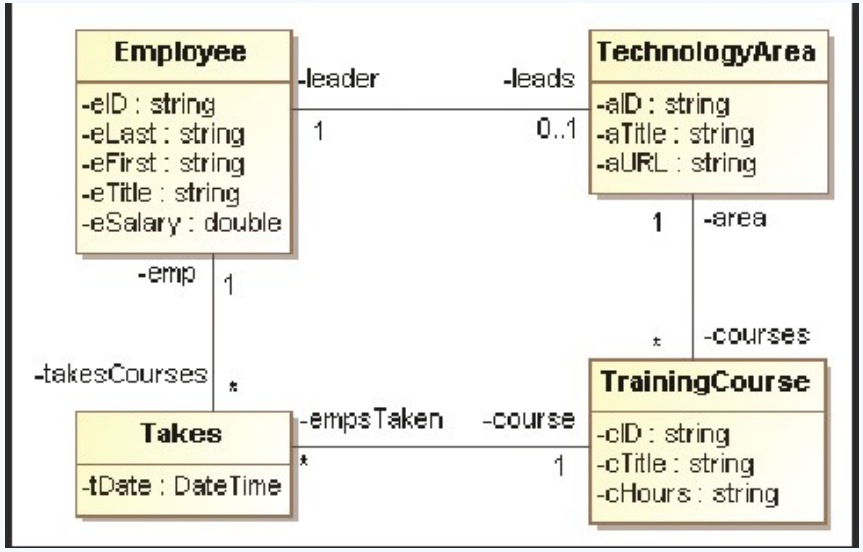
- Novels are bought by Clients (id, name, phone number)

Easy example (II)

Clients (id, name...) rent cars (id, model, color...). It is very import to know the model

Let's try your example...

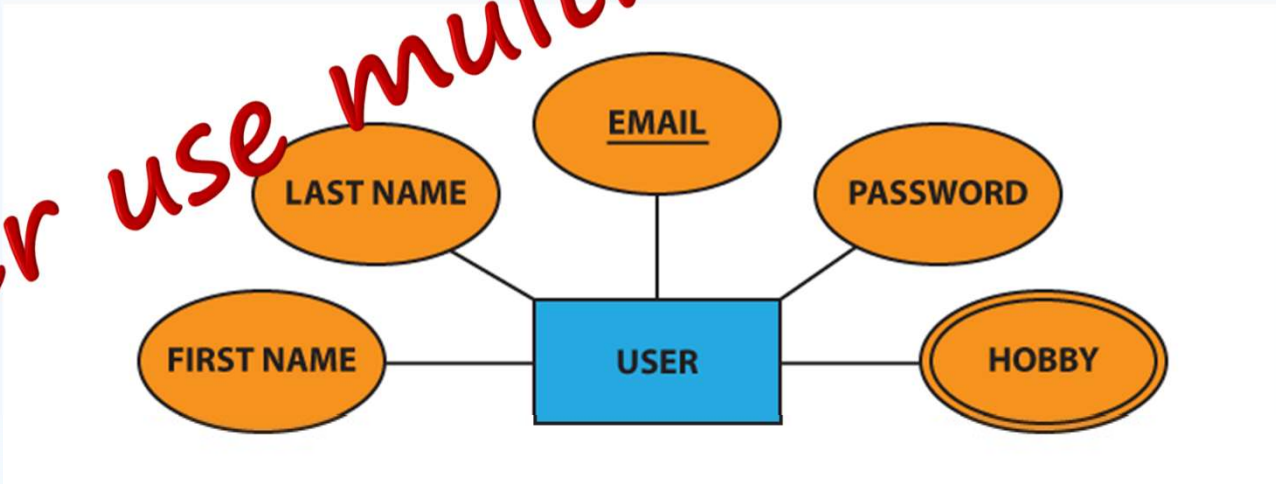
Now, not so easy



Multivalued attribute

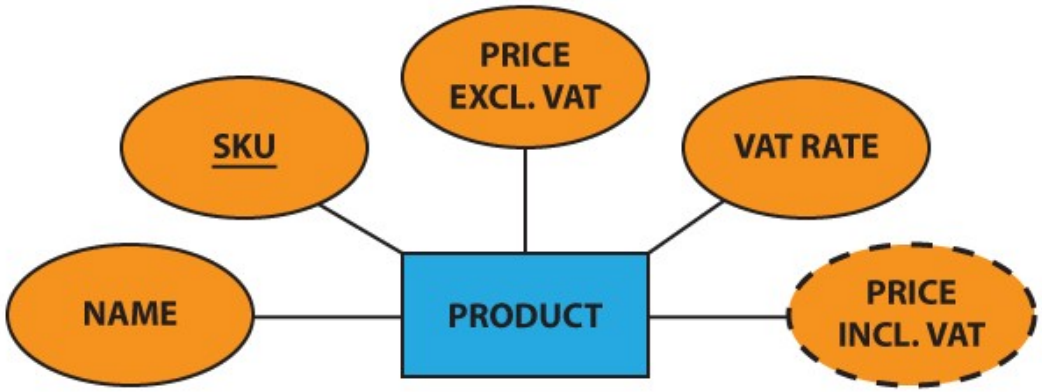
- **multivalued attribute** – an attribute that can have Many values (there are Many distinct values entered for it in the same column of the table). Multivalued attribute is depicted by a dual oval:

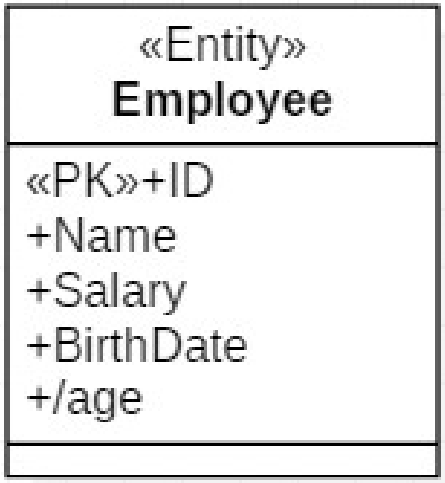
Never use multivalued attributes



Derived attribute

- **derived attribute** (or computed attribute) – an attribute whose value is calculated (derived) from other attributes. The derived attribute may or may not be physically stored in the database.
- In the Chen notation, this attribute is represented by dashed oval

