Database Design

Immanuel Trummer
itrummer@cornell.edu
www.itrummer.org

Database Design Process

- **Requirement analysis**
  - Based on use cases, business process descriptions
- **Conceptual design**
  - Model what the DB is about, e.g. via ER diagrams
- **Schema normalization**
  - E.g., reduce data redundancy via transformation
- **Physical tuning**
  - E.g., decide which indices to create or sort order

Database Design Process

- **Requirement analysis**
  - Based on use cases, business process descriptions
- **Conceptual design**
  - Model what the DB is about, e.g. via ER diagrams
- **Schema normalization**
  - E.g., reduce data redundancy via transformation
- **Physical tuning**
  - E.g., decide which indices to create or sort order

Database Design Process

- **Requirement analysis**
  - Based on use cases, business process descriptions

Conceptual design

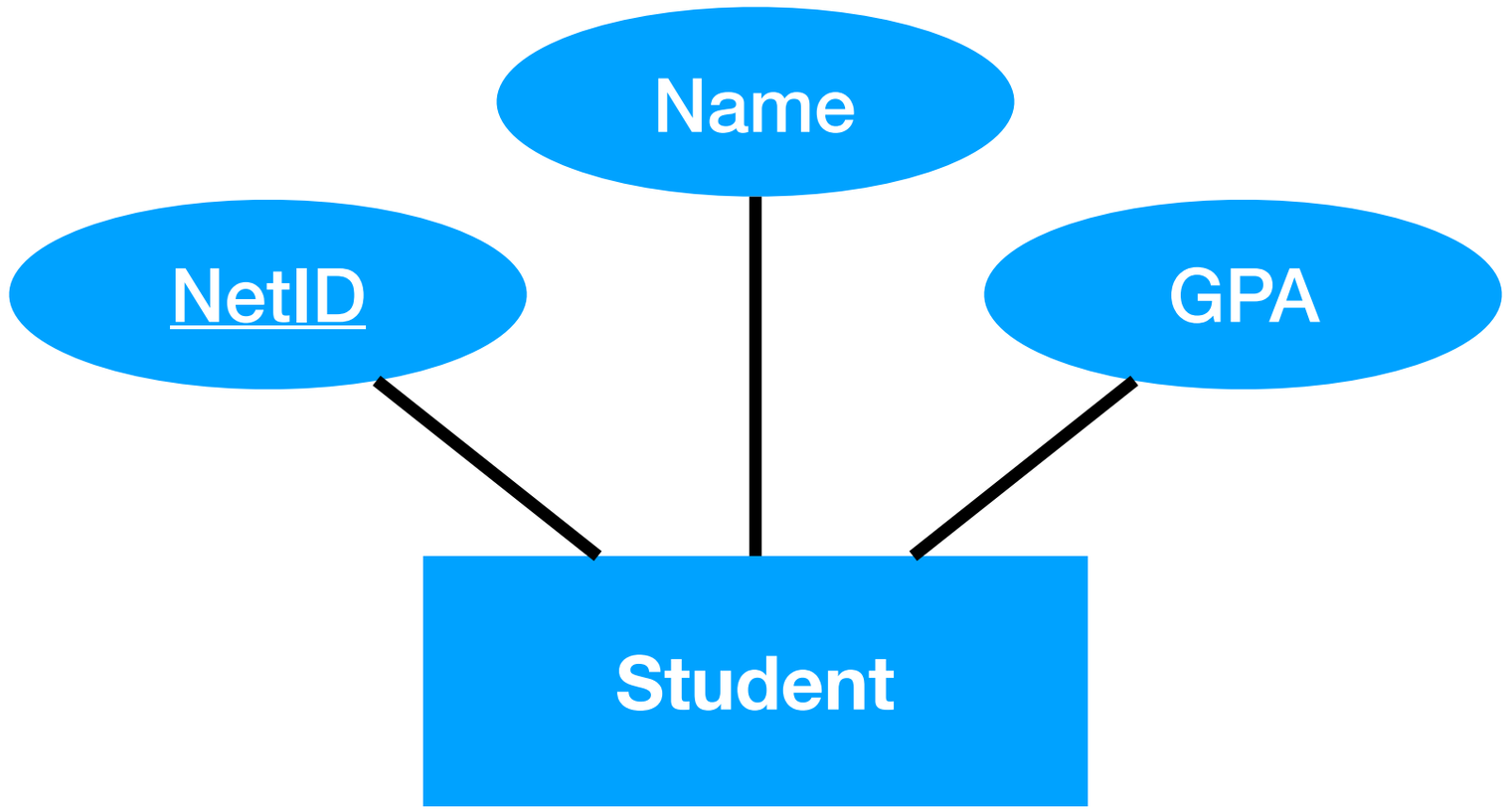
- **Schema normalization**
  - E.g., reduce data redundancy via transformation

