

Data Management

02 Conceptual Design

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Announcements/Org

#1 Video Recording

- Link in **TeachCenter** & **TUbe** (lectures will be public)
- Currently via <https://tugraz.webex.com/meet/m.boehm>



#2 Course Registrations SS21

- Data Management (lectures/exercises): **513/494**
- Databases (combined lectures/exercises): **49**

Total:
562

#3 Exercise 1 Published

- Task description published last night (discussed today)
- Deadline: **Mar 30** in TeachCenter

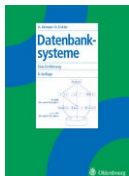
#4 Study Abroad Fair 2021

- Welcome Center: Study Abroad Fair 2021, **Mar 17, 10am**
- <https://tu4u.tugraz.at/go/study-abroad-fair-2021>



Agenda

- **DB Design Lifecycle**
- **ER Model and Diagrams**
- **Exercise 01 – Data Modeling**



[**Credit:** Alfons Kemper, André Eickler: Datenbanksysteme - Eine Einführung, 10. Auflage. De Gruyter Studium, de Gruyter Oldenbourg 2015, ISBN 978-3-11-044375-2, pp. 1-879]

DB Design Lifecycle

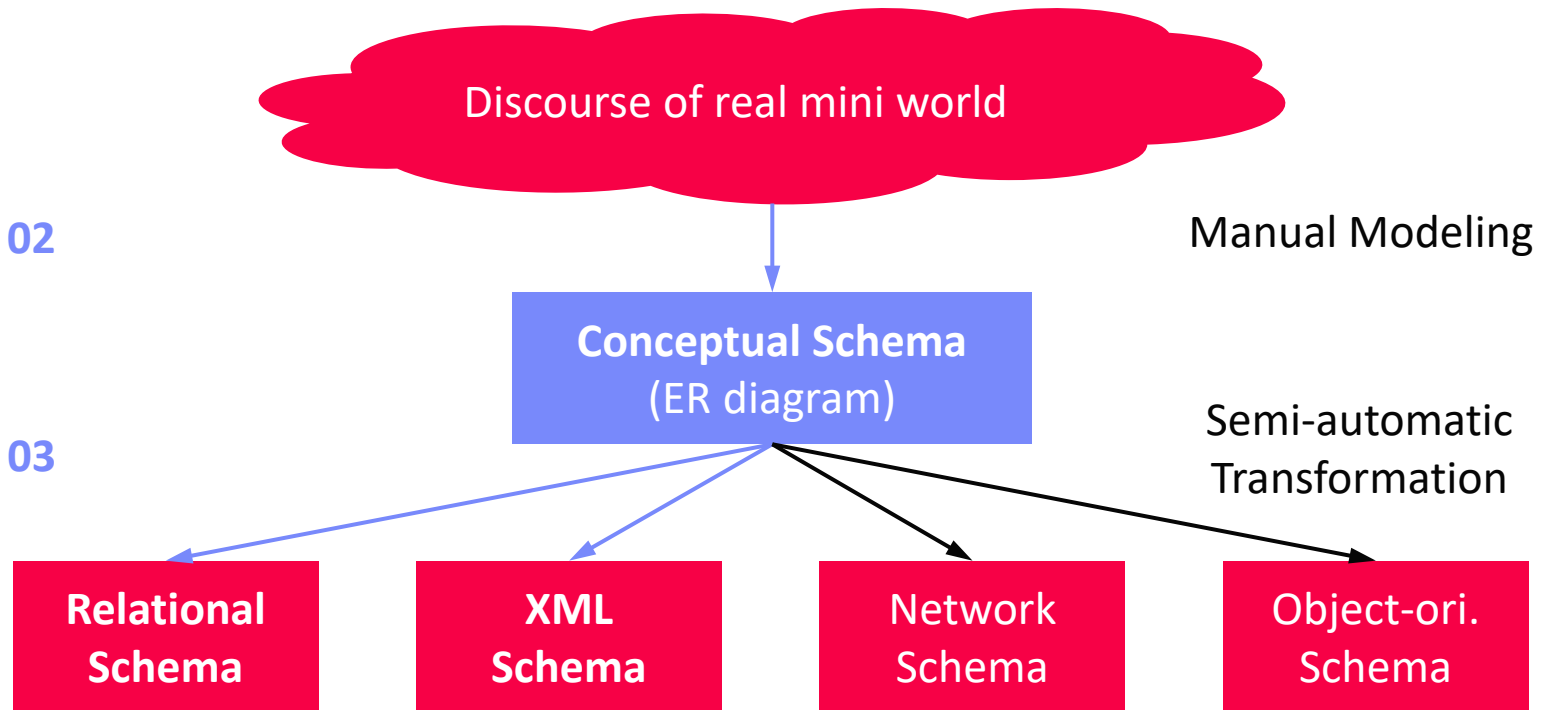
Data Modeling

■ Data Model

- Concepts for describing data objects and their relationships (meta model)
- **Schema:** Description (structure, semantics) of specific data collection

Lecture 02

Lecture 03



Data Models

- **Conceptual Data Models**

- **Entity-Relationship Model (ERM)**, focus on data, ~1975
- Unified Modeling Language (UML), focus on data and behavior, ~1990

- **Logical Data Models**

- **Relational** (Object/Relational)

- Key-Value
- Document (XML, JSON)
- Graph
- Time Series
- Matrix/Tensor

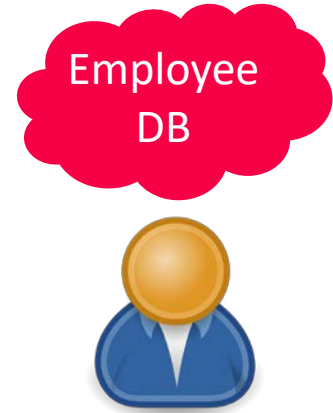
**Partly covered
in part B**

- Object-oriented
- Network
- Hierarchical

Mostly obsolete

DB Design Lifecycle Phases

- **#1 Requirements engineering**
 - Collect and analyze data and application requirements
 - ➔ **Specification documents**
- **#2 Conceptual Design** (lecture 02, exercise 1)
 - Model data semantics and structure, independent of logical data model
 - ➔ **ER model / diagram**
- **#3 Logical Design** (lecture 03, exercise 1)
 - Model data with implementation primitives of concrete data model
 - ➔ **e.g., relational schema** + integrity constraints, views, permissions, etc
- **#4 Physical Design** (lecture 07, exercise 3)
 - Model **user-level data organization** in a specific DBMS (and data model)
 - Account for deployment environment and performance requirements



Relevance in Practice

■ Analogy ERM-UML

- **Model-driven development** (self-documenting, but quickly outdated)
- **But:** Once data is loaded, data model and schema harder to change

■ **Observation: Full-fledged ER modeling rarely used in practice**

- Often the logical schema (relational schema) is directly created, maintained and used for documentation
- **Reasons:** redundancy, indirection, single target (relational)
- Simplified ER modeling used for brainstorming and early ideas

■ Goals

- **Understanding of proper database design** from conceptual to physical schema
- ER modeling as a helpful **tool in database design**
- Schema transformation and normalization as blueprint for **good designs**

Tool Support

■ #1 Visual Design Tools

- Draw ER diagrams in any presentation software (e.g., MS PowerPoint, LibreOffice)
- Many desktop or web-based tools support ER diagrams directly (e.g., MS Visio, creately.com)

■ #2 Design Tools w/ Code Generation

- Draw and validate ER diagrams
- Generate relational schemas as SQL DDL scripts
- **Examples:** SAP (Sybase) PowerDesigner, MS Visual Studio plugins (SQL server), etc.