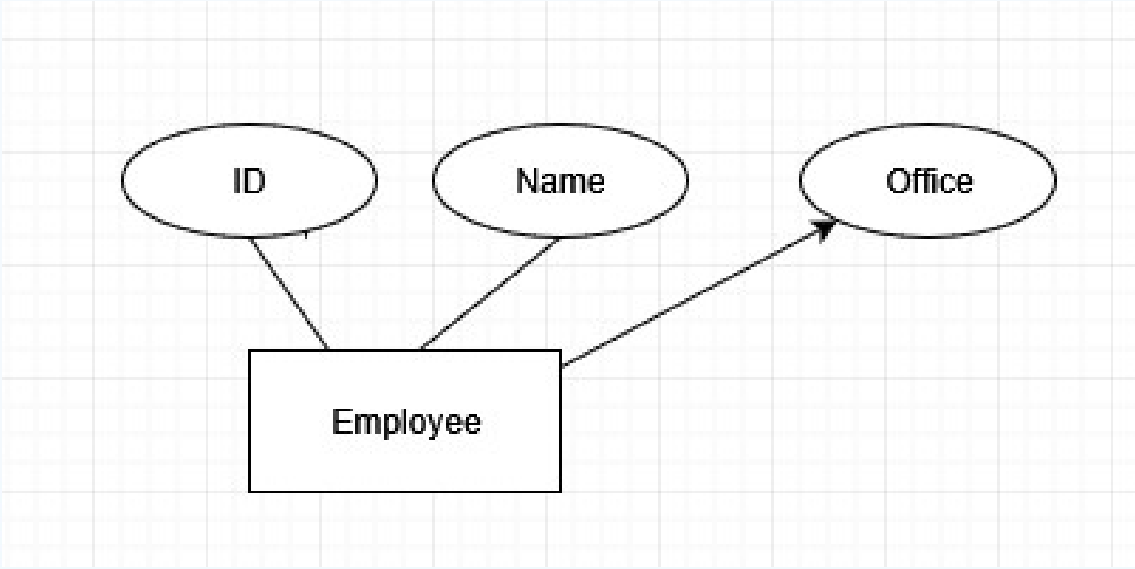


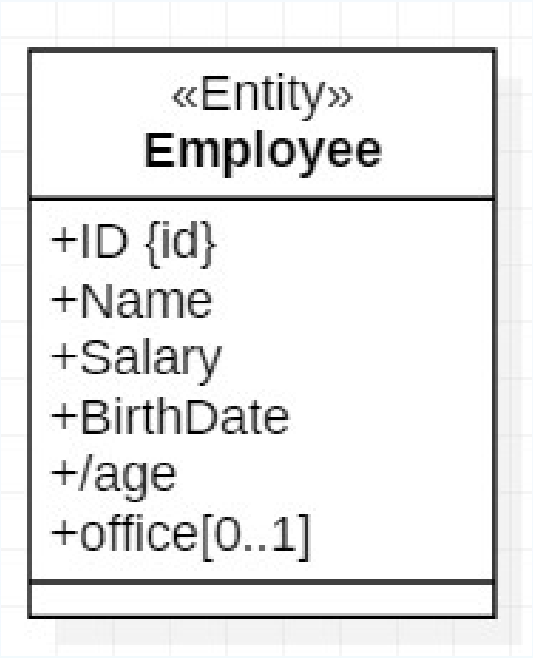


UML

Optional attribute

- Optional attribute: may be left empty





Partial key

- **partial key attribute (discriminator)** – an attribute that, when combined with the key attribute of the owner entity, provides a unique identification for the weak entity. We underline the discriminator with a dashed line:

Weat entitiy

- **weak entity** – an entity that cannot be uniquely identified by its attributes alone. The existence of a weak entity is dependent upon another entity called the owner entity. The weak entity's identifier is a combination of the identifier of the owner entity and the partial key of the weak entity.

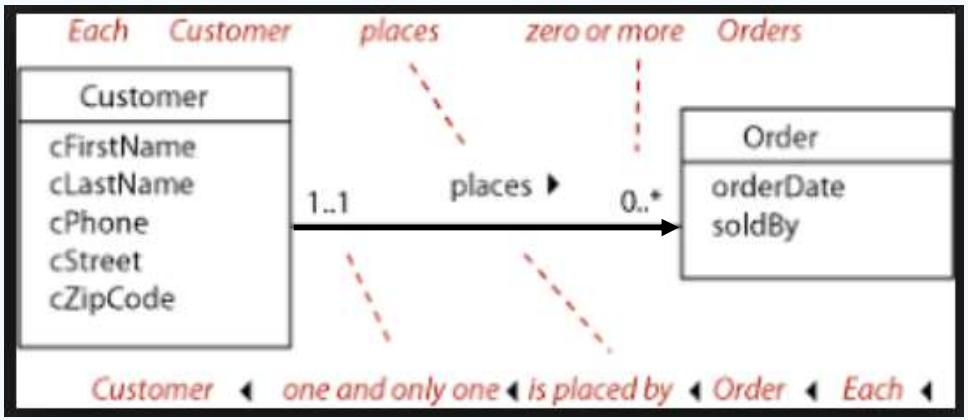
Weat Entity – example

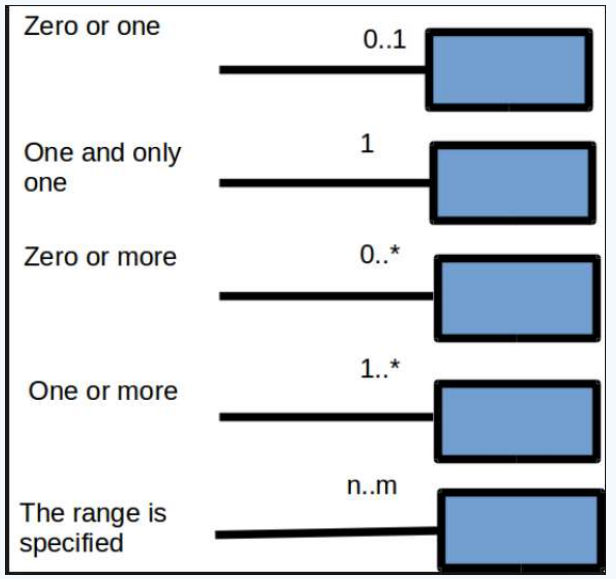
- Consider the building and classroom entities and suppose that there may be classrooms with the same number in different buildings. Class B1.1 and B2.1 can be found in building A, and class B1.1 and B1.2 can be found in building C.

  In this case, the classroom identifier does not completely identify a classroom. In order to fully identify a classroom, it is necessary to take into account in which building it is located. In fact, we can identify a classroom through the interrelation situation, which associates it with a single building. The identifier of the building where it is located together with the classroom number identifies it completely

We will go back to this example after studing relations

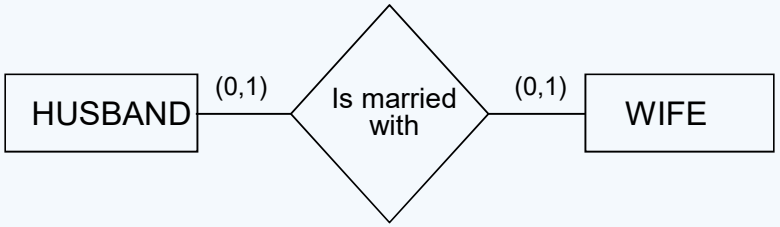
Cardinality

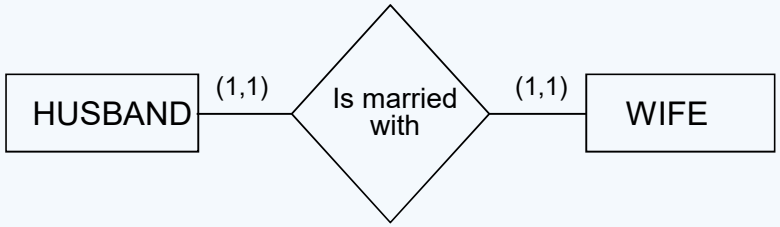


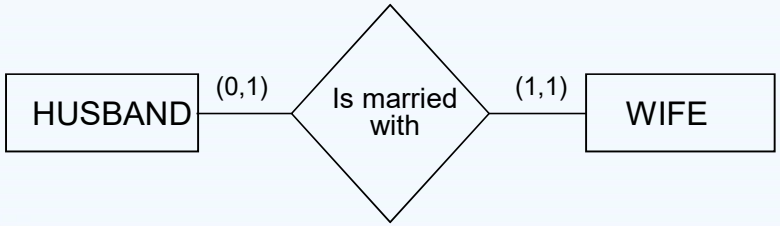


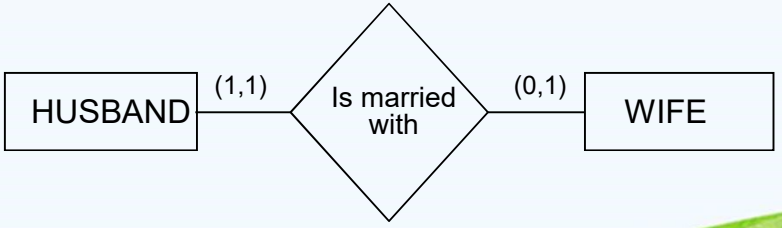
Cardinality

- When both participants can have only one instance of each other. (less used but stable).
- For Example, HUSBAND can have only one WIFE and WIFE can have only one HUSBAND. This is 1:1 relationship between HUSBAND and WIFE participants.