- **Physical tuning**
  - E.g., decide which indices to create or sort order

Entities and Attributes

- **Entity set**: multiple entities of same type
  - Represented as rectangle in ER diagram
- **Attribute**: a property connected to an entity set
  - Represented as oval in ER diagram
  - Connected via lines to associated entity
  - Underlined if (part of) a key attribute
  - Attributes have simple values (e.g., integer)

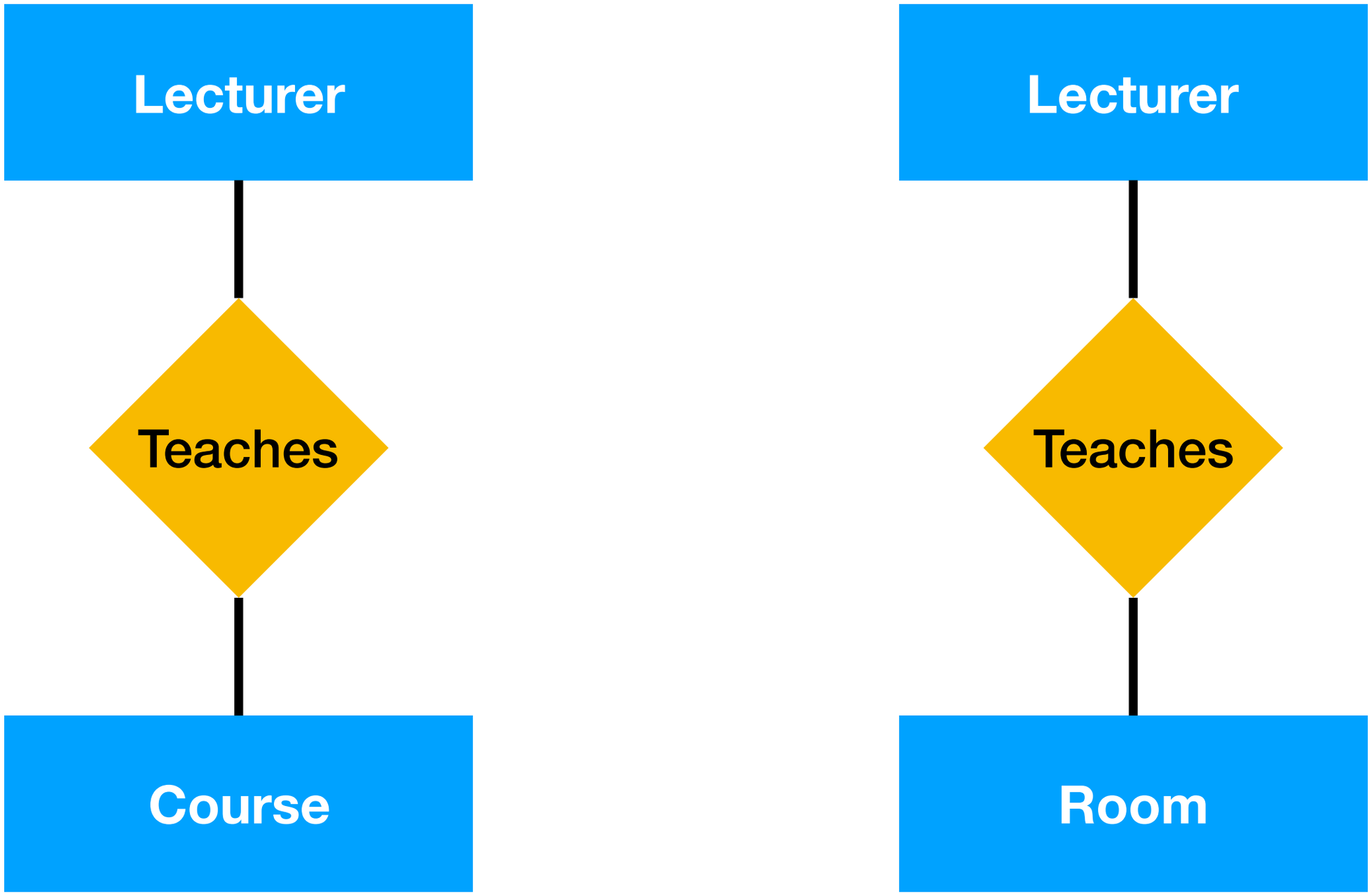
Example Entity Set



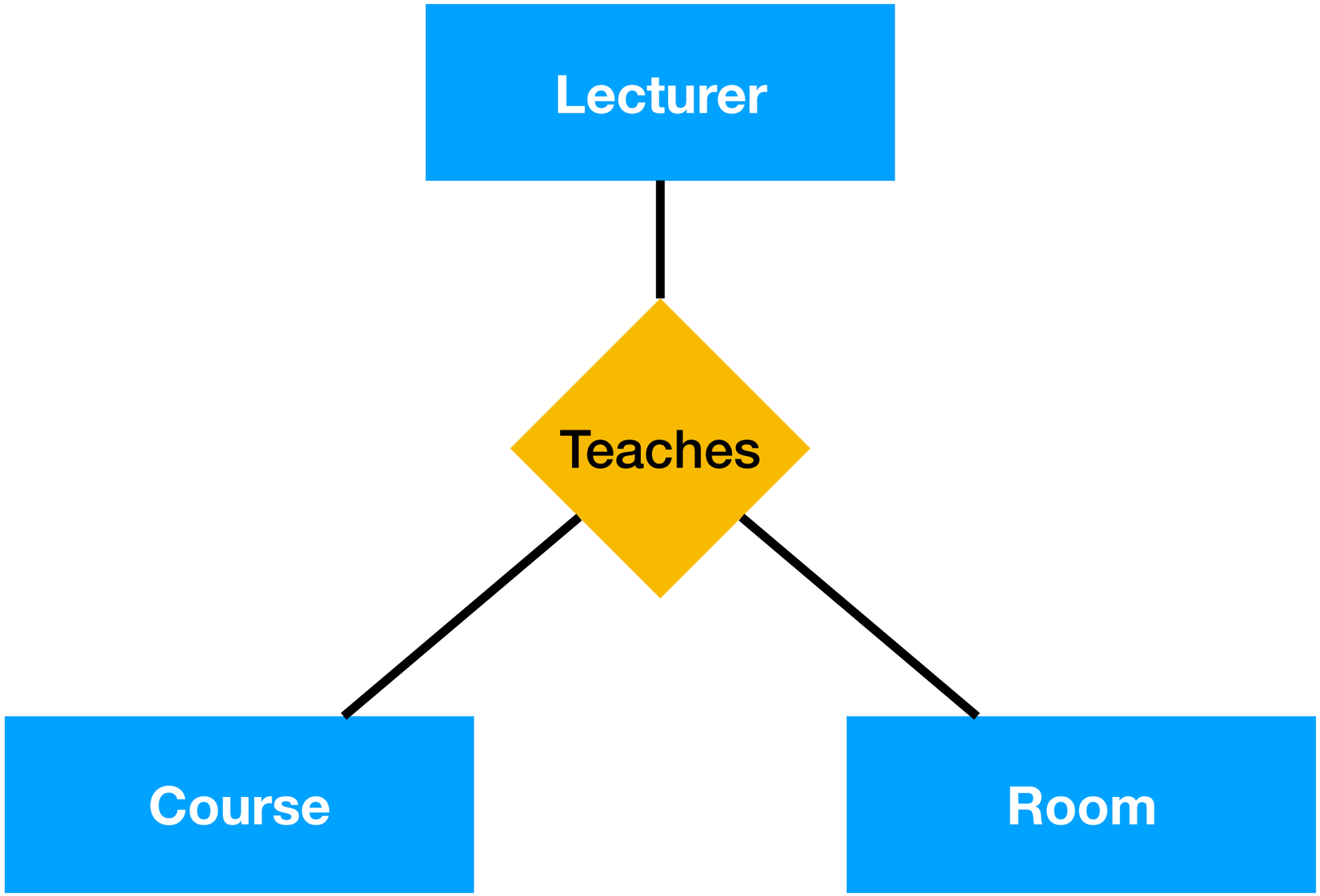
Relationships

- A **relationship** connects entities
- Relationships are represented as **diamonds**
- Connecting **lines** indicate targeted entities
- May connect **two or more** entities

