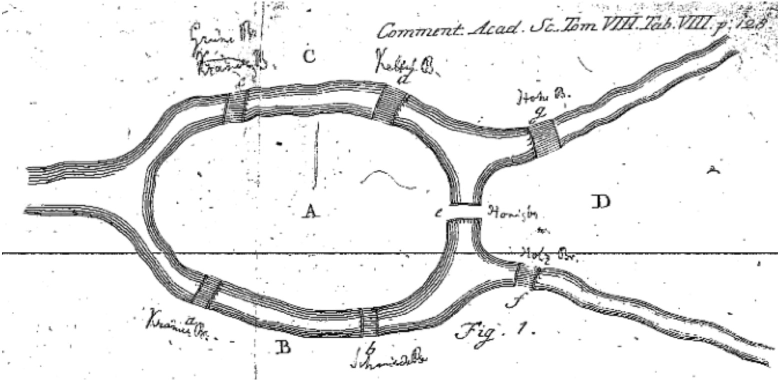
Week 4 Workshop



Housekeeping information

- SQL Assessment (Assignment 1) will be available on Wattle 23:59 tonight, and the submission via Wattle is due 23:59 Sep 3 (Friday, Week 6)
  - **Individual, no group work!**
  - **Do not post any idea/partial solution/result on Wattle.**
  - **Do not wait until the last minute to check/submit your solution.**
  - Sample SQL questions/solutions will be available on Wattle.
  - The correctness of queries does not depend on any database state.
  - Partial marks may be awarded.

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- Drop-in sessions for Assignment 1 (Week 5 and Week 6)
  - Aug 23 (Mon) 2-3 pm (NEW)
  - Aug 24 (Tue) 2-3 pm
  - Aug 25 (Wed) 8-9 pm (NEW)
  - Aug 30 (Mon) 2-3 pm (NEW)
  - Aug 31 (Tue) 2-3 pm
  - Sep 1 (Wed) 8-9 pm (NEW)

Database Design – Four Phases

- The database design process has **four phases**:

  1. **Requirements Collection and Analysis**
  2. **Conceptual Design**
     Entity-Relationship Model
  3. **Logical Design**
     From Entity-Relationship Model to Relation Schemas
  4. **Physical Design**

Phase 2: Conceptual Design

- **Conceptual design** is the process of constructing a conceptual data model that is
  - modeled at a high-level of abstraction;
  - sufficiently simple and often graphical;
  - used to communicate the requirements of a database with nontechnical users.
- A conceptual data model is built using the information in users' requirements specification.

  Note: The conceptual design is based on the **Entity-Relationship Model** in this course.

Model and Modeling

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  - often a graphical depiction of data
  - associated with a modeling language

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  - often a graphical depiction of data
  - associated with a modeling language

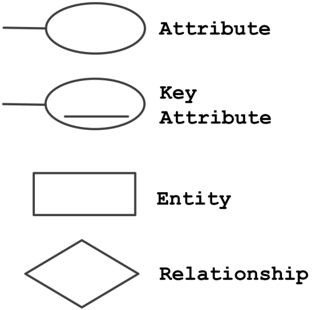
- **What does modeling do?**

  Modeling

  - creates an understanding and relationships of components of a system
  - helps in conceptualising and visualising the structure of a system that we may want to build.
  - facilitates specifications of the behaviour of a system
  - gives rise to a template that guides us in constructing a system
  - . . .

Entity-Relationship (ER) Model

- ER diagrams (Peter Chen in 1976):
  - **Attribute** as *oval*;
  - **Key attribute** with *underlined*;
  - **Entity** as *rectangles*;
  - **Relationship** as *diamonds*.



(Exercise 1) Consider the following data requirements for a university student database that is used to keep track of students' transcripts.

- The university keeps track of each student's name, student number, social security number, address, phone, and birthdate. Both social security number and student number have unique values for each student.
- Each student has exactly one major, and may have a minor (if any) with departments.
- Each department has name, department code, office number, office phone, and college. Both name and code have unique values for each department.
- Each course has a course name, description, course number, number of semester hours, level, and offering department. The value of course number is unique for each course.
- Each section of a course has an instructor, semester, year, and section number and the section number distinguishes different sections of the same course that are taught during the same semester/year; its values are 1, 2, 3, ..., up to the number of sections taught during each semester.
- A grade record refers to each student and a particular section, consisting of a final mark and a letter grade from (F, D, C, B, A).