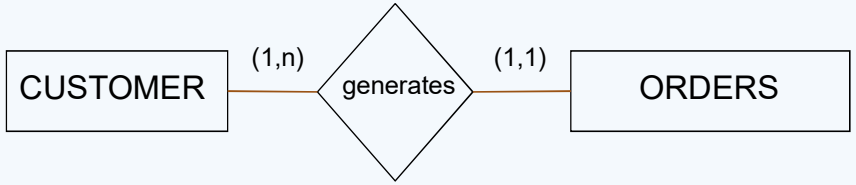




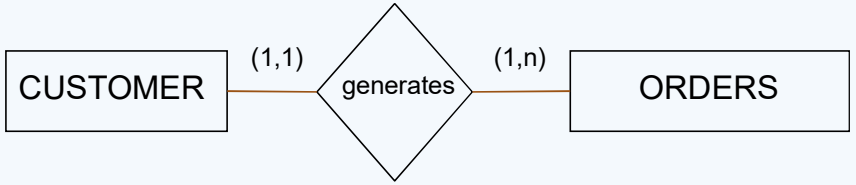
One to One
One to Zero

Cardinality – Example 2

- When one participant can have multiple instances of other participants but other participant can have only one instance of first participants. (mostly used and stable).
- For Example, CUSTOMER may generate many ORDERs but each ORDER is generated by one CUSTOMER. This is 1:M relation between CUSTOMER and ORDER.

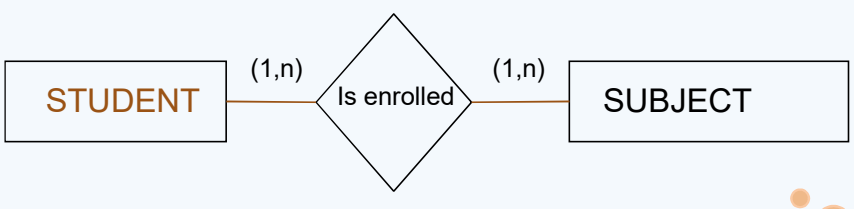


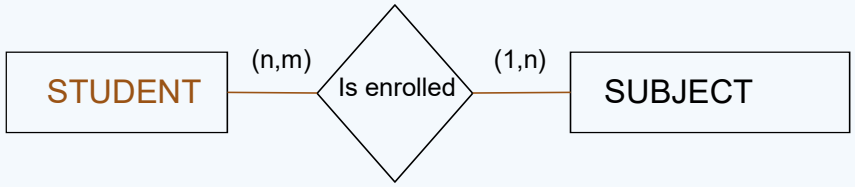
One to Many



Cardinality – Example 3

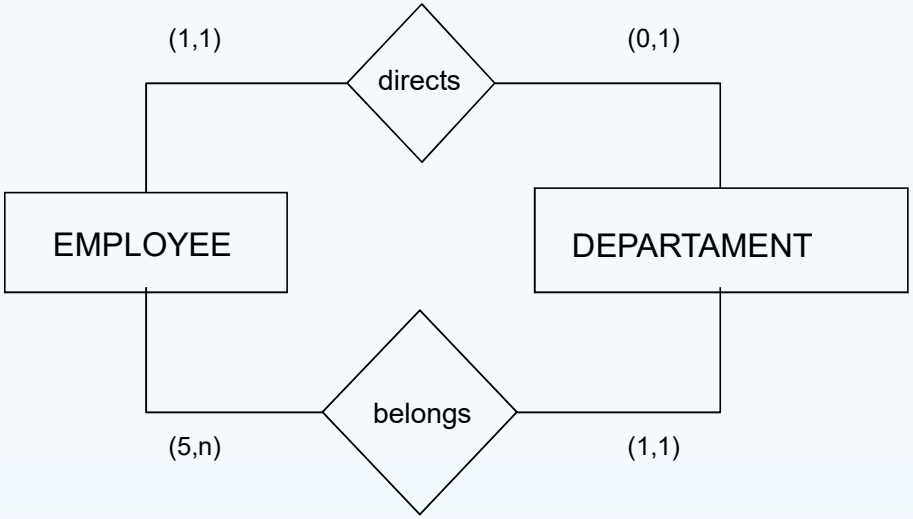
- Both participants can have multiple instances of each other
- A Student can be enrolled in Many Subjects and one Subject can be choosen by Many Students





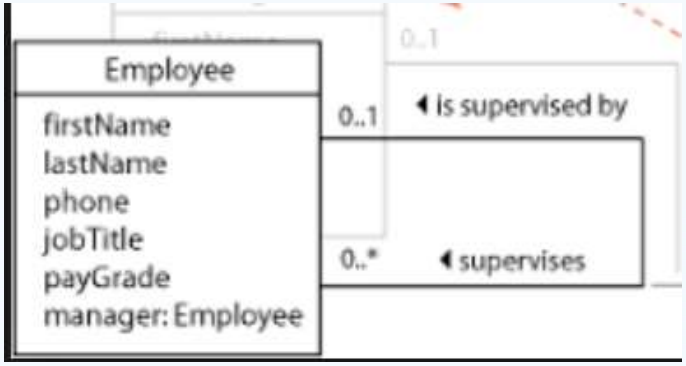
Many to Many

Cardinality – Example 4



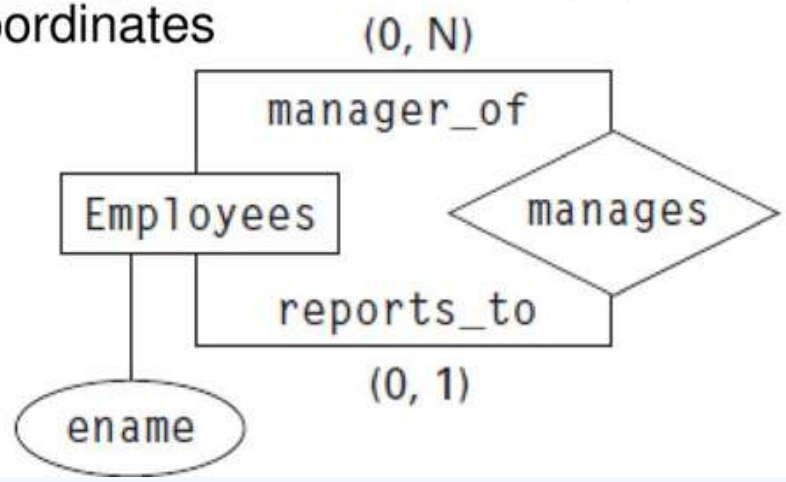
Recursive relationships

- A recursive relationship is one in which a relationship can exists between occurrences of the same entity

