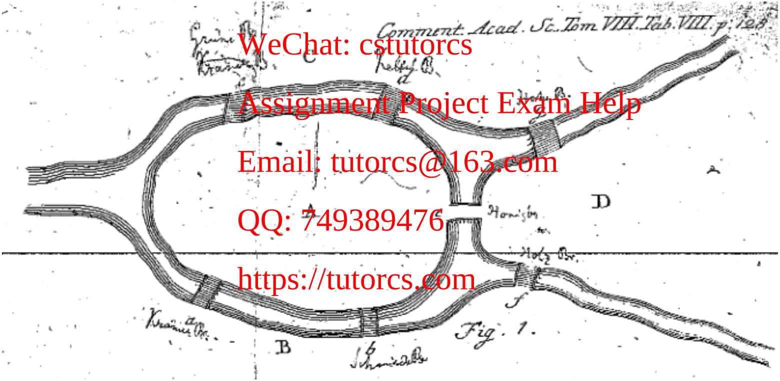
Australian National University

Week 4 ER Model



Housekeeping information

- Assignment 1 (SQL) [illegible] on Wattle, and the submission via Wattle is due 23:59, 30 Aug (T[illegible]ek 6)
  - **Individual, no [illegible]k!**
  - Do not post any idea/partial solution/result on Wattle.
  - Do not wait until the last minute to check/submit your solution.
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    - 18 Aug (Thu) 5-7 pm
    - 23 Aug (Tue) 5-7 pm
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- Welcome our class representatives: Alex Boxall, Daniel Herald, Devanshi Dhall, Naoibh McLoughlin, Wenxuan Zhang, Zhuxuan Yan.

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

- **What is a model?**

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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

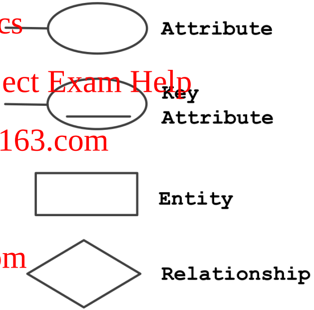
- **What does modeling do?**

  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 [illegible]6):
  - **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 [illegible]eep track of students' transcripts.

- The university keeps [illegible]ch student's name, student number, social security number, add[illegible]e, and birthdate. Both social security number and student [illegible]e 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).

Entities, Relationships and Attributes

- **Entities:** “Things” in the real world (with independent existence).
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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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Cardinality ratios: Every student has at most **one** major and a department may offer **many** majors (to different students)

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

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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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- **Entities:** course, department
- **Relationships:** offer (between **department** and **course**)

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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

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- **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**)

(Exercise 1) Consider the following data requirements for a university student database that is [illegible]eep track of students' transcripts.

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Constructing an ER or EER Model

- Identify the entities (i[illegible]eak entity types)

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- Identify the relationships

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  student, course, de[illegible]**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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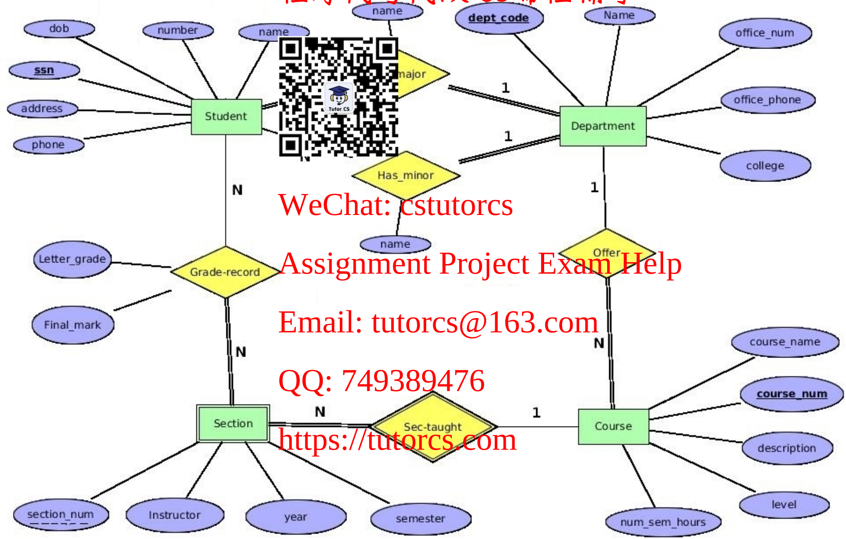
  - **offer** (between **department** and **course**)