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- **Relationships:** Associations between entities.
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Question: What are the entities, relationships and attributes?

- **Entities:** STUDENT
- **Relationships:**
- **Attributes**: name, student number, social security number, address, phone and birthdate for STUDENT

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Question: What are the entities, relationships and attributes?

- **Entities:** STUDENT, DEPARTMENT
- **Relationships:** has_major_with between STUDENT and DEPARTMENT, has_minor_with between STUDENT and DEPARTMENT
- **Attributes**: name for has_major_with, name for has_minor_with

Constraints on Relationships

- **Cardinality ratios**: Specifies the *maximum* number of relationships that an entity can participate in.
- **Participation constraints** (total, partial): Specifies whether the existence of any entity depends on its being related to another entity via the relationship type.

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Participation constraints: Every student **must** have one major (**total**) and each department **must** (typically) offer one major (**total**).

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Question: What are the constraints on relationship "**has_minor_with**"?

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Question: What are the constraints on relationship "**has_minor_with**"?

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Each student has exactly one major, and may have a minor (if any) with departments.

Question: What are the constraints on relationship "**has_minor_with**"?

Cardinality ratios: Every student has at most **one** minor and a department may offer **many** minor (to different students)

Participation constraints: Every student **may or may not** have one minor (**partial**) and each department **must** (typically) offer one minor (**total**).

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Australian National University

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Question: What are the entities, relationships and attributes?

- **Entities:** course, department
- **Relationships:** offer (between **department** and **course**)
- **Attributes**: course name, description, course number, number of semester hours and level (of the entity **course**)

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Question: What are the constraints on relationship "**offer**"?

Cardinality ratios: Every course is offered by at most **one** department and a department may offer **many** courses

Participation constraints: Every course **must** be offered by some department (**total**) and each department **may (or may not)** offer any courses (**partial**).

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  Each section of a course has an instructor, semester, year, and section number and the section number distinguishes different sections of the same course that are taught during the same semester/year; its values are 1, 2, 3, ..., up to the number of sections taught during each semester.

  A grade record refers to each student and a particular section, consisting of a final mark and a letter grade from (F, D, C, B, A).

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  - **Entities:** section, course, student
  - **Relationships:** section_taught (between **section** and **course**), grade_record (between **student** and **section**)

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  Question: What are the entities, relationships and attributes?

  - **Entities:** section, course, student
  - **Relationships:** section_taught (between **section** and **course**), grade_record (between **student** and **section**)
  - **Attributes**: instructor, semester, year, and section number (of the **weak** entity **section**), final mark and letter grade (of the relationship **grade_record**)

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Constructing an ER or EER Model

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  student, course, department, section (weak entity)
- Identify the relationships
  - **has_major** (between **student** and **department**)
  - **has_major** (between **student** and **department**)
  - **offer** (between **department** and **course**)
  - **section_taught** (between **section** and **course**)
  - **grade_record** (between **student** and **section**)

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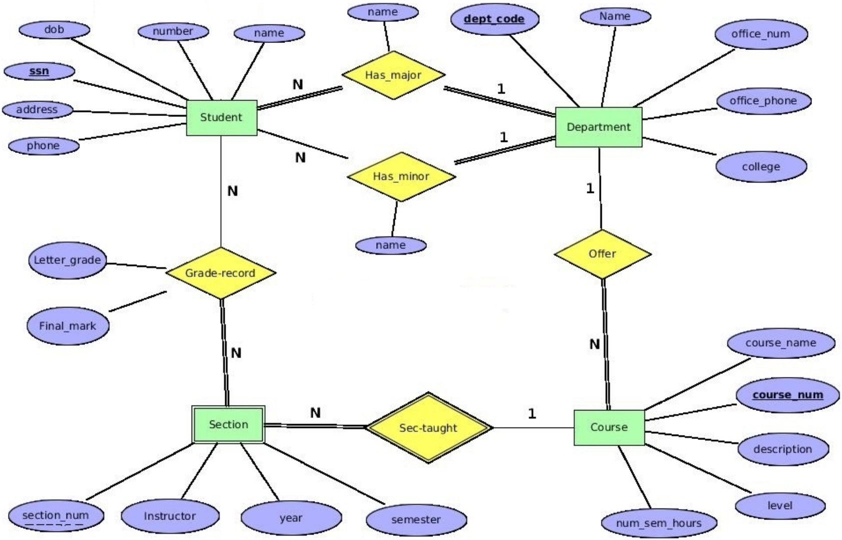
  - **offer** (between **department** and **course**)
  - **section_taught** (between **section** and **course**)
  - **grade_record** (between **student** and **section**)
- Identify the attributes of entities and relationships and identify a primary key for each entity type
- Identify cardinality ratios and participation constraints on relationships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1
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Sec-taught
Course
description
level
section_num
Instructor
year
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Software tool to draw ER diagram