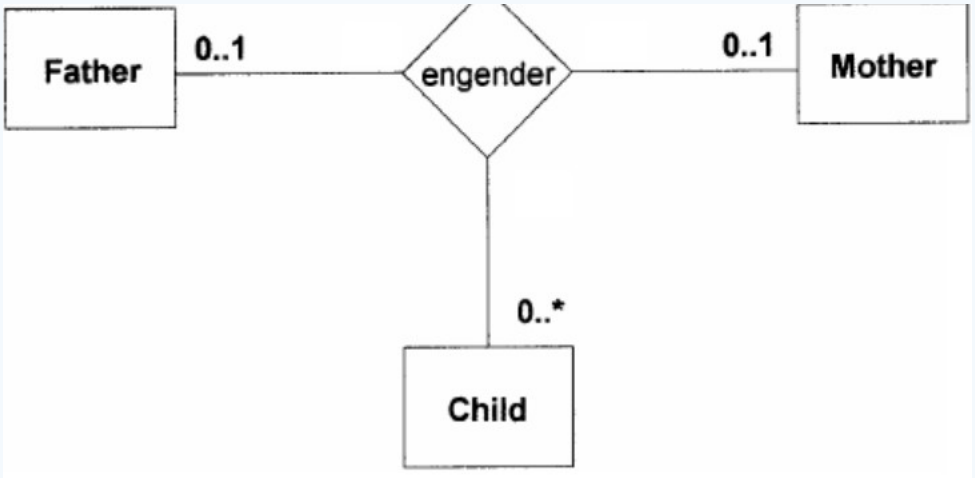


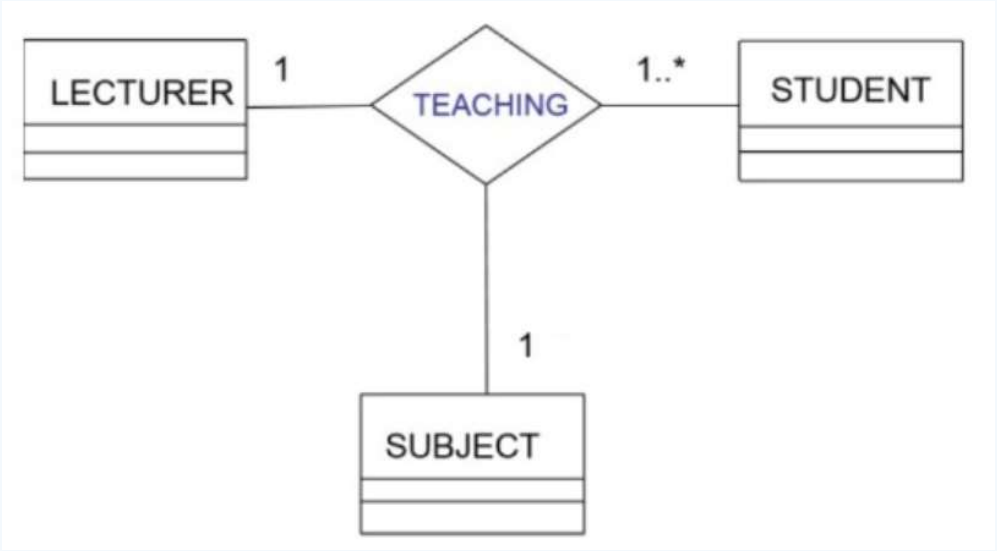
Each employee has at least zero managers (the case of general manager/CEO) and at most one manager (reports to)