➔ **Note:** For the exercises, please use basic drawing tools (existing tools use slightly diverging notations)

Entity-Relationship (ER) Model and Diagrams



[Peter P. Chen: The Entity-Relationship Model - Toward a Unified View of Data. **ACM Trans. Database Syst.** 1(1) 1976]

[Peter P. Chen: The Entity-Relationship Model: Toward a Unified View of Data. **VLDB 1975]**



ER Diagram Components (Chen Notation)

Entity Type (noun)

- Entities are objects of the real world
- An entity type (or **entity set**) represents a collection of entities



Weak entities



Relationship Type (verb)

- Relationships are concrete associations of entities
- Relationship type (or **relationship set**) or relationship of entity types



$$works \subseteq A \times B$$

Attribute

- Entities or relationships are characterized by attribute-value pairs
- Attribute types (or value sets) describe entity and relationship types
- Extended attributes: composite, multi-valued, derived



Multi-valued attributes



ER Diagram Components (Chen Notation), cont.

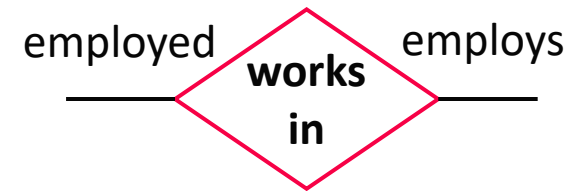
■ Keys

- Attributes that uniquely identify an entity
- Every entity type must have such a key
- Natural or surrogate (artificial) keys



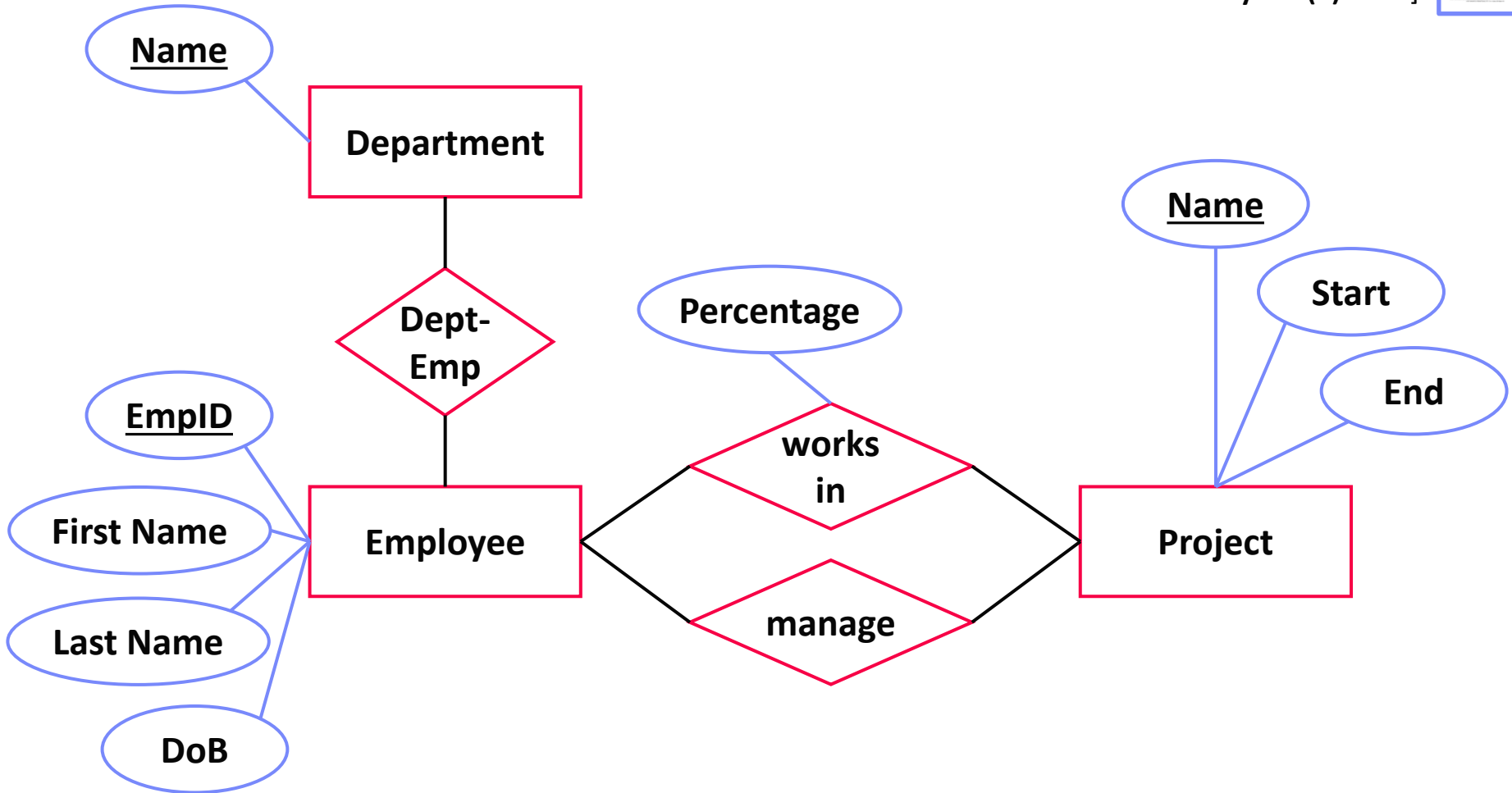
■ Role

- Optional description of relationship types
- Useful for recursive relationships



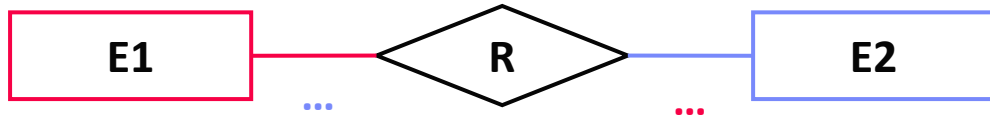
An EmployeeDB Example

[Peter P. Chen: The Entity-Relationship Model - Toward a Unified View of Data. *ACM Trans. Database Syst.* 1(1) 1976]



Multiplicity/Cardinality in Chen Notation

1 .. [0,1]
N ... [0,1,N]