- We require students to use an academic tool, TerraER, to draw the ER diagrams.
- TerraER allows you to save your ER diagrams into xml files and export your ER diagrams as a JPEG figure.
- You can download the jar file from the following website: `https://github.com/rterrabh/TerraER/releases/download/TerraER3.01/TerraER3.01beta.jar`
- You can double-click that file to execute on Windows/Mac/Linux (assume that the Java Runtime Environment JRE has been installed).
- More information on how to use TerraER will be provided next week.

(Exercise 2) A retailer company wants to build a database application for managing information about its sale process. The company sells products in both local shops and webstores on the Internet. Each local shop has a name, contact details (e.g., phone number and email), and a unique location. The database application also needs to store the URL(unique), name and last updated date of each webstore. Every product has a unique productID, a description, an item price, and a quantity in stock. The database application should also record customers' details such as their name, address and email. Every customer is assigned a unique ID. A customer may place an order that consists of at least one product and each order is from either a shop or a webstore. Customers have three payment options (i.e., cash, paypal, and credit card) but for each order only one payment option can be chosen. A delivery may be requested for each order. After full-payment is received, a delivery would be sent out subject to products' availability. Every delivery has a unique tracking number.

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  - disjoint and complete

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- Identify the relationships

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  shop, **webstore**, **product**, **customer**, **order**, **delivery**
- Identify subclass/superclass and the corresponding disjointness and completeness constraints
  - subclass **shop**, **webstore**
  - superclass **store**
- Identify the relationships
  - **customer** **place** **order**
  - **order** **consists of** **product**
  - each order **is from** **store**(superclass) (either subclass **shop** or subclass **webstore**)
  - **delivery** **is for** **order**

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  - subclass **shop**, **webstore**
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Constructing an ER or EER Model

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  - Attributes for superclass **store**: **name**, **location**/**URL**

Constructing an ER or EER Model

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  - Attributes for superclass **store**: **name**, **location/URL**
  - Primary key for superclass **store**: <u>**location/URL**</u>
  - Attributes for subclass **shop**: **phone number, email**
  - Attributes for subclass **webstore**: **last updated date**

Constructing an ER or EER Model

- Identify the entities (including weak entity types)
- Identify subclass/superclass
- Identify the relationships
  - **customer** **place** **order**
  - . . .
- Identify the attributes of entities and relationships
- Identify cardinality ratios and participation constraints on relationships

Constructing an ER or EER Model

- Identify the entities (including weak entity types)
- Identify subclass/superclass
- Identify the relationships
  - **customer** **place** **order**
  - ...
- Identify the attributes of entities and relationships
- Identify cardinality ratios and participation constraints on relationships
  - A **customer** may **place** an **order**

Constructing an ER or EER Model

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  - A **customer** may **place** an **order**
  - Cardinality ratios: A customer may **place** **many** orders and an order **is placed by** **one** customer.

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  - A **customer** may **place** an **order**
  - Cardinality ratios: A customer may **place** **many** orders and an order **is placed by** **one** customer.
  - Participation constraints: A **customer** **may or may not** **place** any orders (**Partial**). An **order** **must** **be placed by** one customer (**Total**).

Constructing an ER or EER Model

- Identify the entities (including weak entity types)
- Identify subclass/superclass
- Identify the relationships
  - **delivery** **is for** **order**
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- Identify the attributes of entities and relationships
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  - A **delivery** may be requested **for** each **order**.

Constructing an ER or EER Model

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  - **delivery** **is for** **order**
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  - A **delivery** may be requested **for** each **order**.
  - Cardinality ratios: A delivery **is for** at most **one** order and an order **has** at most **one** delivery.
  - Participation constraints: A **delivery** **must** **be for** an order (**Total**). An **order** **may or may not** **have** a delivery (**Partial**).