Binary Relationship Examples



Ternary Relationship Example

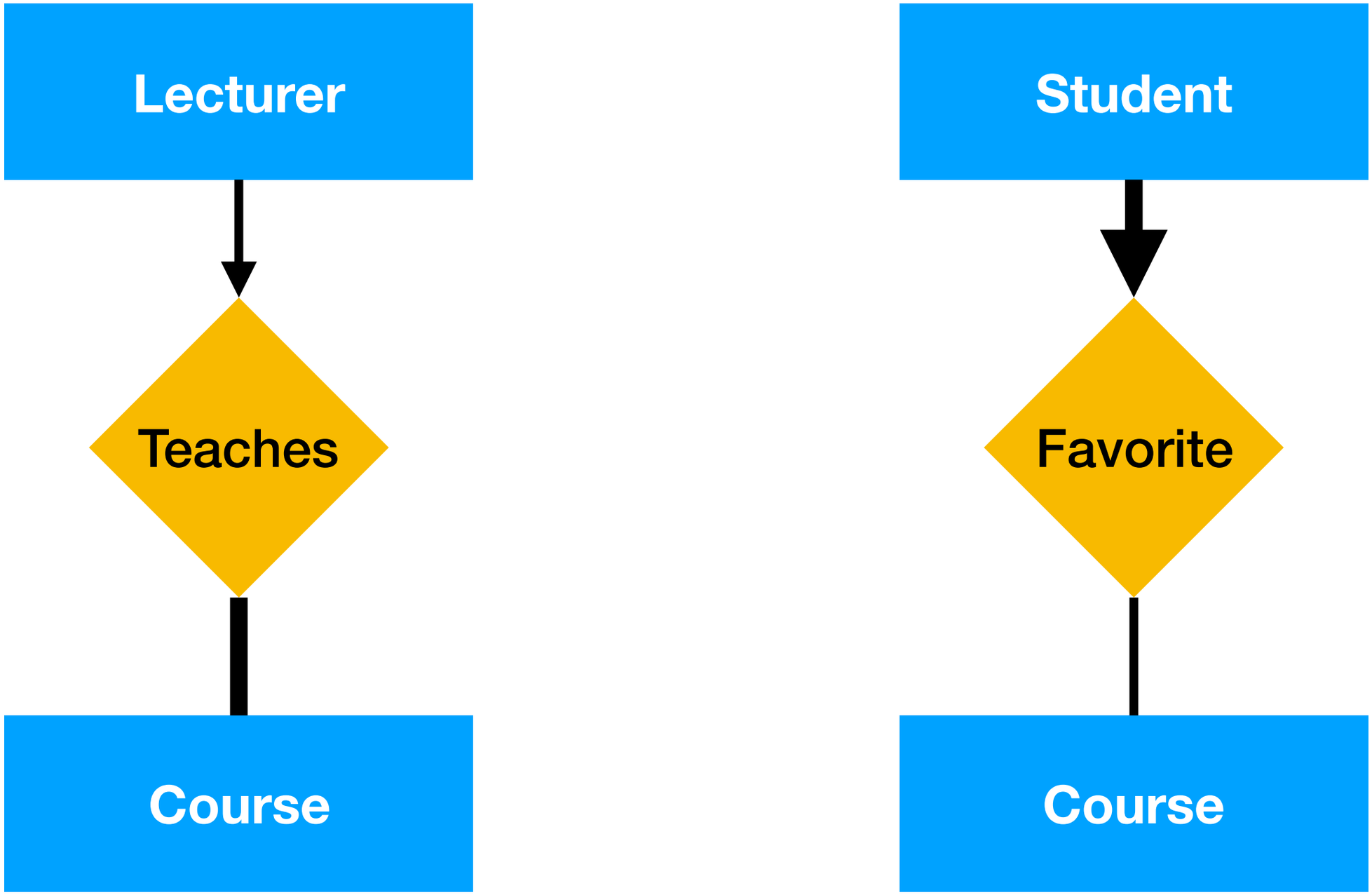


What is the Difference?