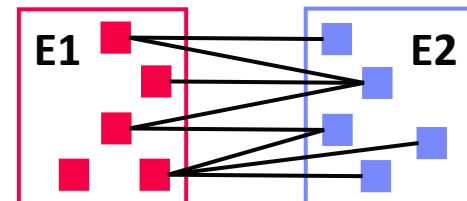
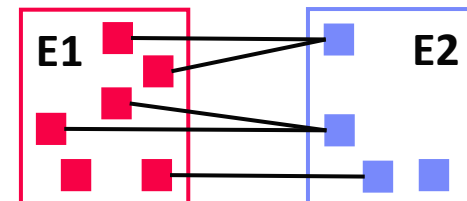
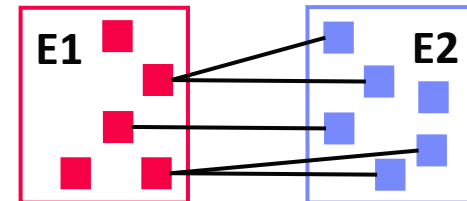
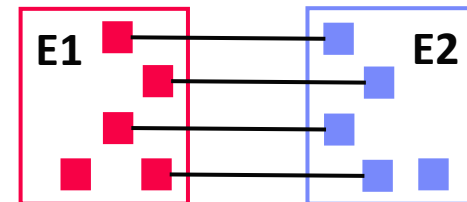
$$R \subseteq E1 \times E2$$

- **1:1 (one-to-one)** ← →
 - Each e1 relates to at most one e2
 - Each e2 relates to at most one e1

- **1:N (one-to-many)** ←
 - Each e1 relates to many e2 (0,1,...N)
 - Each e2 relates to at most one e1

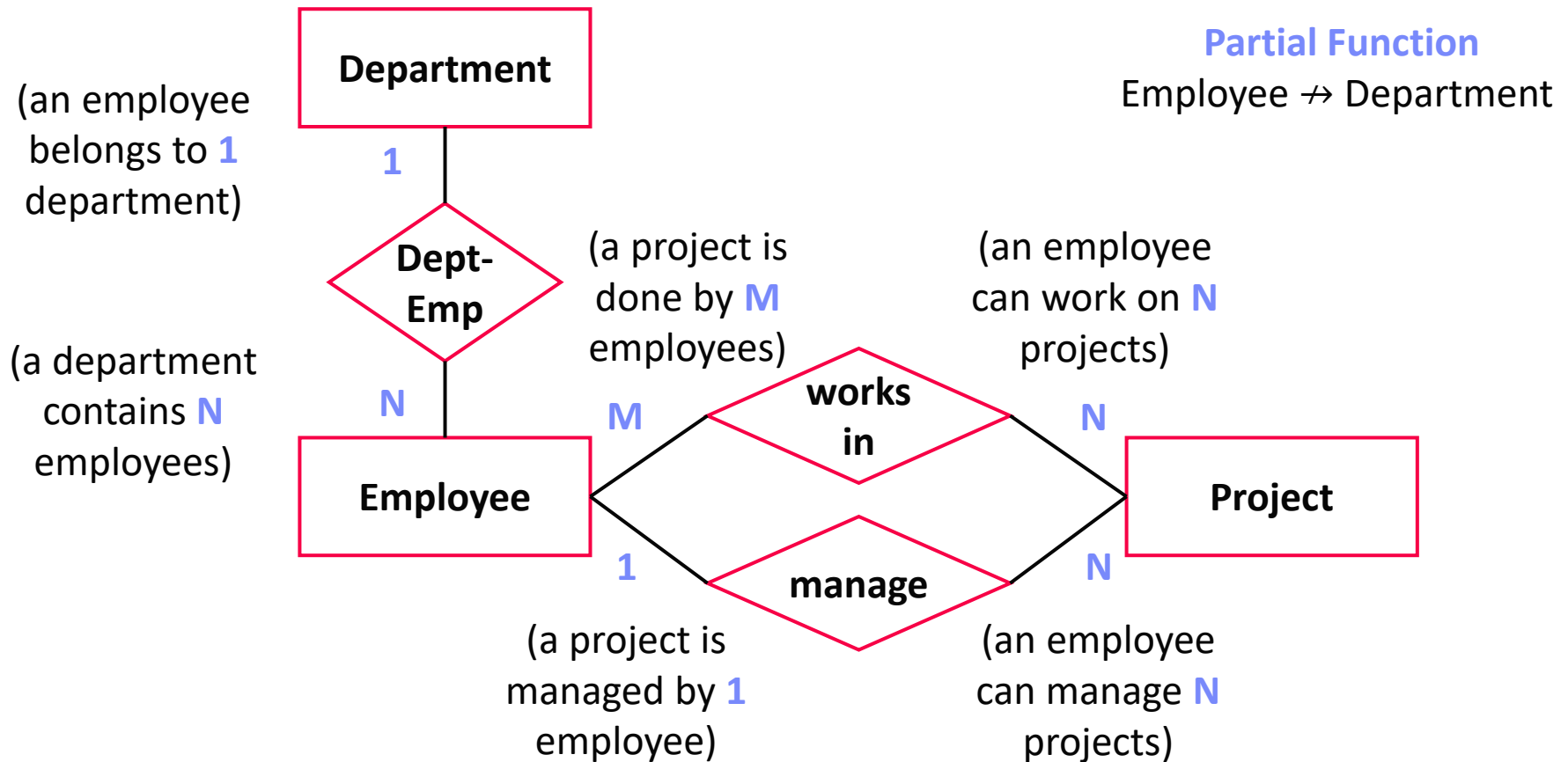
- **N:1 (many-to-one)** →
 - Symmetric to 1:N

- **N:M (many-to-many)**
 - Each e1 relates to many e2 (0,1,...M)
 - Each e2 related to many e1 (0,1,...N)



An EmployeeDB Example, cont.

[Peter P. Chen: The Entity-Relationship Model - Toward a Unified View of Data. ACM Trans. Database Syst. 1(1) 1976]



Multiplicity in Modified Chen Notation

- **Extension:** C (“choice”/“can”) to model 0 or 1, while 1 means exactly 1 and M means at least 1.

4 alternatives (1, C, M, MC)

→ 4*4 = 16 combinations

(symmetric combinations omitted)

- **1:1** – [1] to [1]

- **1:C** – [1] to [0 or 1]

- **1:M** – [1] to [at least 1]

- **1:MC** – [1] to [arbitrary many]

1	1	1	1
0	1	1	1
0	0	1	1
0	0	0	1

$$\frac{n \cdot (n + 1)}{2}$$

- **C:C** – [0 or 1] to [0 or 1] → see **1:1 in Chen**

- **C:M** – [0 or 1] to [at least 1]

- **C:MC** – [0 or 1] to [arbitrary many] → see **1:N in Chen**

- **M:M** – [at least 1] to [at least 1]

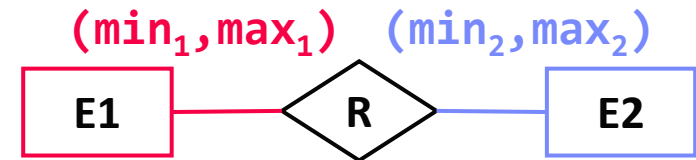
- **M:MC** – [at least 1] to [arbitrary many]