Constructing an ER or EER Model

- Identify the entities (including weak entity types)
- Identify subclass/superclass
- Identify the relationships
  - **order** **consists of** **product**
  - . . .
- Identify the attributes of entities and relationships
- Identify cardinality ratios and participation constraints on relationships

Constructing an ER or EER Model

- Identify the entities (including weak entity types)
- Identify subclass/superclass
- Identify the relationships
  - **order** **consists of** **product**
  - . . .
- Identify the attributes of entities and relationships
- Identify cardinality ratios and participation constraints on relationships
  - Each order **consists of** at least one **product**

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  - **order** **consists of** **product**
  - . . .
- Identify the attributes of entities and relationships
- Identify cardinality ratios and participation constraints on relationships
  - Each order **consists of** at least one **product**
  - Cardinality ratios: An order may **contain** **many** products and an product may **be contained** in **many** orders.

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- Identify the entities (including weak entity types)
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  - **order** **consists of** **product**
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- Identify the attributes of entities and relationships
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  - Each order **consists of** at least one **product**
  - Cardinality ratios: An order may **contain** **many** products and an product may **be contained** in **many** orders.
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Constructing an ER or EER Model

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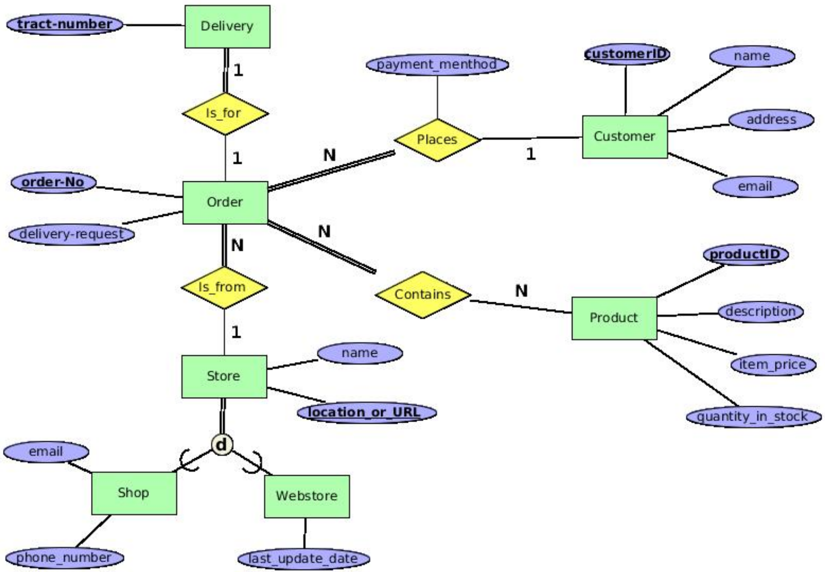
- **Not all the constraints can be expressed in the ER model**

(Exercise 2) A retailer company wants to build a database application for managing information about its sale process. The company sells products in both local shops and webstores on the Internet. Each local shop has a name, contact details (e.g., phone number and email), and a unique location. The database application also needs to store the URL(unique), name and last updated date of each webstore. Every product has a unique productID, a description, an item price, and a quantity in stock. The database application should also record customers' details such as their name, address and email. Every customer is assigned a unique ID. A customer may place an order that consists of at least one product and each order is from either a shop or a webstore. **Customers have three payment options (i.e., cash, paypal, and credit card) but for each order only one payment option can be chosen.** A delivery may be requested for each order. **After full-payment is received, a delivery would be sent out subject to products' availability**. Every delivery has a tracking number.


tract-number
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1
Is_for
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customerID
name
Customer
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order-No
Order
delivery-request
N
N
Is_from
Contains
N
productID
Product
description
item_price
quantity_in_stock
1
Store
name
location_or_URL
d
email
Shop
Webstore
phone_number
last_update_date

Phase 3: Logical Design

- **Logical design** is the process of constructing a logical data model (e.g. relational or object-oriented).
- A conceptual data model is translated onto a logical data model, which can be further refined (e.g., normalisation) to meet the data requirements. For example,
  - **From:** An ER model
  - **To:** Relations with their primary and foreign keys, which facilitates SQL to deal with retrieving, updating and deletion.

  Note: The logical design is based on the **relational data model** in this course.