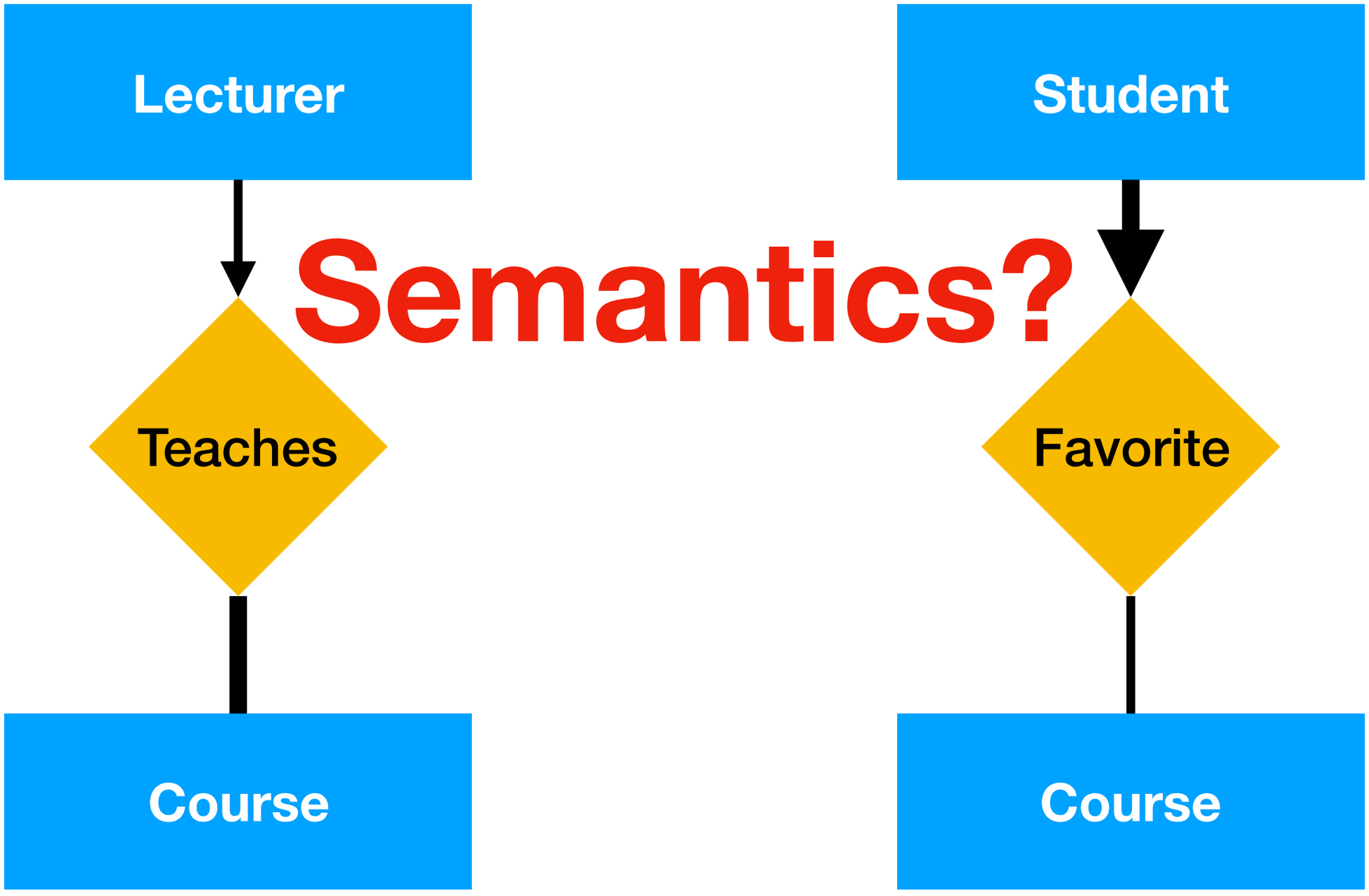
Classifying Relationships

- Can **constrain** number of relationships per entity
- **Participation** constraint: entity must relate at least once
  - Represented by a thick line (entity to relationship)
- **At-most-one** constraint: entity relates at most once
  - Represented by arrow (from entity to relationship)