- **MC:MC** – [arbitrary many] to [arbitrary many] → see **M:N in Chen**

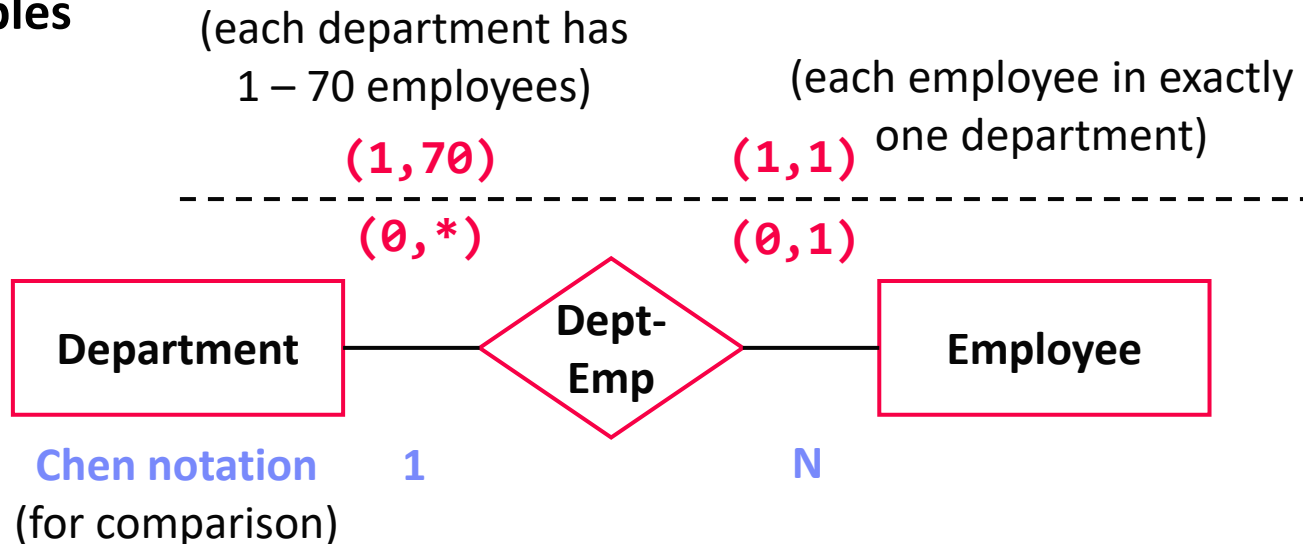
(min,max)-Notation

Alternative Cardinality Notation

- Indicate concrete min/max constraints (each entity is part of at least/at most x relationships)
- Chen and (min,max) notation generally incomparable
- Wildcard *** indicates arbitrary many (i.e., N)



Examples

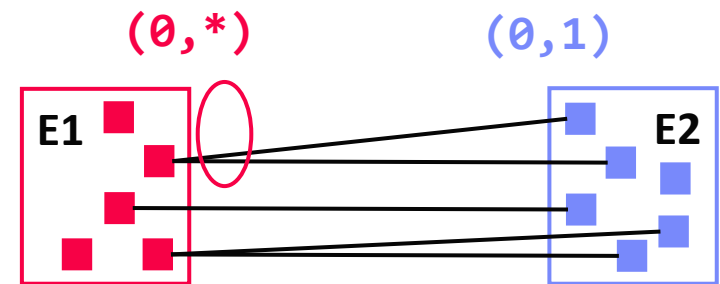


(min,max)-Notation, cont.

- **Problem:** Where do these conflicting notations come from?

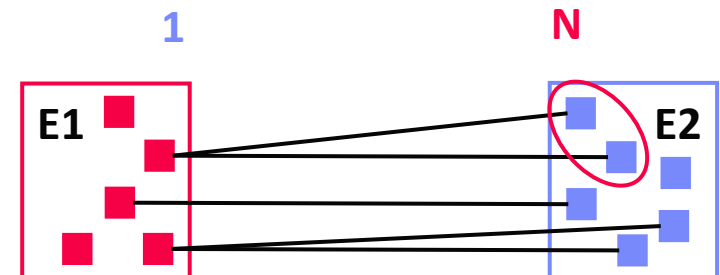
- **Understanding (min, max)-Notation**

- **Focus on relationships!**
- Describes number of outgoing relationships for each entity



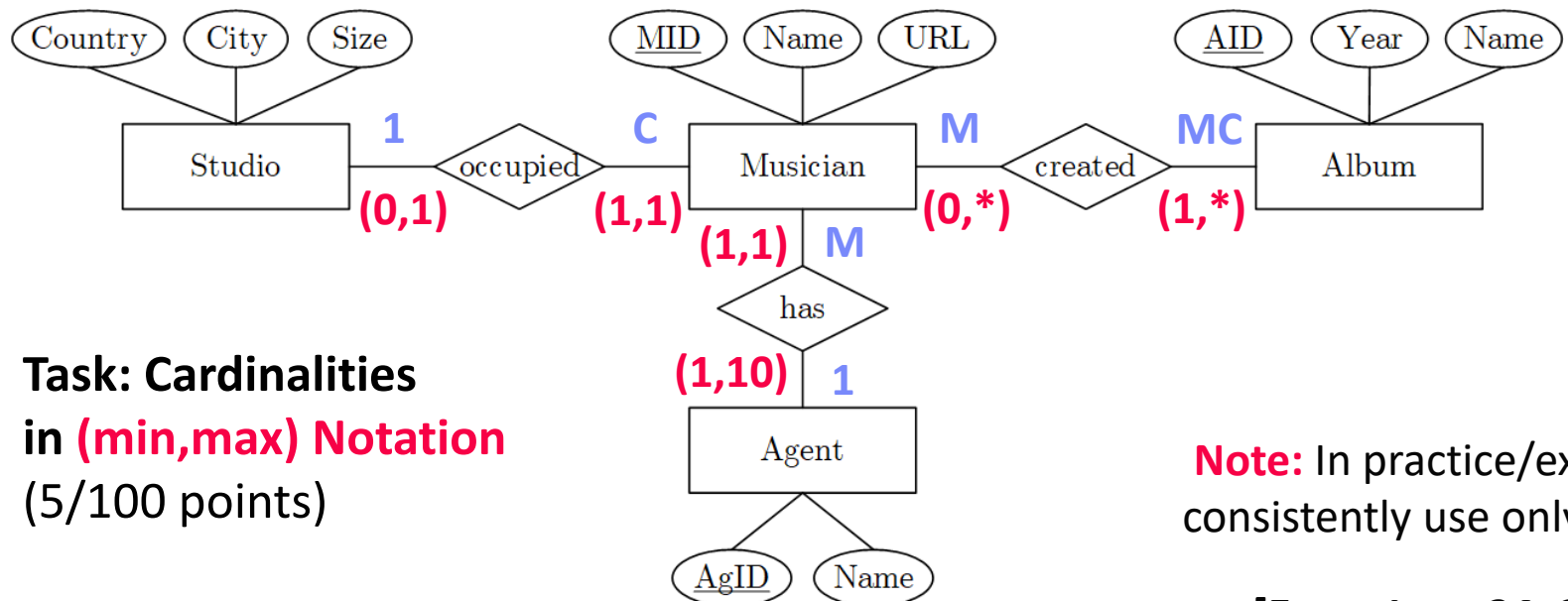
- **Understanding Chen- / Modified-Chen-Notation**

- **Focus on entities!**
- Describes number of target entities (over relationships) for each entity



BREAK (and Test Yourself)

- Task: Cardinalities in Modified-Chen Notation** (prev. exam 6/100 points)
 - A musician might have created none or arbitrary many albums, and any album is created by at least one musician.
 - Every musician has exactly one agent, and an agent might be responsible for one to ten musicians.
 - Every musician occupies exactly one studio, and musicians never share a studio.