ER-to-Relations Algorithm

- 7-step algorithm to convert the basic ER model into relations, and more steps for the EER model.

  Step 1: Mapping of Regular Entity Types

  Step 2: Mapping of Weak Entity Types

  Step 3: Mapping of Binary 1:1 Relationship Types

  - Foreign key approach
  - Merged relation approach
  - Cross-reference approach

  Step 4: Mapping of Binary 1:N Relationship Types

  Step 5: Mapping of Binary M:N Relationship Types

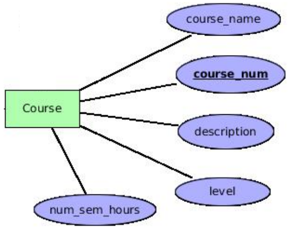
  Step 6: Mapping of Multi-valued Attributes

  Step 7: Mapping of N-ary Relationship Types

  Step 8: Mapping of Superclass/Subclass

Step 1: Regular Entity types

- For each regular entity type *E*, **create a relation schema** with the attributes of *E* (ignore multi-valued attributes until Step 6), where
  - **PK:** the key attributes of *E*



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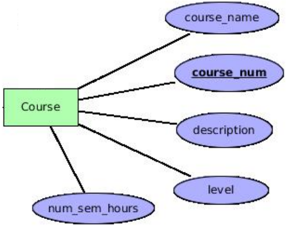
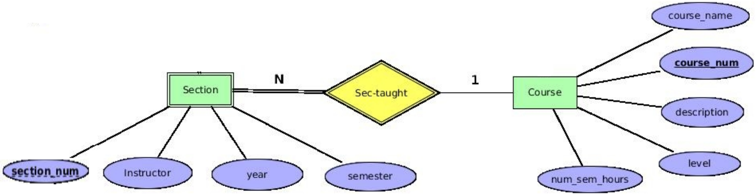


- COURSE(course_num, course_name, description, num_sem_hours, level) with PK: {course_num}
- **Note:** This is not necessarily the final relation schema of COURSE.

Step 2: Weak Entity Types

- For each weak entity type E_w, **create a relation schema** with the attributes of E_w plus the PK of its identifying entity type, where
  - **PK:** the partial key attributes of E_w plus the PK of its identifying entity type
  - **FK:** references the PK of its identifying entity type



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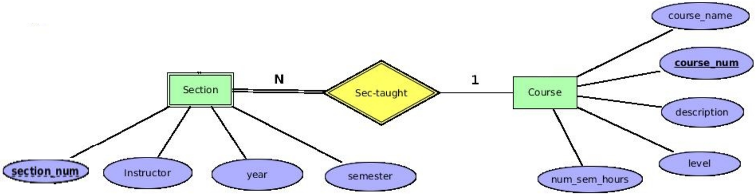

- SECTION(section_num, instructor, semester, year, course_num)
  with PK: {section_num, course_number}
  with FK: [course_num]$\subseteq$COURSE[course_num]

Step 3: Binary 1:1 Relationship Types - (Foreign key)

- For a 1:1 relationship type *R* with one total participation, **extend the relation schema of the total-side entity type** by the attributes of *R* and the PK of the partial-side entity type, where
  - **PK:** still the PK of the total-side entity type
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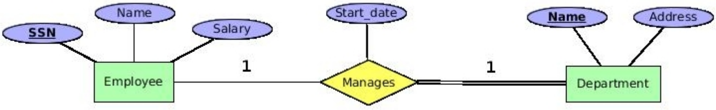

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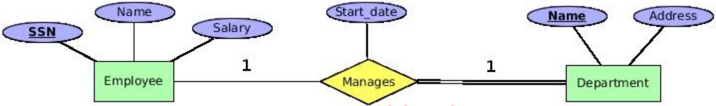

- DEPARTMENT(Name, Address, Mgr_SSN, Start_date) with

  PK: {Name}

  FK: [Mgr_SSN]$\subseteq$EMPLOYEE[SSN].

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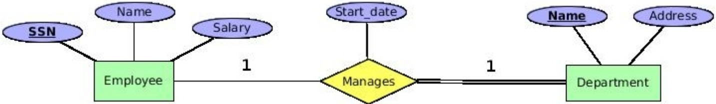

- DEPARTMENT(Name, Address, Mgr_SSN, Start_date) with

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  FK: [Mgr_SSN]$\subseteq$EMPLOYEE[SSN].
- How can we model the total participation?