Binary Relationship Examples



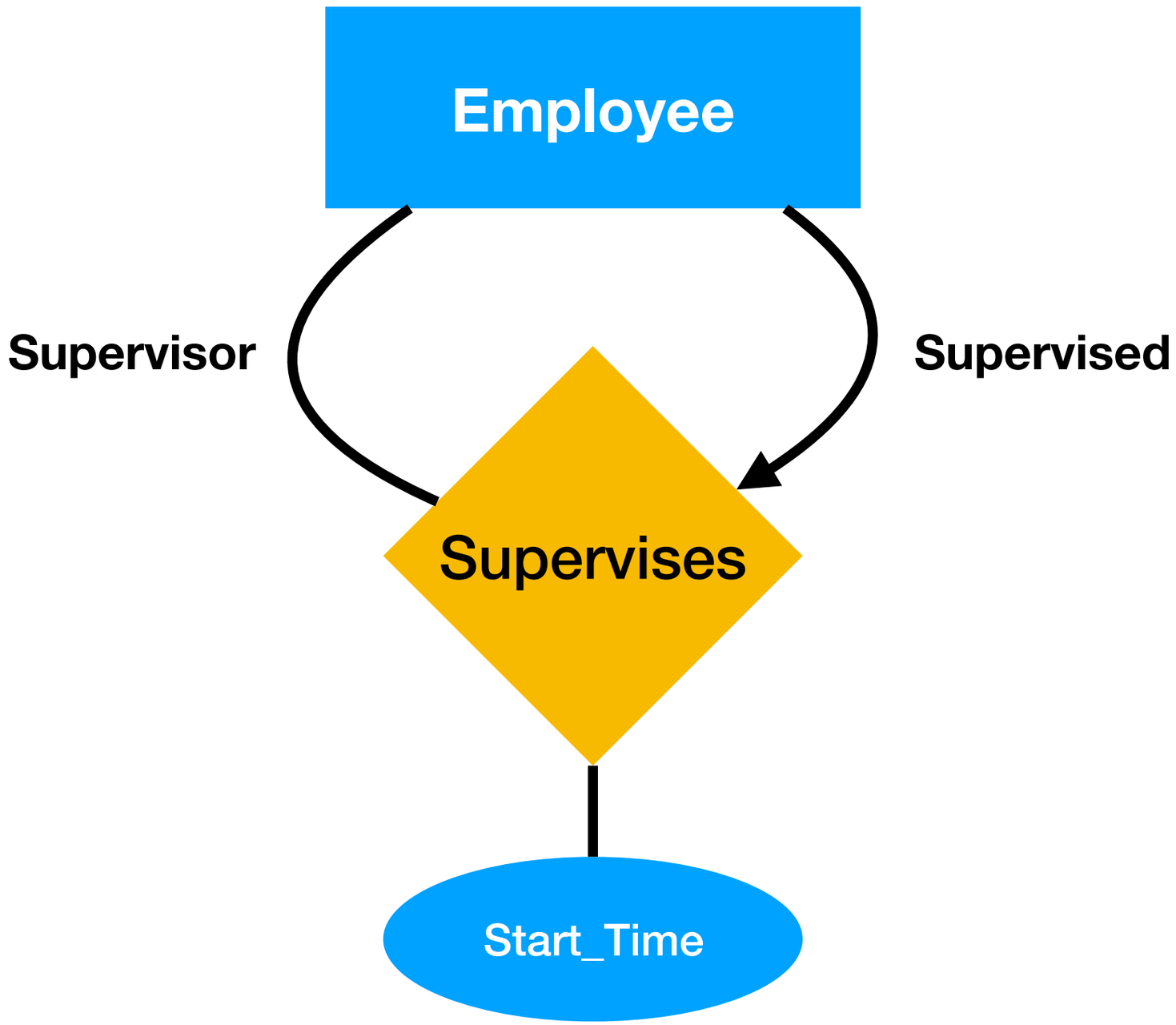
Binary Relationship Examples



More Relationship Features

- Can associate relationships with **attributes**
  - Same representation as for entity attributes
  - Refers to related entity combinations
- Can assign entities to **roles**
  - Represent role as label for connecting edge
  - Required when connecting entities of same type