  - **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


dob
number
name
ssn
address
phone
Student
name
major
dept_code
Name
office_num
office_phone
Department
college
1
1
Has_minor
name
N
1
Letter_grade
Grade-record
Final_mark
Offer
N
N
course_name
course_num
description
level
num_sem_hours
Course
Section
N
Sec-taught
1
section_num
Instructor
year
semester

Software tool to draw ER diagram

- We require students [illegible]cademic 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 sh[illegible] webstores on the Internet. Each local shop has a name, conta[illegible] (e.g., phone number and email), and a unique location. The da[illegible]plication 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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  - The company sells products in both local **shops** and **webstores** on the Internet.

  - Each **order** is associated with either a **shop** or a **webstore**.

Constructing an ER or EER Model

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  - subclass **shop**, **webstore**

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  - superclass **store**

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  - disjoint and complete

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  - disjoint and complete

- Identify the relationships

(Exercise 2) A retailer company wants to build a database application for managing information ab[illegible]e process. The company sells **products** in both local [illegible] **webstores** on the Internet. Each local **shop** has a name, conta[illegible] (e.g., phone number and email), and a unique location. The da[illegible]plication 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.

(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 s[illegible] **webstores** on the Internet. Each local **shop** has a name, conta[illegible] (e.g., phone number and email), and a unique location. The da[illegible]plication 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.

Constructing an ER or EER Model

- Identify the entities (including weak entity types)
  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**

Constructing an ER or EER Model

- Identify the entities (i[illegible]eak entity types)
  shop, **webstore**, **pr**[illegible]**omer**, **order**, **delivery**
- Identify subclass/superclass and the corresponding disjointness and completeness constraints
  - subclass **shop**, **webstore**
  - superclass **store**
- Identify the relationships
- Identify the attributes of entities and relationships and identify a primary key for each entity type

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  - Every **product** has a unique productID, a description, an item price, and a quantity in stock.

Constructing an ER or EER Model

- Identify the entities (i[illegible]eak entity types)
  shop, **webstore**, **pro**[illegible]**omer**, **order**, **delivery**
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  - subclass **shop**, **webstore**
  - superclass **store**
- Identify the relationships
- Identify the attributes of entities and relationships and identify a primary key for each entity type
  - Every **product** has a unique productID, a description, an item price, and a quantity in stock.
  - Attributes for **product**: **productID, description, item price, quantity**

Constructing an ER or EER Model

- Identify the entities (including weak entity types)
  shop, **webstore**, **product**, **customer**, **order**, **delivery**
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  - subclass **shop**, **webstore**
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  - Every **product** has a unique productID, a description, an item price, and a quantity in stock.
  - Attributes for **product**: **productID, description, item price, quantity**
  - Primary key for **product**: **productID**

Constructing an ER or EER Model

- Identify the entities (i… …eak entity types)
  shop, **webstore**, **pr… …omer**, **order**, **delivery**
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Constructing an ER or EER Model

- Identify the entities (including weak entity types)
  shop, **webstore**, **product**, **customer**, **order**, **delivery**
- Identify subclass/superclass and the corresponding disjointness and completeness constraints
  - subclass **shop**, **webstore**
  - superclass **store**
- Identify the relationships
- Identify the attributes of entities and relationships and identify a primary key for each entity type
  - The database application should also record **customers**' details such as their name, address and email. Every **customer** is assigned a unique ID.
  - Attributes for **customer**: **name, address, email, CustomerID**