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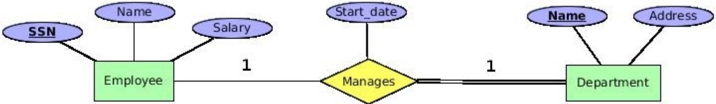

- DEPARTMENT(Name, Address, Mgr_SSN, Start_date) with

  PK: {Name}

  FK: [Mgr_SSN]$\subseteq$EMPLOYEE[SSN].

- How can we model the total participation?

  Add `NOT NULL` constraint to Mgr_SSN for total participation.

Step 3: Binary 1:1 Relationship Types - (Foreign key)

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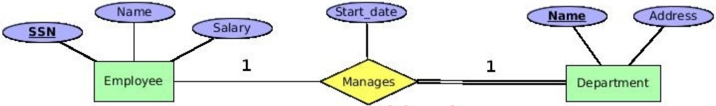

- DEPARTMENT(Name, Address, Mgr_SSN, Start_date) with

  PK: {Name}

  FK: [Mgr_SSN]$\subseteq$EMPLOYEE[SSN].

- Why don't we extend the relation schema of the partial-side entity type?

Step 3: Binary 1:1 Relationship Types - (Foreign key)

- For a 1:1 relationship type *R* with one total participation, **extend the relation schema of the total-side entity type** by the attributes of *R* and the PK of the partial-side entity type, where
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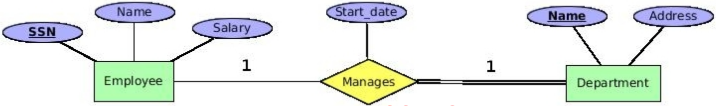


- DEPARTMENT(Name, Address, Mgr_SSN, Start_date) with

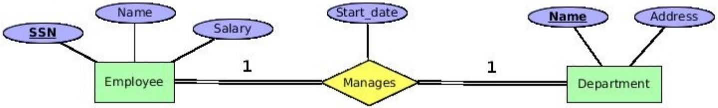
  PK: {Name}

  FK: [Mgr_SSN]⊆EMPLOYEE[SSN].
- Why don't we extend the relation schema of the partial-side entity type?

  This may cause many `NULL` values.

Step 3: Binary 1:1 Relationship Types - (Merged relation)

- How can we translate the following kind of 1:1 relationship type?



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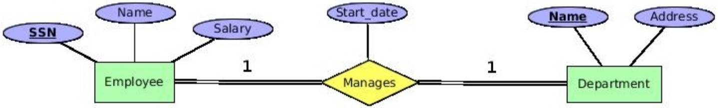

- If participation on both sides is total, we may **merge the relation schemas of both entity types and the attributes of the relationship type into a single relation**.
- EMPLOYEE-DEP(SSN, Name, Salary, Start_date, Dname, Address) with PK: {SSN} or {Dname}

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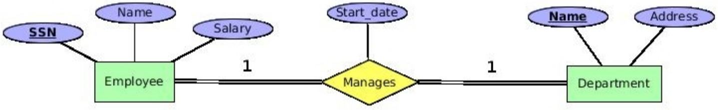

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- EMPLOYEE-DEP(SSN, Name, Salary, Start_date, Dname, Address) with PK: {SSN} or {Dname}
- How can we model the total participations?

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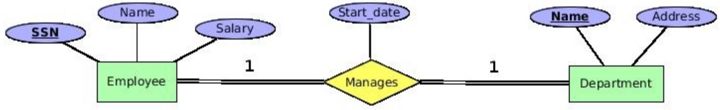

- If participation on both sides is total, we may **merge the relation schemas of both entity types and the attributes of the relationship type into a single relation**.
- EMPLOYEE-DEP(SSN, Name, Salary, Start_date, Dname, Address) with PK: {SSN} or {Dname}
- How can we model the total participations?

  Add `NOT NULL` constraint to both SSN and Dname for total participations.

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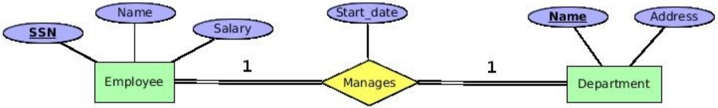
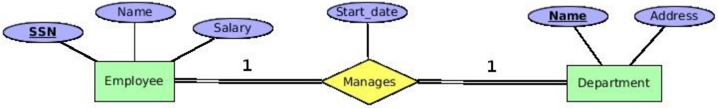


- If participation on both sides is total, we may **merge the relation schemas of both entity types and the attributes of the relationship type into a single relation**.
- EMPLOYEE-DEP(SSN, Name, Salary, Start_date, Dname, Address) with PK: {SSN} or {Dname}
- How can we model the total participations?