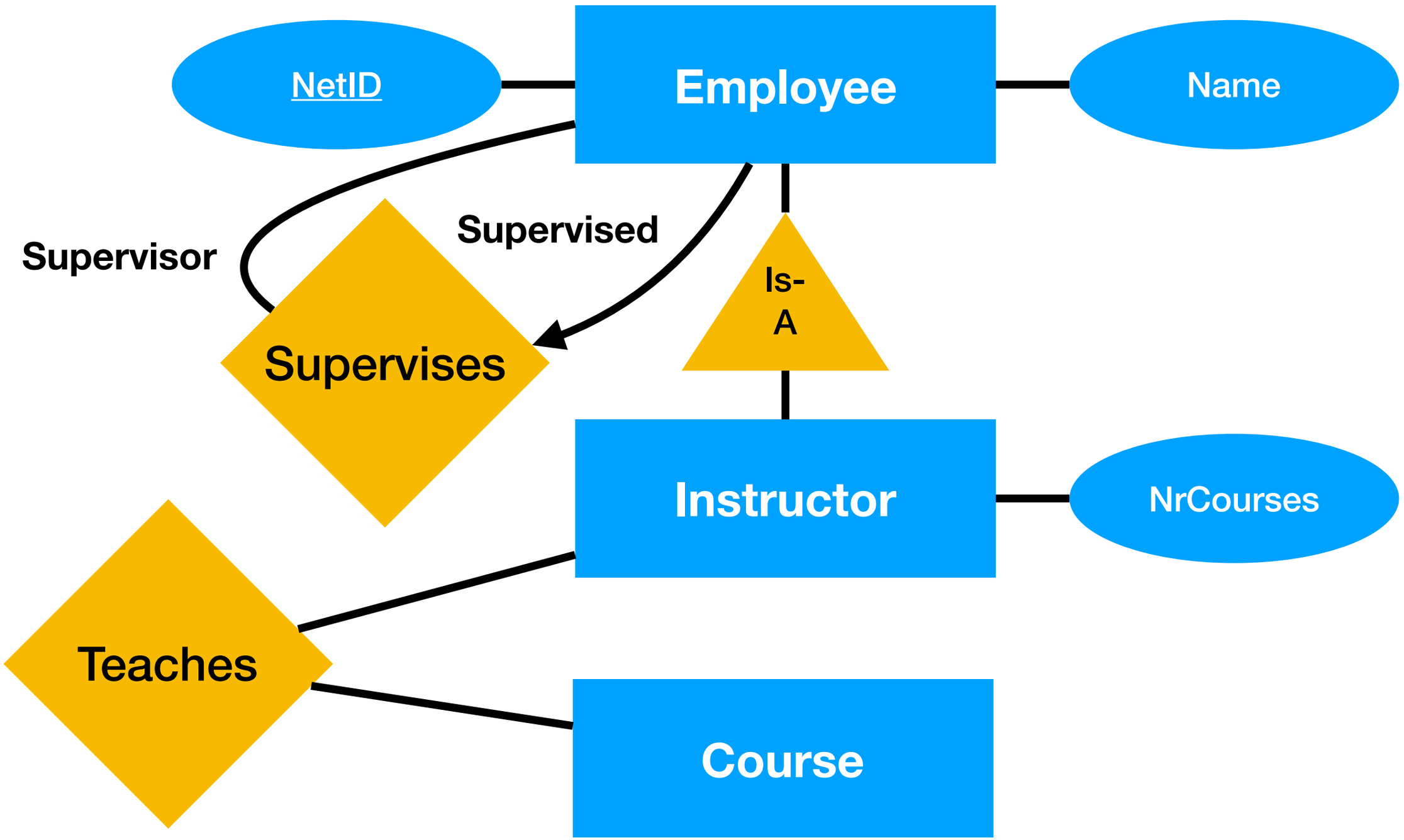
More Features Examples



Sub-Classes

- You most likely know concept from OO languages
- Sub-classing allows to **reduce redundancy** in diagram
  - Sub-classes inherit the attributes from parent
  - Sub-classes inherit relationships from parent
- Represent sub-classes via **triangles** ("Is-A")
  - No multiple inheritance (sub-classes form tree)