Constructing an ER or EER Model

- Identify the entities (i[illegible]eak entity types)
  shop, **webstore**, **pr**[illegible]**omer**, **order**, **delivery**
- Identify subclass/superclass and the corresponding disjointness and completeness constraints
  - subclass **shop**, **webstore**
  - superclass **store**
- Identify the relationships
- Identify the attributes of entities and relationships and identify a primary key for each entity type
  - The database application should also record **customers**' details such as their name, address and email. Every **customer** is assigned a unique ID.
  - Attributes for **customer**: **name, address, email, CustomerID**
  - Primary key for **customer**: **CustomerID**

Constructing an ER or EER Model

- Identify the entities (i... ak entity types)
  shop, **webstore**, **pr**... **omer**, **order**, **delivery**
- Identify subclass/sup... the corresponding disjointness and completeness constraints
  - subclass **shop**, **webstore**
  - superclass **store**
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Constructing an ER or EER Model

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- Identify subclass/sup[illegible] the corresponding disjointness and completeness constraints
  - subclass **shop**, **webstore**
  - superclass **store**
- Identify the relationships
- Identify the attributes of entities and relationships and identify a primary key for each entity type
  - 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**.

Constructing an ER or EER Model

- Identify the entities (i[illegible]ak entity types)
  shop, **webstore**, **pr**[illegible]**omer**, **order**, **delivery**
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  - subclass **shop**, **webstore**
  - superclass **store**
- Identify the relationships
- Identify the attributes of entities and relationships and identify a primary key for each entity type
  - 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**.
  - Attributes for superclass **store**: **name**, **location**/**URL**

Constructing an ER or EER Model

- Identify the entities (i[illegible]ak entity types)
  shop, **webstore**, **pr**[illegible]**omer**, **order**, **delivery**
- Identify subclass/sup[illegible] the corresponding disjointness and completeness constraints
  - subclass **shop**, **webstore**
  - superclass **store**
- Identify the relationships
- Identify the attributes of entities and relationships and identify a primary key for each entity type
  - 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**.
  - Attributes for superclass **store**: **name**, **location/URL**
  - Primary key for superclass **store**: <u>**location/URL**</u>

Constructing an ER or EER Model

- Identify the entities (i[illegible]ak entity types)
  shop, **webstore**, **pr**[illegible]**omer**, **order**, **delivery**
- Identify subclass/sup[illegible] the corresponding disjointness and completeness constraints
  - subclass **shop**, **webstore**
  - superclass **store**
- Identify the relationships
- Identify the attributes of entities and relationships and identify a primary key for each entity type
  - 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**.
  - Attributes for superclass **store**: **name**, **location/URL**
  - Primary key for superclass **store**: **location/URL**
  - Attributes for subclass **shop**: **phone number, email**
  - Attributes for subclass **webstore**: **last updated date**

Constructing an ER or EER Model

- Identify the entities (i[illegible]eak entity types)
- Identify subclass/sup[illegible]
- 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 (i[illegible]eak entity types)
- Identify subclass/sup[illegible]
- 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

- Identify the entities (i[illegible]eak entity types)
- Identify subclass/sup[illegible]
- 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**
  - Cardinality ratios: A customer may **place** **many** orders and an order **is placed by** **one** customer.

Constructing an ER or EER Model

- Identify the entities (i[illegible]eak entity types)
- Identify subclass/sup[illegible]
- 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**
  - 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 (i... ...ak entity types)
- Identify subclass/sup...
- Identify the relationships
  - **delivery is for 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 (i… …ak entity types)
- Identify subclass/sup…
- Identify the relationships
  - **delivery** **is for** **order**
  - . . .
- Identify the attributes of entities and relationships
- Identify cardinality ratios and participation constraints on relationships
  - A **delivery** may be requested **for** each **order**.

Constructing an ER or EER Model

- Identify the entities (i[illegible]ak entity types)
- Identify subclass/sup[illegible]
- Identify the relationships
  - **delivery** **is for** **order**
  - . . .
- Identify the attributes of entities and relationships
- Identify cardinality ratios and participation constraints on relationships
  - 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.