A manager could have zero (☺) or more subordinates

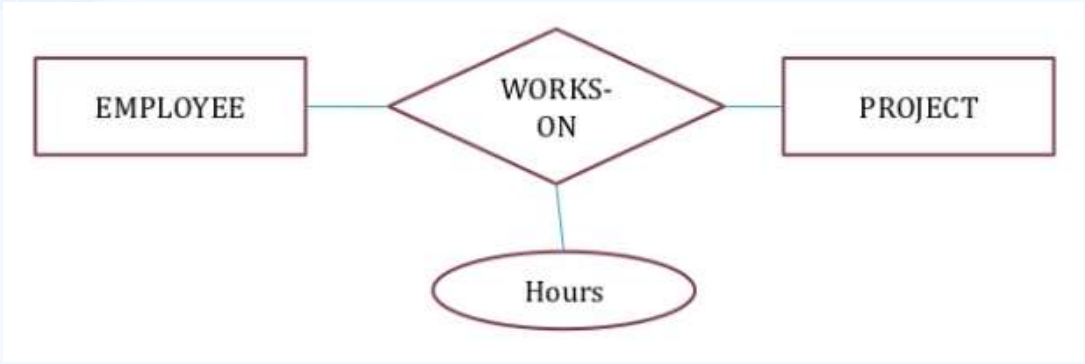


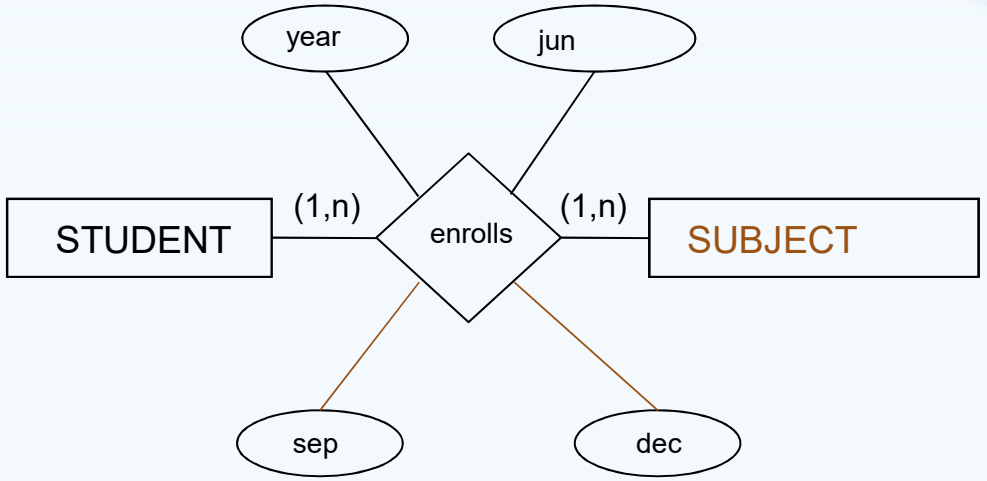
Ternary Relationships

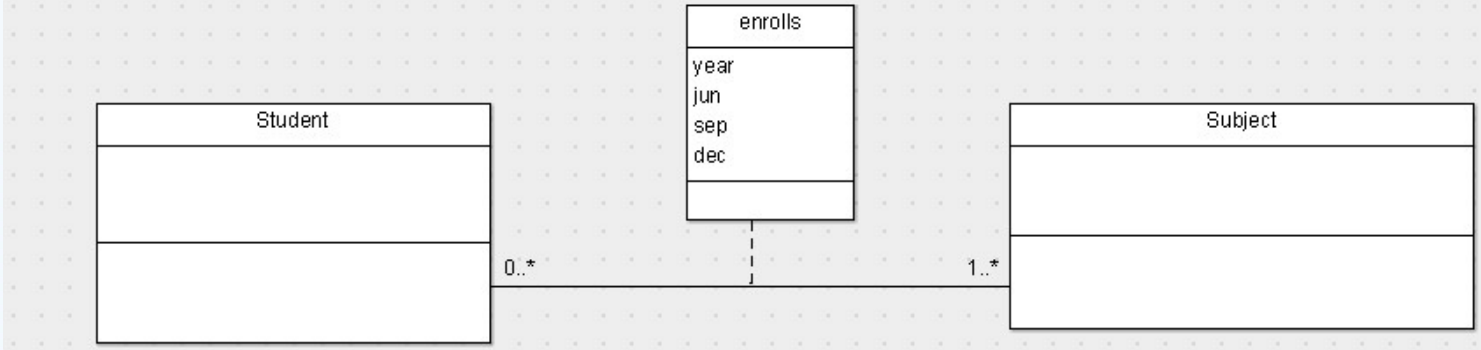




Relatioships with attributes





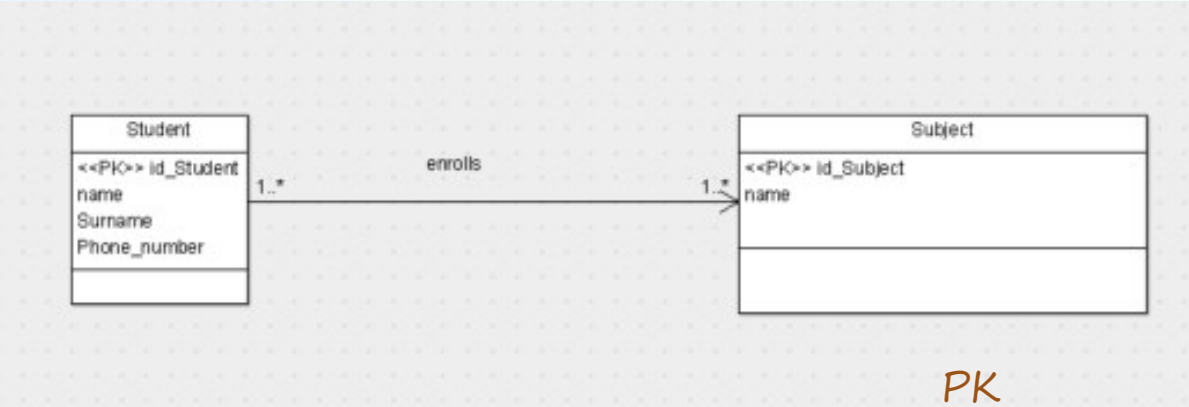


Conceptual Model->Logical Model

Three fundamental principles:

- Every entity is transformed into a table
- Every relationship with maximum cardinality Many to Many (M: N) is transformed into a table
- Any relationship with maximum cardinality one to Many (1: N) can be transformed in two ways:
  - by key propagation
  - by transforming into a new table

Relationships – Implementation (I)
M:N



STUDENT (id_Student, name, surname, phone_number)
PK: id_Student
NN: name
NN: surname
NN: pone_number

SUJECT (id_Subject, name)
PK: id_Subject
Unique: name
NN: name

ENROLLS(id_Student, id_Subject)
PK: (id_Student, id_Subject)
FK: id_Student → STUDENT
id_Subject → SUBJECT

PK

Id_Student	name	Surname	Phone_number
S001	Patricia	Smith	567889988
S002	Silvia	Perez	33344466888
S003	Carlos	Smith	222333444

PK

id_Student	Id_Subject
S001	ID01
S002	ID01
S003	ID01
S002	ID89

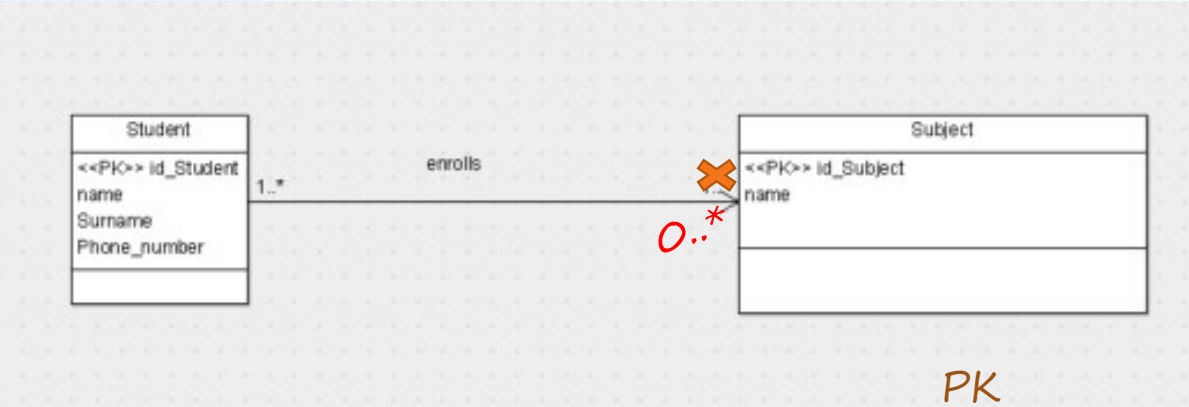
FK

PK

Id_Subject	name
ID01	Information Systems
ID89	Meteorology

FK

Relationships – Implementation (II)



STUDENT (id_Student, name, surname, phone_number)
PK: id_Student
NN: name
NN: surname
NN: pone_number

SUJECT (id_Subject, name)
PK: id_Subject
Unique: name
NN: name

ENROLLS(id_Student, id_Subject)
PK: (id_Student, id_Subject)
FK: id_Student → STUDENT
id_Subject → SUBJECT

PK

Id_Student	name	Surname	Phone_number
S001	Patricia	Smith	567889988
S002	Silvia	Perez	33344466888
S003	Carlos	Smith	222333444

PK

id_Student	Id_Subject
S001	ID01
S003	ID01
S002	ID89

FK

PK

Id_Subject	name
ID01	Information Systems
ID89	Meteorology

FK

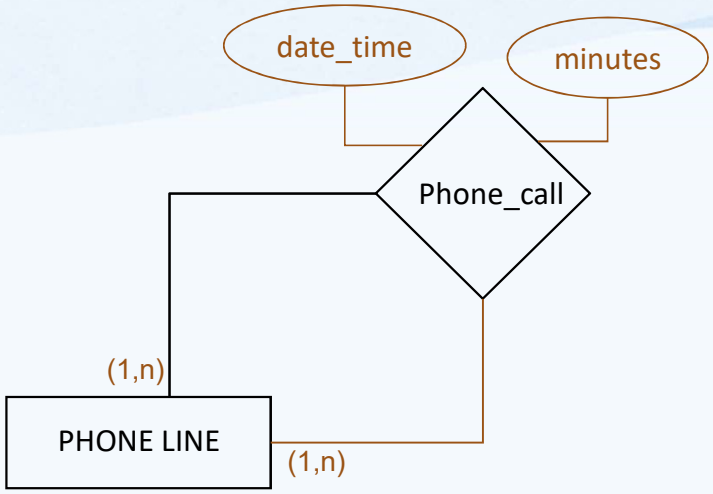
Relatioships – Implementation – Many to Many

An M: N relation is transformed into a table whose primary key is the concatenation of the primary keys of the tables that are generated when transforming the entities that are part of the relationship. Along with these attributes are included the attributes of the relationship

Each of the attributes that form the primary key of this table are foreign keys (FK) that refer to each of the tables where said attribute is a primary key

In a transformation of a Many-to-Many relationship, it is sometimes necessary to include, in the primary key, some attribute proper to the relationship. It usually occurs when the relationship between the same two rows can be repeated and / or we wish to maintain a historical record over time

Exceptions



PHONE_CALL (origin, destination, date_time, minutes)
PK: (origin, date_time)
UNIQUE: (destination, date_time)
NN: minutes

origin	destination	Date_time	minutes
4444	5555	2018/01/01 14:10:00	30
4444	5555	2018/01/01 14:50:00	45
5555	4444	2018/01/03 19:00:00	120