  Add `NOT NULL` constraint to both SSN and Dname for total participations.
- **Is merging them always a good solution?**

Step 3: Binary 1:1 Relationship Types - (Merged relation)

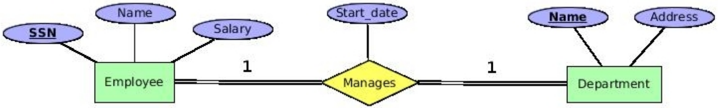
- How can we translate the following kind of 1:1 relationship type?



- If participation on both sides is total, we may **merge the relation schemas of both entity types and the attributes of the relationship type into a single relation**.
- However, **merging them is not always a good solution**. Why?

Step 3: Binary 1:1 Relationship Types - (Merged relation)

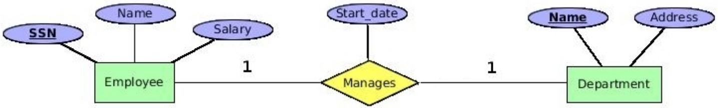
- How can we translate the following kind of 1:1 relationship type?



- If participation on both sides is total, we may **merge the relation schemas of both entity types and the attributes of the relationship type into a single relation**.
- However, **merging them is not always a good solution**. Why?
  (1) The two entity types represent different entities in the real world.
  (2) The two entity types participate in different relationship types.
  (3) Having separate relation schemas for two entity types often leads to more efficient updates than a single relation schema.
  (4) ...

Step 3: Binary 1:1 Relationship Types - (Cross-reference)

- How can we translate the following kind of 1:1 relationship type?



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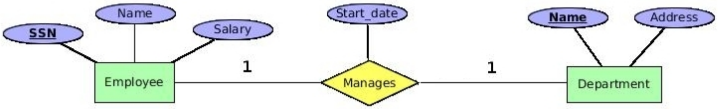

- If both sides are partial, we may **create a (new) relation schema** which cross-references the PKs of the relation schemas of the two entity types.

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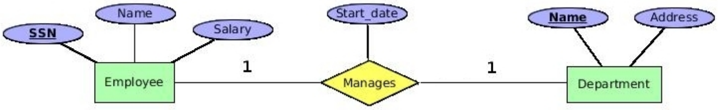

- If both sides are partial, we may **create a (new) relation schema** which cross-references the PKs of the relation schemas of the two entity types.
- MANAGES(SSN, Dname, Start_date) with

  PK: {SSN} or {Dname}

  FKs: [SSN]$\subseteq$EMPLOYEE[SSN] and [Dname]$\subseteq$DEPARTMENT[Name]

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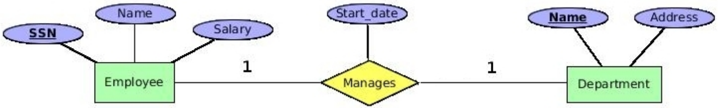

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- Can we still merge them into a single relation using previous approaches?

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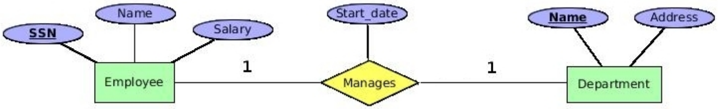

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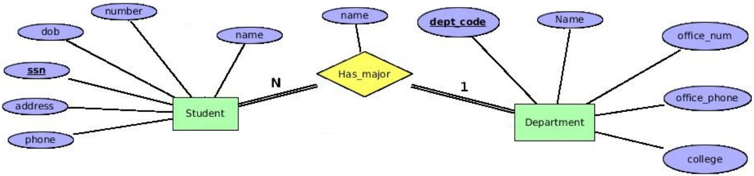
  PK: {SSN} or {Dname}

  FKs: [SSN]⊆EMPLOYEE[SSN] and [Dname]⊆DEPARTMENT[Name]
- Can we still merge them into a single relation using previous approaches?

  We cannot; otherwise what would be the primary key for the merged relation schema?