Constructing an ER or EER Model

- Identify the entities (i… eak entity types)
- Identify subclass/sup…
- Identify the relationships
  - **delivery is for order**
  - . . .
- Identify the attributes of entities and relationships
- Identify cardinality ratios and participation constraints on relationships
  - 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 (i[illegible]eak entity types)
- Identify subclass/sup[illegible]
- 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 (i… eak entity types)
- Identify subclass/sup…
- 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**

Constructing an ER or EER Model

- Identify the entities (i[illegible]eak entity types)
- Identify subclass/sup[illegible]
- 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**
    - Cardinality ratios: An order may **contain** **many** products and an product may **be contained** in **many** orders.

Constructing an ER or EER Model

- Identify the entities (i[illegible]eak entity types)
- Identify subclass/sup[illegible]
- 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**
  - Cardinality ratios: An order may **contain** **many** products and an product may **be contained** in **many** orders.
  - Participation constraints: A **order** **must** **contain** some product (**Total**). A **product** **may or may not** **be contained** in an order (**Partial**).

Constructing an ER or EER Model

Constructing an ER or EER Model

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

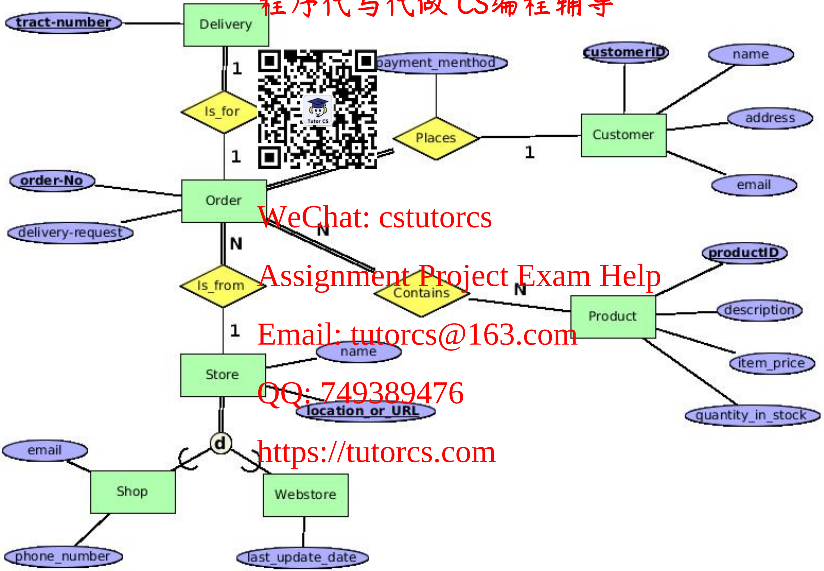
Constructing an ER or EER Model

Constructing an ER or EER model

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

- **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.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N
Is_from
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N
productID
description
Product
item_price
quantity_in_stock
1
Store
name
location or URL
d
email
Shop
phone_number
Webstore
last_update_date

Phase 3: Logical Design

- **Logical design** is th[illegible]f constructing a logical data model (e.g. relational or object-o[illegible]).
- 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 c[illegible]basic ER model into relations, and more steps for the EER m[illegible]

  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

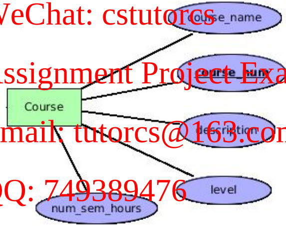
  Step 6: Mapping of Multi-valued Attributes

  Step 7: Mapping of N-ary Relationship Types

  Step 8: Mapping of Superclass/Subclass

Step 1: Regular Entity types

- For each regular enti[illegible] **reate a relation schema** with the attributes of *E* (ignore multi-val[illegible]es until Step 6), where
  - **PK:** the key att[illegible]