- This PK (table PHONE_CALL) can not be formed only by the origin and destination phone lines since it would prevent that from a phone line, the same phone number could be called more than once.
- Adding the date to the key would solve that problem However, this solution would allow that from one telephone you could call several phone numbers at the same time (only the combination of "origin, date_time") would be repeated.
- That situation can not occur in this problem
in this case there is a subset of attributes that would also identify each row of the talbe. Therefore, that will be the main key

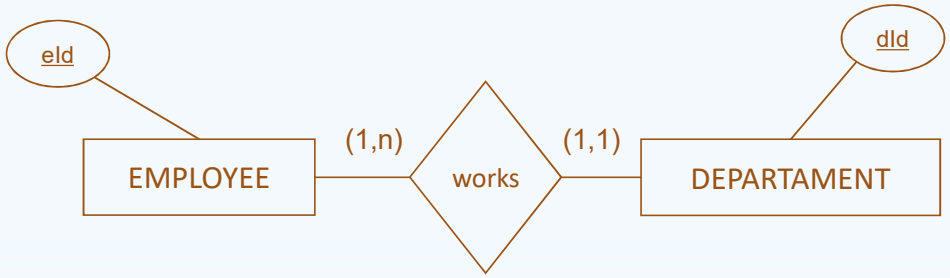
Example

- Draw an E-R schema to describe the following domain

The University of Huelva has several departments. Each department is Managed by a department Manager (professor). Professors must be assigned to one, but possibly more departments. At least one professor teaches each course, but a professor may be on sabbatical and not teach any course. Each course may be taught more than once by different professors. We know of the department name, the professor name, the professor employee id, the course names, the course schedule, the term/year that the course is taught, the departments the professor is assigned to and the department that offers the course.

Relatioships – Implementation – One to Many

- 2 ways:
  - Include in the M-side the PKof the entity 1-side (PK) and all the attributes of the relatioship.
  - Create a new relation whose attributes are the primary keys of the other two, which will also be foreign keys to them. PK will be the PK of the M-side

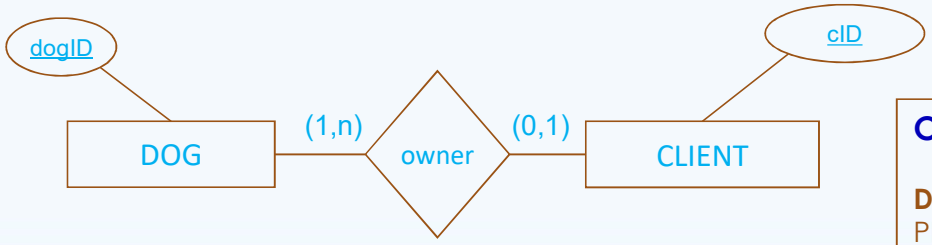


EMPLOYEE (eID, …, departament)
Pk: eID
FK: departament → DEPARTAMENT(dID)
NN: departament

DEPARTAMENT (dID, …)
Pk: dID

Relatioships – Implementation – One to Many

- 2 ways:
  - Include in the M-side the PKof the entity 1-side (PK) and all the attributes of the relatioship.
  - Create a new relation whose attributes are the primary keys of the other two, which will also be foreign keys to them. PK will be the PK of the M-side
    - This option can be used if few tuples participate in the relationship to avoid excessive NULL values in the foreign key or
    - When the relationships has attributes and we want to keep the meaning



OPTION 1

DOG (dogID, name, size, …, owner)
PK: dogID
FK: owner → CLIENT (cID)
NN: name

CLIENT (cID, name, …)
PK: cID

OPTION 2

DOG (dogID, name, size, …)
PK: dogID
NN: name

CLIENT (cID, name, …)
PK: cID

owner (dogID, cID)
PK: dogID
FK: dogID → DOG
cID → CLIENT
NN: cID

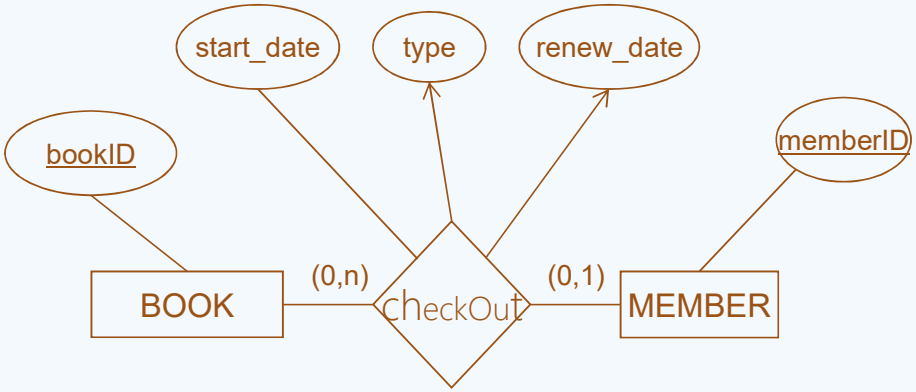
Relatioships – Implementation – One to Many

- When the relationships has attributes and we want to keep the meaning

Book (bookID, title, …)
PK: bookID
NN: title

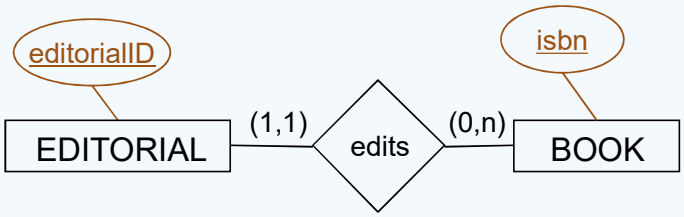
member (memberID, passport, name, …)
PK: memberID
Unique: passport
NN: passport, name

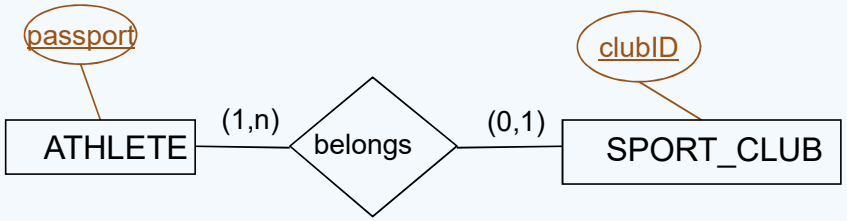
checkout (bookID, memberID, start_date, renew_date, type)
PK: bookID
FK: bookID → Book
memberID → member
NN: memberID, start_date



Relatioships – Implementation – One to Many

- Pay special attention to mínimum cardinality to assign NN constraint correctly





EDITORIAL (editorialID, city, …)
PK: editorialID

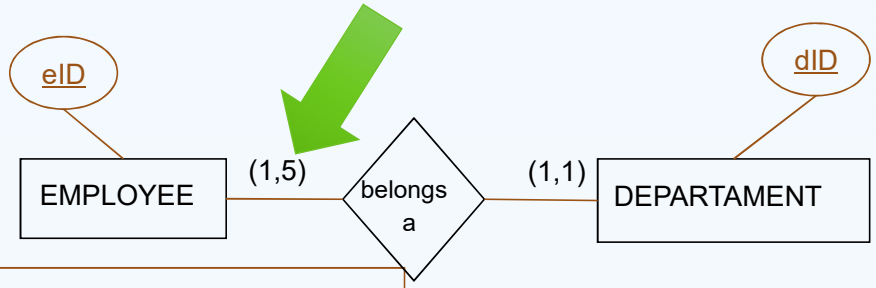
BOOK (isbn, title, …, editorial)
PK: isbn
FK: editorial → EDITORIAL(editorialID)
NN: editorial

SPORT_CLUB (clubID, name, city, …)
PK: clubID

ATHLETE (passport, name, …, club)
PK: passport
FK: club → SPORT_CLUB(clubID)

Relatioships – Implementation – One to Many

- What if we find this?