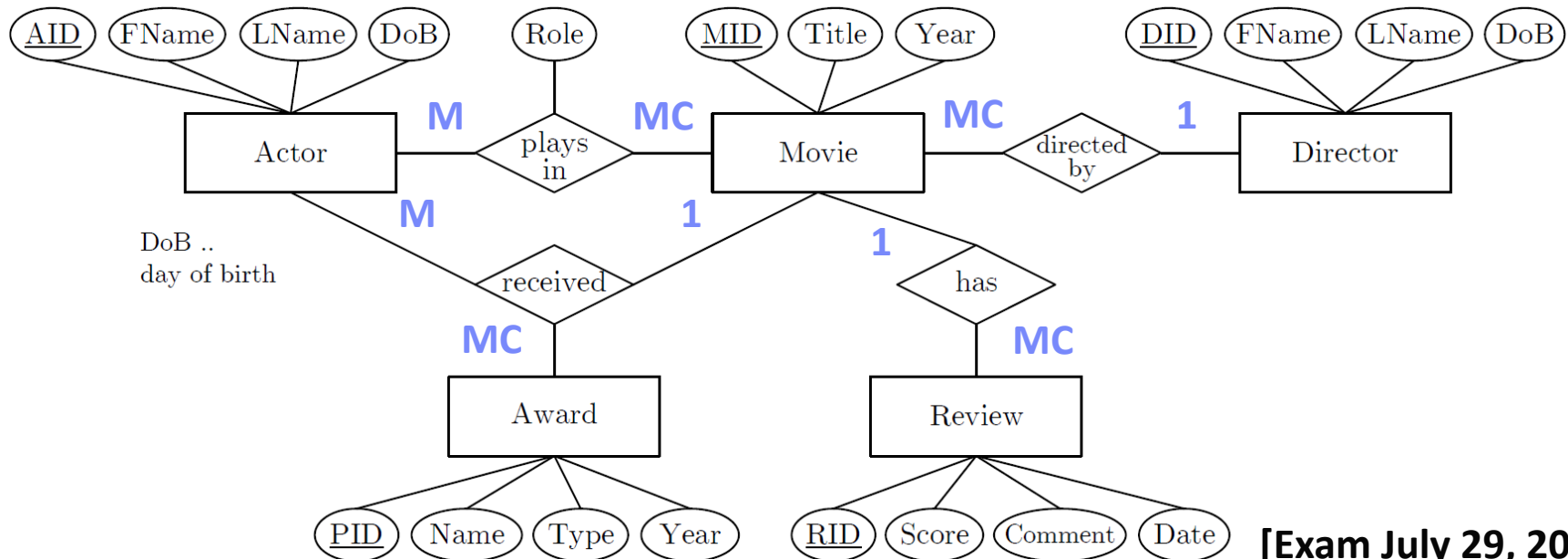
- Task: Cardinalities in (min,max) Notation** (5/100 points)

Note: In practice/exams, consistently use only one

[Exam June 24, 2019]

BREAK (and Test Yourself), cont.

- Task: Cardinalities in Modified-Chen Notation** (prev. exam 9/100 points)
 - An actor may play roles in an arbitrary number of movies (incl. none), every movie has a cast of at least one but potentially many actors
 - A movie is directed by 1 director, directors produce arbitrary many movies
 - A movie review refers to 1 movie, but there can be 0-many reviews per movie
 - Actors (incl a single actor) may receive multiple awards for a single movie. An actor can receive only 1 per movie. Awards to 1-many actors are possible.



Weak Entity Types

Existence Dependencies

- Entities **E2** whose existence depends on the other entities **E1**
- Visualized as a special rectangle with double border
- Primary key is contains primary key of **E1**
- Relationship between strong and weak entity types **1:N** (sometimes **1:1**)

Examples

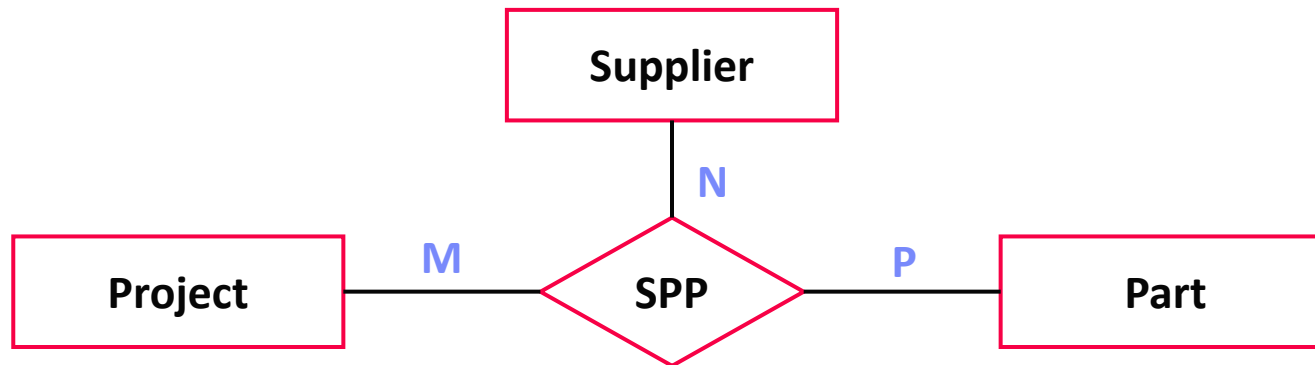
- Dependents of an employee (spouse, children)
- Rooms of a building



N-ary Relationships

■ Use of n-ary relationships

- Relationship type among multiple entity types
- N-ary relationship can be converted to binary relationships
- Design choice: **simplicity** and **consistency constraints**