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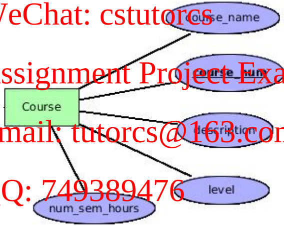
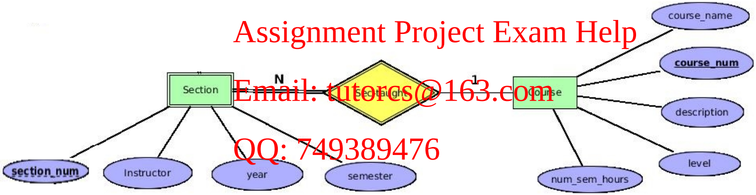


- COURSE(course_num, course_name, description, num_sem_hours, level) with PK: {course_num}
- **Note:** This is not necessarily the final relation schema of COURSE.

Step 2: Weak Entity Types

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



Step 2: Weak Entity Types

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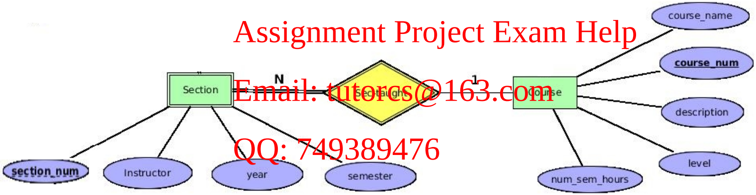
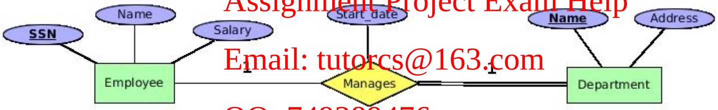


- SECTION(section_num, instructor, semester, year, course_num)
  with PK: {section_num, course_number}
  with FK: [course_num]⊆COURSE[course_num]

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

- For a 1:1 relationship … n one total participation, **extend the relation schema of** … **de entity type** by the attributes of *R* and the PK of the partial- … ype, where
  - **PK:** still the PK of the total-side entity type
  - **FK:** references the PK of the partial-side entity type



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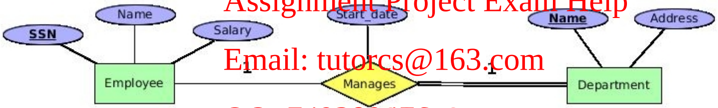
  - **FK:** references the PK of the partial-side entity type



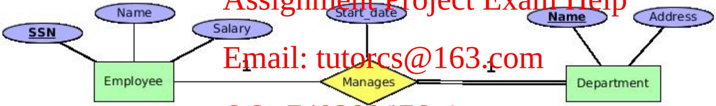
- DEPARTMENT(Name, Address, Mgr_SSN, Start_date) with

  PK: {Name}

  FK: [Mgr_SSN]⊆EMPLOYEE[SSN].

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
  - **FK:** references the PK of the partial-side entity type



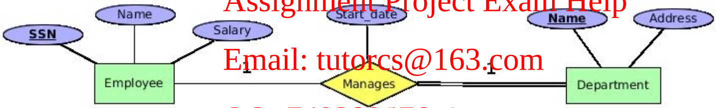
- DEPARTMENT(Name, Address, **Mgr_SSN, Start_date**) with

  PK: {Name}

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

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

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



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

  PK: {Name}

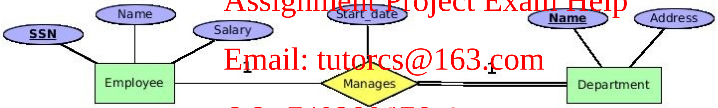
  FK: [Mgr_SSN]$\subseteq$EMPLOYEE[SSN].

- 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)

- For a 1:1 relationship [illegible] one total participation, **extend the relation schema of [illegible]de entity type** by the attributes of *R* and the PK of the partial-[illegible]ype, where
  - **PK:** still the PK of the total-side entity type
  - **FK:** references the PK of the partial-side entity type



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

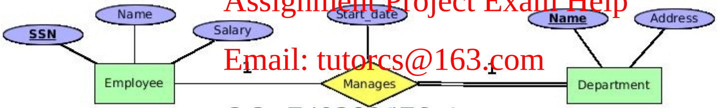
  PK: {Name}

  FK: [Mgr_SSN]⊆EMPLOYEE[SSN].