EMPLOYEE (eID, name, …, departament)
PK: eID
FK: departament → DEPARTAMENT(dID)
NN: departament

DEPARTAMENT (dID, name, …)
PK: dID

```
CREATE OR REPLACE TRIGGER maxEmployee
  BEFORE INSERT ON EMPLOYEE
  FOR EACH ROW
DECLARE
  numEmployee INTEGER;
BEGIN
  SELECT COUNT(*) INTO numEmployee FROM EMPLOYEE
         WHERE departament = :new.departament;
  IF numEMPLOYEEs == 5  THEN RAISE_APPLICATION_ERROR (-20001, 'Department' ||
                  :new.departament ||  'is full');
  END IF;
END;
```

To take into account

- When an application that interacts with a DBMS is developed, it is necessary to decide in which layer they will control or test the restrictions or business rules

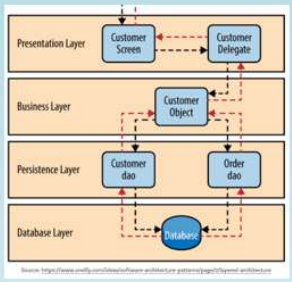
  It is recommended to control restrictions at the database level

  That way, the ide will be much simpler and portable

Software Architecture Pattern

- **Presentation layer**
  - Presentation of the web pages, UI forms and end user interacting API's
- **Business layer**
  - The logic behind the accessibility, security and authentication happens in this layer. This includes ESB (Enterprise Service Buses), middle ware and other various request interceptors to perform validations.
- **Persistence layer**
  - This is the presentation layer for the Data. This includes the DAO (Data Access Object) presentation, ORM (Object Relational Mappings) and Other modes of presenting persistent data in the application level
  - The persistence layer will be responsible for mapping between the Oracle DBMS relational model and the OO model of the Java programming language.

    All the classes and methods necessary to manage the data stored in the database will be defined and programmed in this layer and also those business rules that could not be defined in the data layer



Database layer

- Our data layer is the Oracle DBMS 11g
- Each user will have their own space in which they will store the schema of the database (tables) and it will accessed from the persistence layer

  In this layer you can define some of the business rules (LDD restrictions)
- SQL

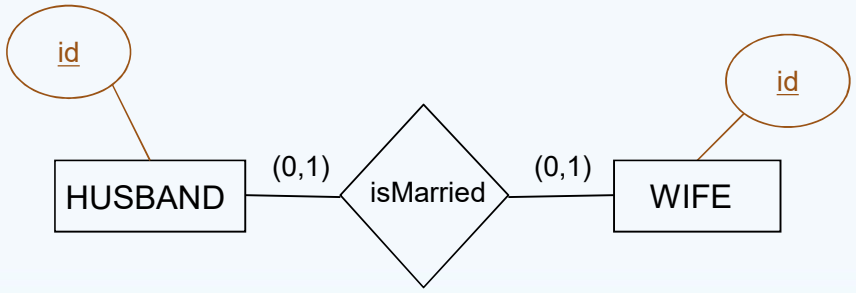
https://towardsdatascience.com/software-architecture-patterns-98043af8028

Relatioships – Implementation – One to One

- 2 options
  - Create a new table (like in M:N)
  - Add the PK of one table to the other as a PK

- Keep the meaning
- Avoid null values
- Mininum cardinalities
- Efficiency

If both are 0:1 and we know there isn't a lof to relations, we créate a new table to avoid nulls



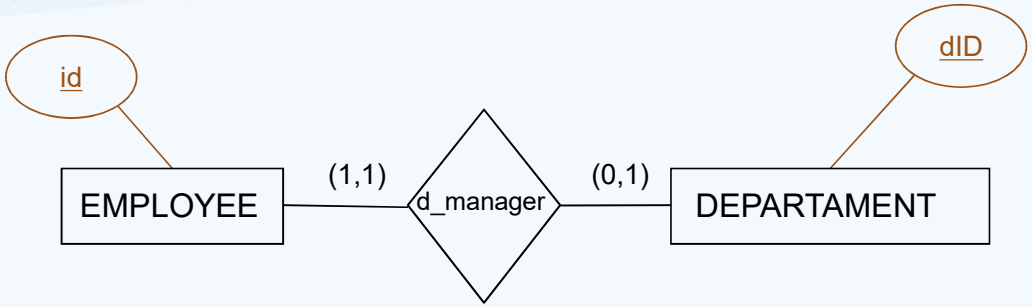
HUSBAND (id, name, …)
PK: id

WIFE (id, name, …)
PK: id

isMarried (idH, idW)
PK: idW
FK: idH → HUSBAND(id)
idW → WIFE(id)
NN: idH
UNIQUE: idH

Relatioships – Implementation – One to One

If one is O:1 and other is 1:1, to avoid NULLs we add the 1:1 PK to the O:1 side as a FK



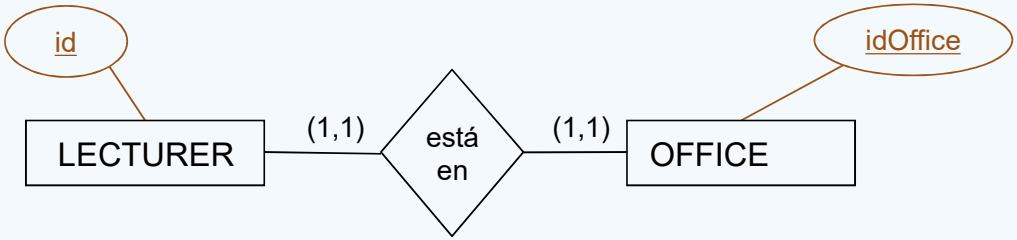
EMPLOYEE (id, name, address, …)
PK: id

DEPARTAMENT (dID, city, …, manager)
PK: dID
FK: manager → EMPLOYEE(id)
NN: manager
Unique: manager

If both are 1:1 we can créate a table or add PK as FKs

Relatioships – Implementation – One to One

- If both are 1:1 we can keep all the information in only one table or add PK as FKs



LECTURER (id, name, …)
PK: id
NN: name

OFFICE (idOffice, floor, …, LECTURER)
PK: idOFFICE
FK: LECTURER → LECTURER(id)
NN: floor, LECTURER
Unique: LECTURER

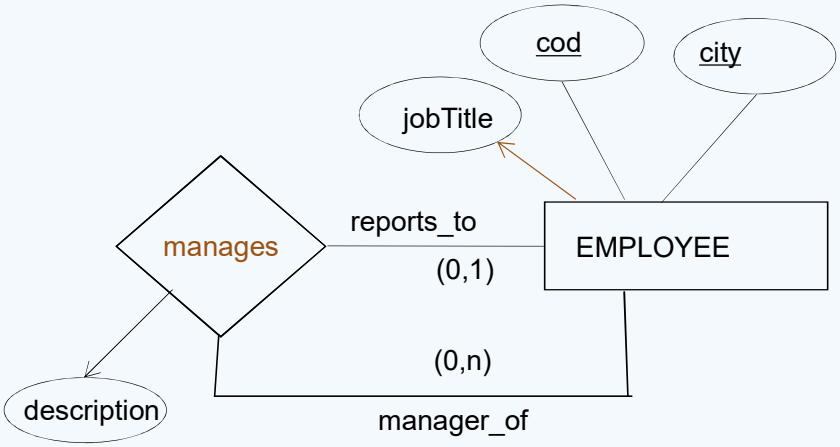
LECTURER (id, name, …, OFFICE)
PK: id
FK: OFFICE → OFFICE(idOFFICE)
NN: name, OFFICE
Unique: OFFICE