■ Multiplicity

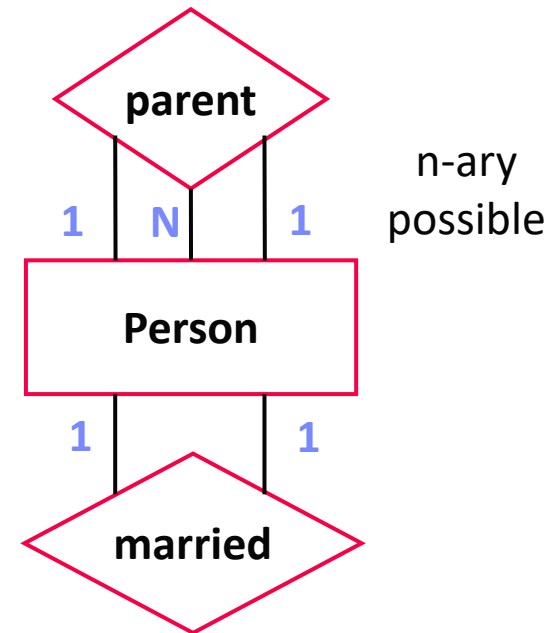
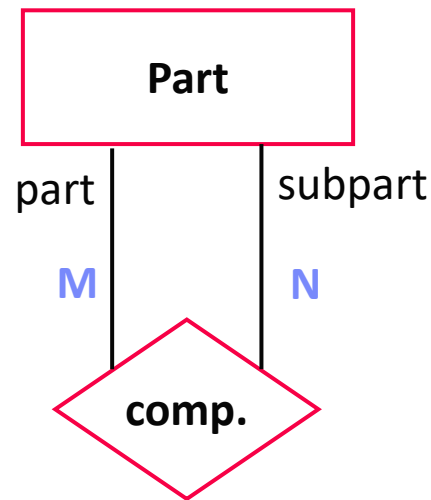
- 1 Project and 1 Supplier → supply **P** parts
- 1 Project and 1 Part → supplied by **N** suppliers (**1 instead of N?**)
- 1 Supplier and 1 Part → supply for **M** projects

Recursive Relationships

Definition

- Recursive relationships are relations between entities of the same type
- Use roles to differentiate cardinalities

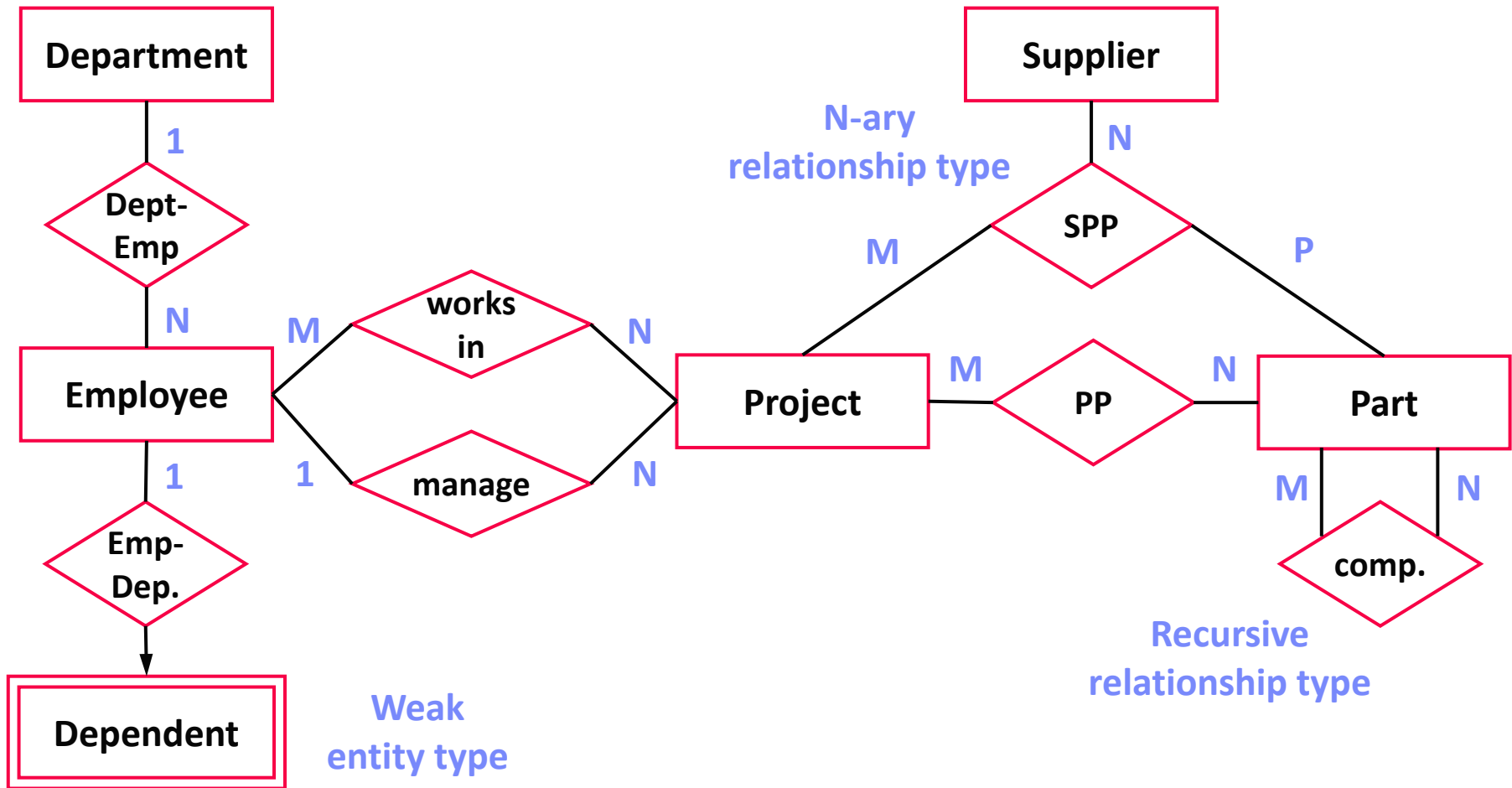
Examples



- Beware of [at least 1] constraints in recursive relationships** (e.g., (min,max)-notation, or MC notation)

An EmployeeDB Example, cont.

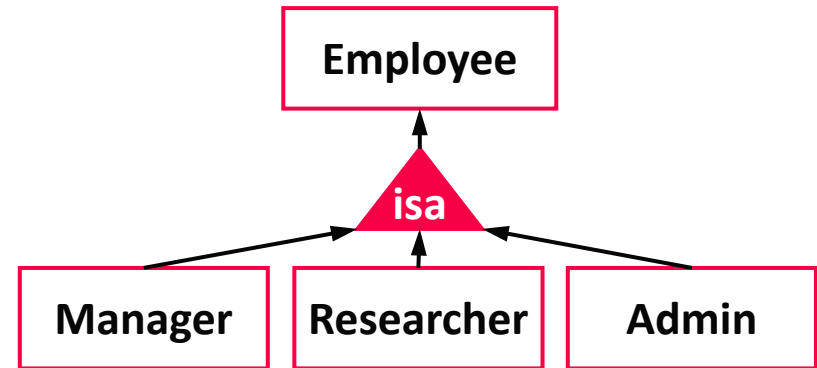
[Peter P. Chen: The Entity-Relationship Model - Toward a Unified View of Data. ACM Trans. Database Syst. 1(1) 1976]