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

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

- For a 1:1 relationship [illegible] one total participation, **extend the relation schema of** [illegible] **de entity type** by the attributes of *R* and the PK of the partial-[illegible] ype, where
  - **PK:** still the PK of the total-side entity type
  - **FK:** references the PK of the partial-side entity type



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

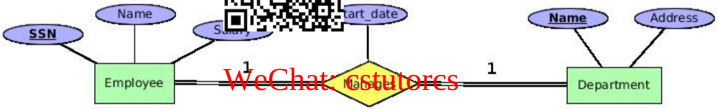
  PK: {Name}

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

  This may cause many `NULL` values.

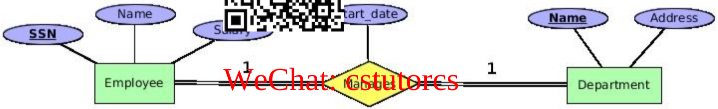
Step 3: Binary 1:1 Relationship Types - (Merged relation)

- How can we translate … ng kind of 1:1 relationship type?



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

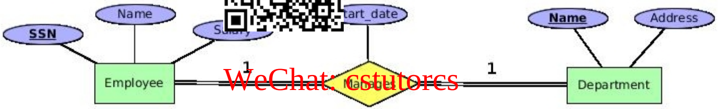
- How can we translate the following kind of 1:1 relationship type?



- 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**.
- EMPLOYEE-DEP(SSN, Name, Salary, Start_date, Dname, Address) with PK: {SSN} or {Dname}

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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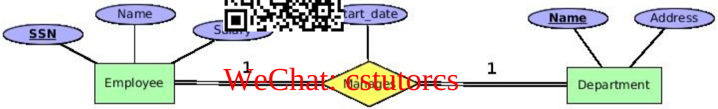

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  Add `NOT NULL` constraint to both SSN and Dname for total participations.

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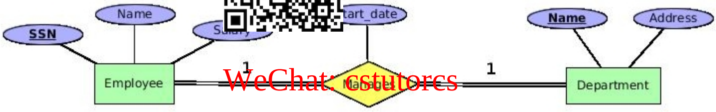

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- **Is merging them always a good solution?**

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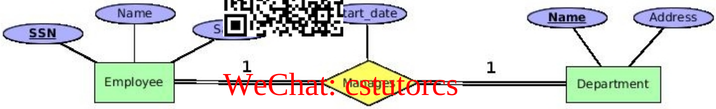

- If participation on both sides is total, we may **merge the relation schemas of both entity types and the attributes of the relationship type into a single relation**.

- However, **merging them is not always a good solution**. Why?

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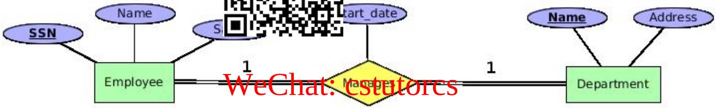

- If participation on both sides is total, we may **merge the relation schemas of both entity types and the attributes of the relationship type into a single relation**.

- 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 [illegible]ng kind of 1:1 relationship type?

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

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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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- MANAGES(SSN, Dname, Start_date) with

  PK: {SSN} or {Dname}

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

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- 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 relation , **extend the relation schema of the N-side entity type** b tes of *R* and the PK of the 1-side entity type, where
  - **PK:** still the PK of the N-side entity type
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  - **PK:** still the PK of the N-side entity type
  - **FK:** references the PK of the 1-side entity type

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

  PK: {SSN}

  FK: [major_dept]⊆DEPARTMENT[dept_code]

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)

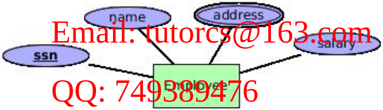
  PK: {ssn, section_num, course_num}

  FK: [ssn] $\subseteq$ STUDENT[ssn]

  FK: [section_num, course_num] $\subseteq$ SECTION[section_num, course_num].