OFFICE (idOFFICE, floor, …)
PK: idOFFICE
NN: floor

LECTURER_AND_OFFICE (id, name, …, idOFFICE, floor, …)
PK: id
NN: name, floor, idOFFICE
Unique: idOFFICE

Recursive relationships - Implementation

- To derive reflexive relations the same rules are applied (but in this case there is only one entity associated with the relationship)

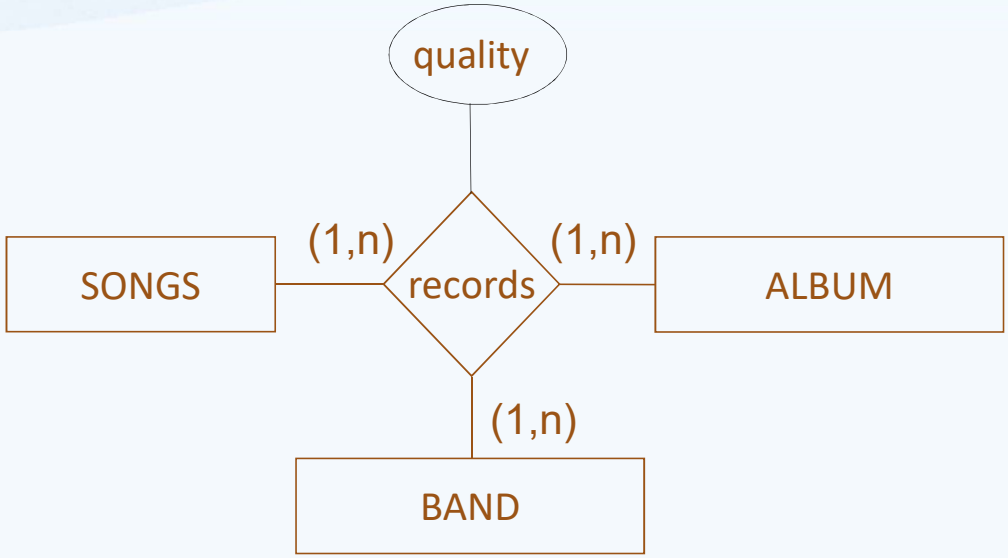


EMPLOYEE (**cod, city**, jobTitle, …, codManager, cityManager, description)
PK: (cod, city)
FK: (codManager, cityManager) → EMPLOYEE(cod, city)

EMPLOYEE (**cod, city**, jobTitle, …)
PK: (cod, city)

manager_of (**cod, city**, codManager, cityManager, description)
PK: (cod, city)
FK: (cod, city) → EMPLOYEE
(codManager, cityManager) → EMPLOYEE(cod, city)
NN: codManager, cityManager

Ternary relationships M:M:M- Implementation



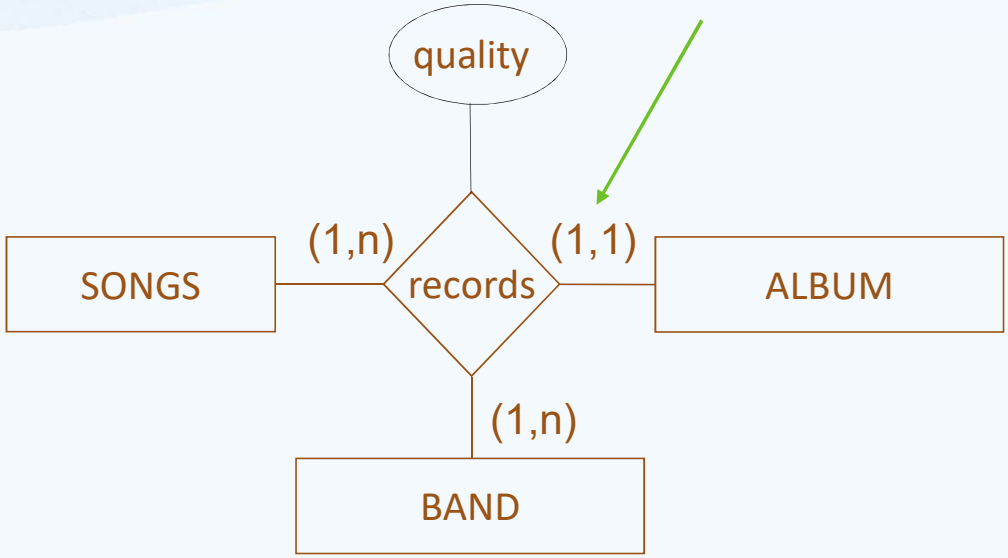
SONGS (songID, title, …)
PK: songID

BAND (bandID, name, nationality, …)
PK: bandID

ALBUM (idA, title,…)
PK: idA

records (**songID, bandID, idA**, quality)
PK: (songID, bandID, idD)
FK: songID → SONGS
idA → ALBUM
bandID → BAND
NN: quality

Ternary relationships M:M:1 - Implementation



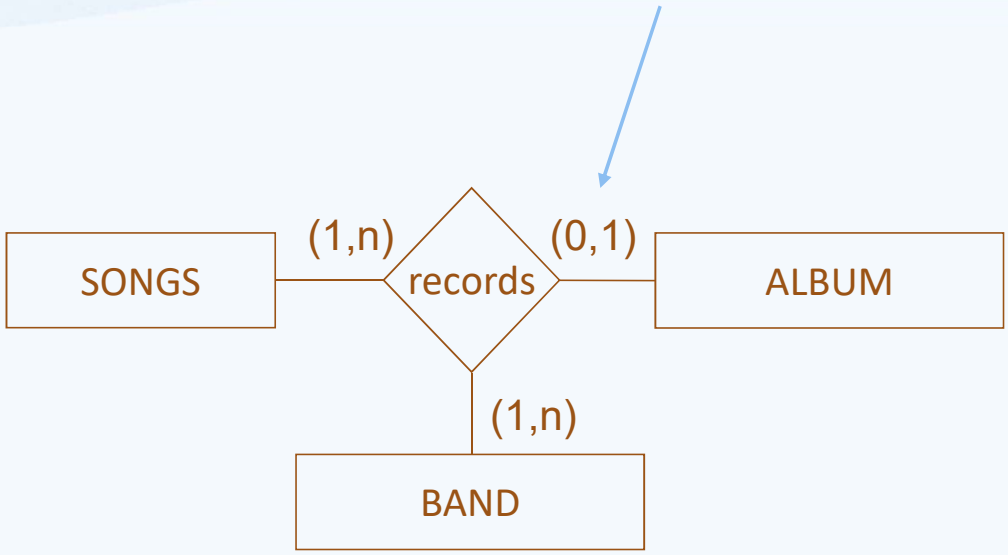
SONGS (songID, title, …)
PK: songID

BAND (bandID, name, nationality, …)
PK: bandID

ALBUM (idA, title,…)
PK: idA

records (**songID, bandID,** idA, quality)
PK: (songID, bandID)
FK: songID → SONGS
idA → ALBUM
bandID → BAND
NN: quality
NN: idA

Take into account...



Nulls -----> Efficiency problems

SONGS (songID, title, ...)
PK: songID

BAND (bandID, name, nationality, ...)
PK: bandID

ALBUM (idA, title,...)
PK: idA

records (**songID, bandID,** idA)
PK: (songID, bandID)
PK: songID → SONGS
idA → ALBUM
bandID → BAND

Ternary M:1:1?

Ternary 1:1:1?