Specialization and Aggregation

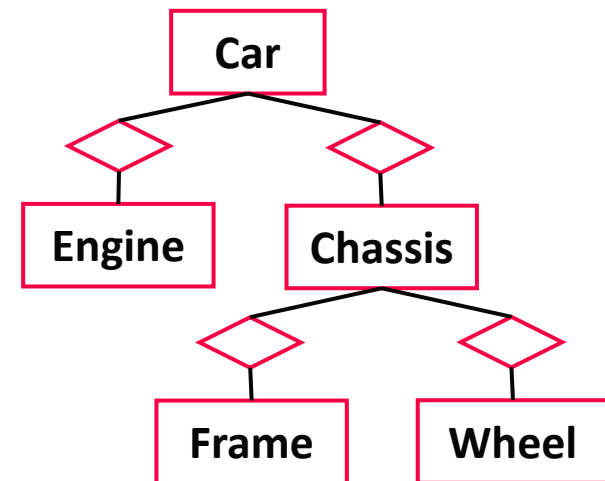
Specialization via Subclasses

- **Tree of specialized entity types** (no multi-inheritance)
- Graphical symbol: triangle (or hexagon, or subset)
- Each entity of subclass is entity of superclass, but not vice versa



Aggregation (composition, not specialization)

- **#1: Recursive relationship types**, or
- **#2: Explicit tree of entity** and relationship types
- Design choice: number of types known and finite, and heterogeneous attributes

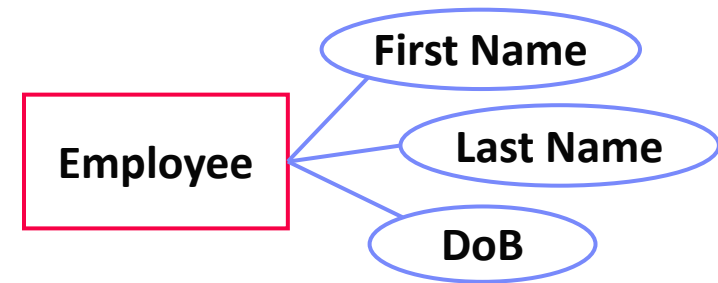


Beware: **Simplicity is key**

Types of Attributes

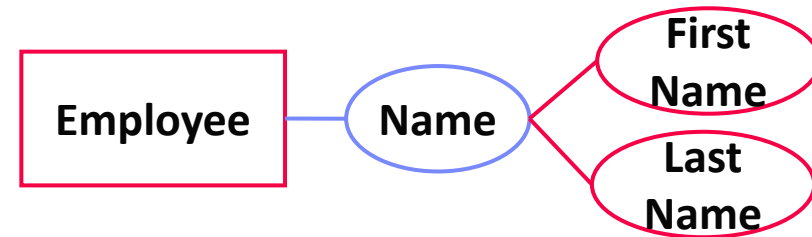
Atomic Attributes

- Basic, single-valued attributes



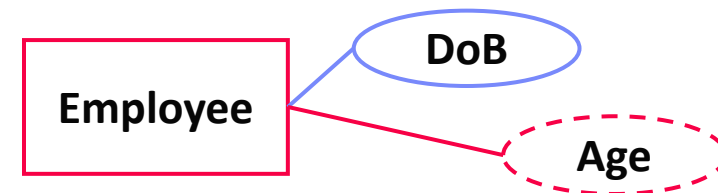
Composite Attributes

- Attributes as structured data types
- Can be represented as a hierarchy



Derived Attributes

- Attributes derived from other data
- Examples: Number of employees in dep, employee age, employee yearly salary



Multi-valued Attributes

- Attributes with list of homogeneous entries






Excursus: Influence of Chinese Characters?



“What does the Chinese character construction principles have to do with ER modeling? The answer is: both Chinese characters and the ER model are trying to model the world – trying to use graphics to represent the entities in the real world. [...]”

[Peter Pin-Shan Chen: Entity-Relationship Modeling: Historical Events, Future Trends, and Lessons Learned. **Software Pioneers 2002**]

- Chinese characters representing real-world entities

<u>Original Form</u>	<u>Current Form</u>	<u>Meaning</u>
	日	Sun
	月	Moon
	人	Person

- Composition of two Chinese characters

日 (sun) + 月 (moon) = 明 (Bright/ Brightness by light)

Design Decisions

Avoid redundancy
 Avoid unnecessary complexity

■ Meta-Level:

- Which notations to use (Chen, Modified Chen, (min,max)-notation)?

■ Entities

- What are the entity types (entity vs relationship vs attribute)?
- What are the attributes of each entity type?
- What are key attributes (one or many)?
- What are weak entities (with partial keys)?

■ Relationships

- What are the relationship types between entities (binary, n-ary)?
- What are the attributes of each relationship type?
- What are the cardinalities?

■ Attributes

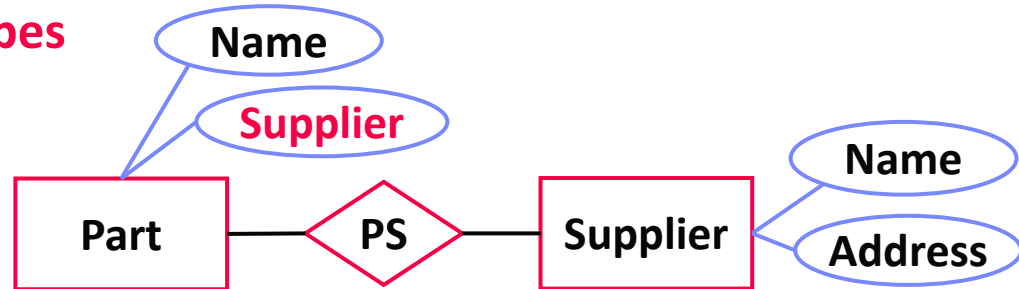
- What are composite, multi-valued, or derived attributes?

Design Decisions – Examples of **Poor** Choices

- #1 Overuse of **weak entity types**

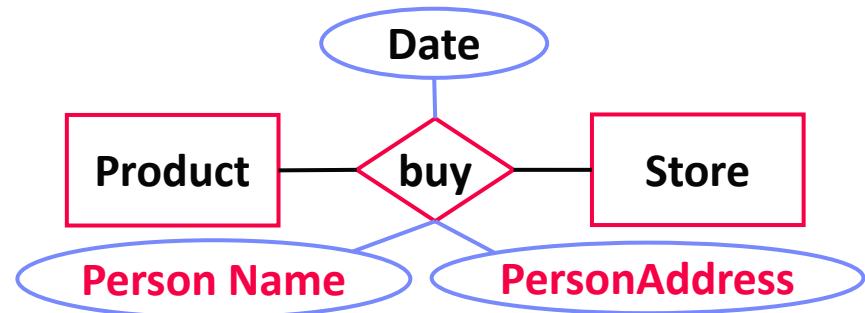
- #2 Redundant attributes

- Redundant supplier name in Part and Supplier



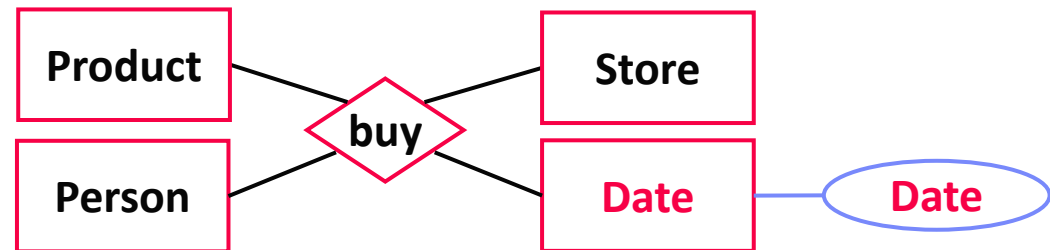
- #3 Repeated information

- Missing person entity type → redundancy per purchase



- #4 Unnecessary Complexity

- Unnecessary entity type **Date**
- Avoid single-attribute entity types unless in many relationships