Step 4: Binary 1:N Relationship Types

- For each 1:N relationship type *R*, **extend the relation schema of the N-side entity type** by the attributes of *R* and the PK of the 1-side entity type, where
  - **PK:** still the PK of the N-side entity type
  - **FK:** references the PK of the 1-side entity type



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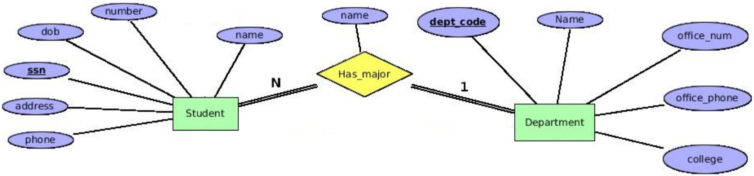

- STUDENT(SSN, Name, Number, DoB, address, phone, major_dept, major_name) with

  PK: {SSN}

  FK: [major_dept]$\subseteq$DEPARTMENT[dept_code]

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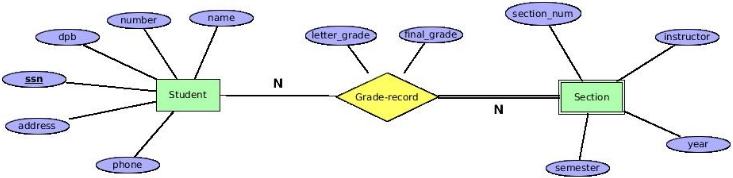
Step 5: Binary M:N (N:N) Relationship Types

- For each M:N (N:N) relationship type *R*, **create a relation schema** with the attributes of *R* plus the PKs of the participating entity types, where
  - **PK:** the combination of the PKs of the participating entity types
  - **FKs:** references the PKs of the participating entity types



- GRADE_RECORD(ssn, section_num, course_num, letter_grade, final_grade)

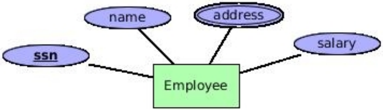
  PK: {ssn, section_num, course_num}

  FK: [ssn] ⊆ STUDENT[ssn]

  FK: [section_num, course_num] ⊆ SECTION[section_num, course_num].

Step 6: Multi-valued Attributes

- For each multi-valued attribute *A*, **create a relation schema** with an attribute corresponding to A plus the PK of the entity/relationship type that has *A* as an attribute, where
    - **PK:** the combination of *A* and the PK of the entity/relationship type that has *A*
    - **FK:** references the PK of the entity/relationship type that has *A*



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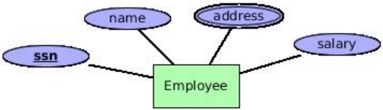


- EMPLOYEE_ADDRESS(SSN, Address) with

  PK: {SSN, Address}

  FK: [SSN]$\subseteq$EMPLOYEE[SSN]

ER-to-Relations Algorithm (Recall)

- The algorithm to first convert the basic ER model into relations, and then convert superclass/subclass from the EER model into relations.

  Step 1: Mapping of Regular Entity Types

  Step 2: Mapping of Weak Entity Types

  Step 3: Mapping of Binary 1:1 Relationship Types

  - Foreign key approach
  - Merged relation approach
  - Cross-reference approach

  Step 4: Mapping of Binary 1:N Relationship Types

  Step 5: Mapping of Binary M:N Relationship Types

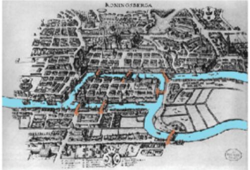
  Step 6: Mapping of Multi-valued Attributes

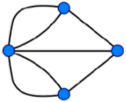
  Step 7: Mapping of N-ary Relationship Types

  Step 8: Mapping of Superclass/Subclass

(Credit Cookie) Graph Model and ER Diagram

Carl Gottlieb Ehler
(1685-1753)





Seven Bridges of Königsberg

Euler
(1707-1783)

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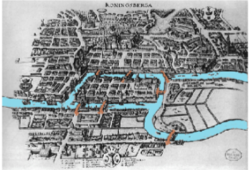

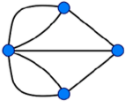

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- 1st paper in ACM Transactions on Database Systems in 1976
- 1st international conference on very large data bases (VLDB) in 1975

The Entity-Relationship Model—Toward a Unified View of Data

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