Step 6: Multi-valued Attributes

- For each multi-value… , **create a relation schema** with an attribute correspondi… the PK of the entity/relationship type that has *A* as an attribute…
  - **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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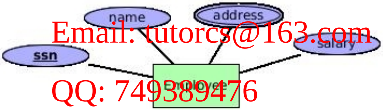

- EMPLOYEE_ADDRESS(SSN, Address) with

  PK: {SSN, Address}

  FK: [SSN]⊆EMPLOYEE[SSN]

ER-to-Relations Algorithm (Recall)

- The algorithm to first [illegible] basic ER model into relations, and then convert superclass/s[illegible]m 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

Revisit Subqueries – Use LEFT/RIGHT JOIN?

- List all students' IDs who are under-enrolled ($<$ 4 courses) in Semester 2 2016.

```
SELECT s.StudentID, s.Name
FROM (SELECT e.StudentID, COUNT(*) AS NoOfEnrols
      FROM ENROL e
      WHERE e.Semester = '2016 S2'
      GROUP BY e.StudentID) ne RIGHT JOIN STUDENT s
ON (s.StudentID = ne.StudentID) AND (ne.NoOfEnrols < 4);
```

```
WITH StudEnrols AS (
      SELECT e.StudentID, COUNT(*) AS NoOfEnrols
      FROM ENROL e
      WHERE e.Semester = '2016 S2'
      GROUP BY e.StudentID)
SELECT s.StudentID, s.Name
FROM STUDENT s LEFT JOIN StudEnrols ne
ON (s.StudentID = ne.StudentID) AND (ne.NoOfEnrols < 4);
```

Subqueries – Using LEFT/RIGHT JOIN Is Still Incorrect!

- List all students' IDs who are under-enrolled (< 4 courses) in Semester 2 2016.

ENROL

StudentID	CourseNo	Semester
111	BUSN2011	2016 S2
111	COMP1100	2016 S2
111	COMP2400	2016 S2
111	ECON2102	2016 S2
222	BUSN2011	2016 S2
222	COMP2400	2016 S2
333	BUSN2011	2016 S2
333	COMP2400	2016 S2
333	ECON2102	2016 S2

Result (still incorrect?):

StudentID	Name
111	Tom
222	Emily
333	John
444	Ana

STUDENT

StudentID	Name
111	Tom
222	Emily
333	John
444	Ana

- The reason why "111, Tom" is incorrectly included in the final result is due to "Query Processing and Optimisation", which will be discussed in Week 8.

Subqueries – Use Set Operations

- List all students' IDs who are under-enrolled (< 4 courses) in Semester 2 2016.

  The set of all students EXCEPT the set of students enrolled in at least 4 courses in Semester 2 2016.


```
SELECT s.StudentID, s.Name
FROM (SELECT StudentID
      FROM Student
      EXCEPT
      SELECT e.StudentID
      FROM Enrol e
      WHERE e.Semester = '2016 S2'
      GROUP BY e.StudentID
      HAVING COUNT(*) > 3) e4 INNER JOIN Student s
ON (e4.StudentID = s.StudentID);
```

Subqueries – Using Set Operations Works.

- List all students' IDs who are under-enrolled (< 4 courses) in Semester 2 2016.

ENROL

StudentID	CourseNo	Semester
111	BUSN2011	2016 S2
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Result:

StudentID	Name
222	Emily
333	John
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STUDENT

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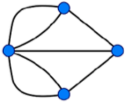
(Credit Cookie) Graph Model and ER Diagram

Carl Gottlieb Ehler
(1685-1753)



Seven Bridges of Königsberg

Euler
(1707-1783)

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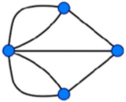

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The Entity-Relationship Model—Toward a Unified View of Data

PETER PIN-SHAN CHEN
Massachusetts Institute of Technology

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