A UniversityDB Example

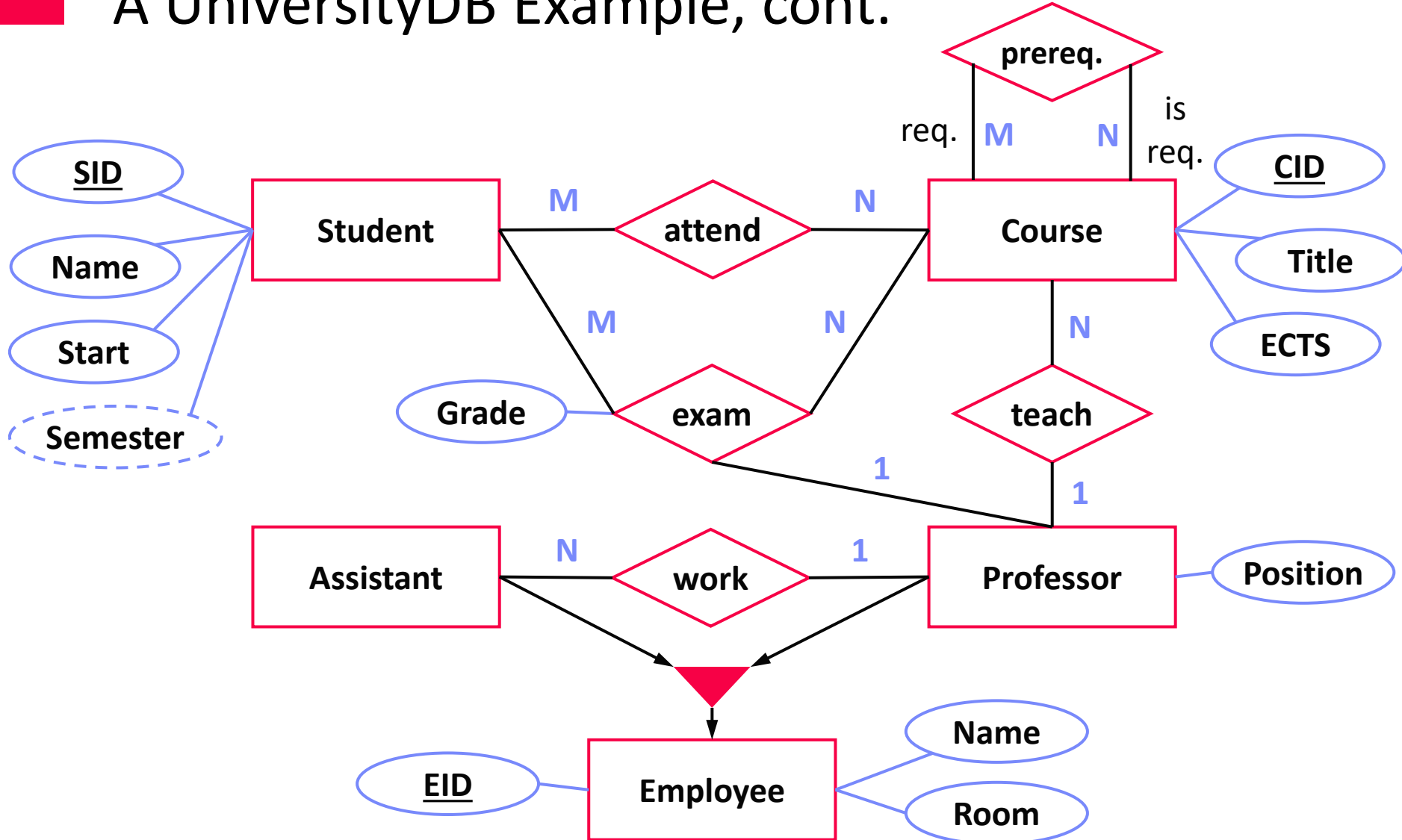
▪ Discourse of Real Mini World

- **Students** (with SID, name, and semester) attend **courses** (CID, title, ECTS), and take graded exams per course
- **Professors** teach courses and have positions, **assistants** work for professors
- A course may have another course as prerequisites
- Both professors and assistants are university **employees** (EID, name, and room number); professors also have a position

▪ Task: **Create an ER diagram in Chen notation**

- Include entity types, relationship types, attributes, and generalizations
- Mark primary keys, roles for recursive relationships, and derived attributes

A UniversityDB Example, cont.



Exercise 01 – Data Modeling

Published: **Mar 07, 2021**

Deadline: **Mar 30, 2021**

Exercises: Summer Olympics

■ Dataset

- Past Summer Olympics (games, teams, athletes, events, medals)
- Clone or download your copy from <https://github.com/tugraz-isds/datasets.git> (summer_olympics)
- **Note: Still in process of data extraction/cleaning**



■ Exercises

- **01** Data modeling (relational schema)
- **02** Data ingestion and SQL query processing
- **03** Physical design tuning, query processing, and transaction processing
- **04** Large-scale data analysis (distributed query processing and ML model training)

Overview Exercise 1 Tasks

[https://mboehm7.github.io/teaching/ss21_dbs/01_ExerciseModeling.pdf]

- **Task 1.1: ER Modeling (15/25)**
 - Summer Olympics: games, teams, athletes, events, medals
 - Create an ER diagram in Modified Chen (MC) notation
 - Partial Result: ERDiagram.pdf
- **Task 1.2: Mapping ER Diagram into Relational Model (10/25)**
 - Create a relational schema in 3NF for the ER diagram from Task 1.1
 - a) text-based schema, **OR** b) SQL DDL script
 - Partial Result: Schema.txt or CreateSchema.sql
- **Expected result (for all three subtasks)**
 - **DBExercise01_<studentID>.zip**



**Don't get your own
studentID wrong**

Summary and Q&A

■ Summary

- DB Design lifecycle from requirements to physical design
- Entity-Relationship (ER) Model and Diagrams

■ Importance of Good Database Design

- Poor database design → **development and maintenance costs**, as well as performance problems
- Once data is loaded, **schema changes very difficult** (data model, or conceptual and logical schema)

■ Exercise 1: Data Modeling

- Published Mar 07, 2021; deadline: Mar 30, 2021
- **Recommendation:** start with task 1.1 this week; ask questions in upcoming lectures or on news group

■ Next lecture: **03 Data Models and Normalization** [Mar 15]