Sub-Classes Example

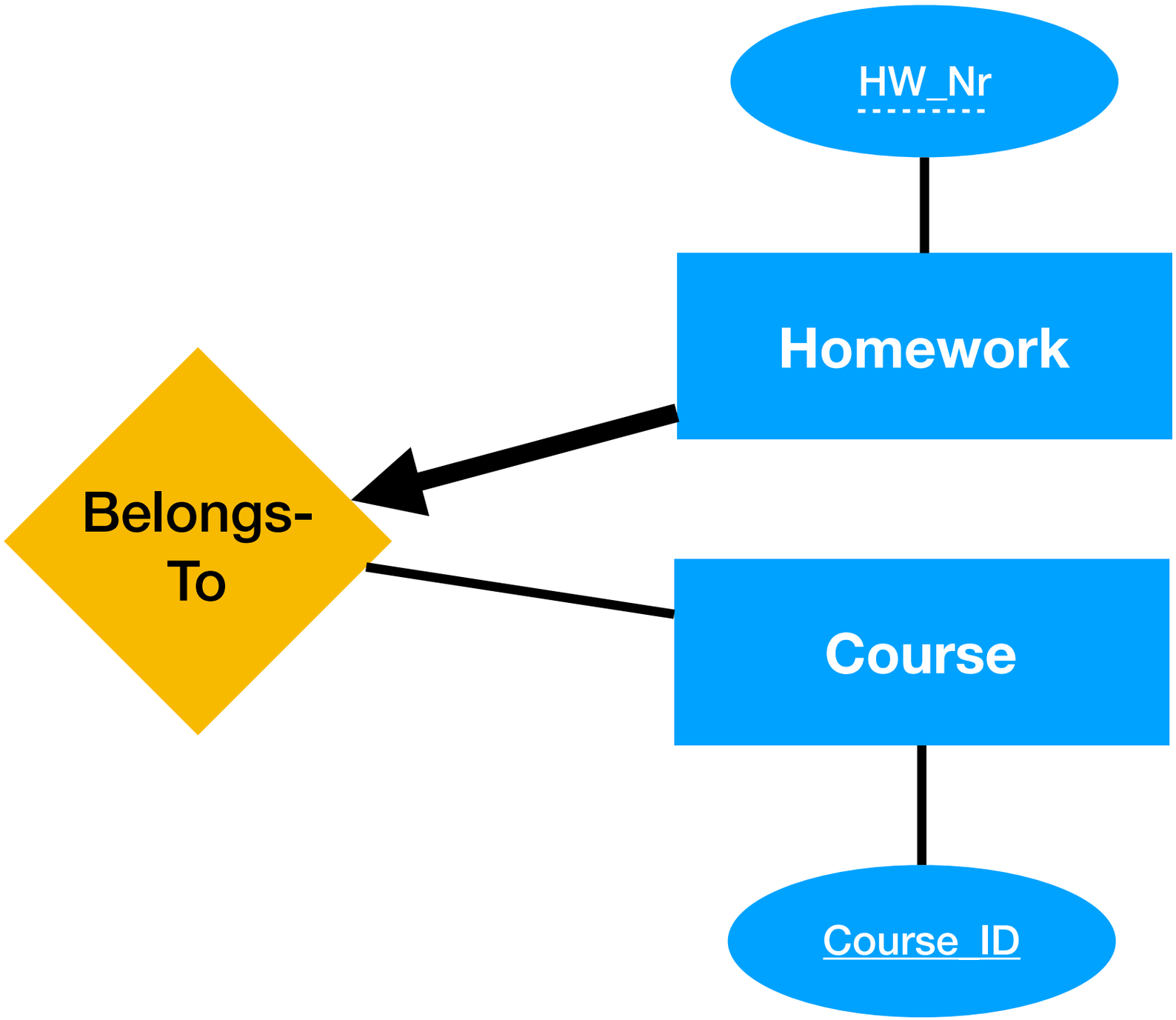


Slides by Immanuel Trummer, Cornell University

Weak Entities

- Weak entity can only be uniquely identified by considering the **primary key of another ("owner") entity**
- Weak entity connects to **owner** via identifying relationship
- Weak entity must **participate** in identifying relationship
- Also, each weak entity can appear **at most once** in it

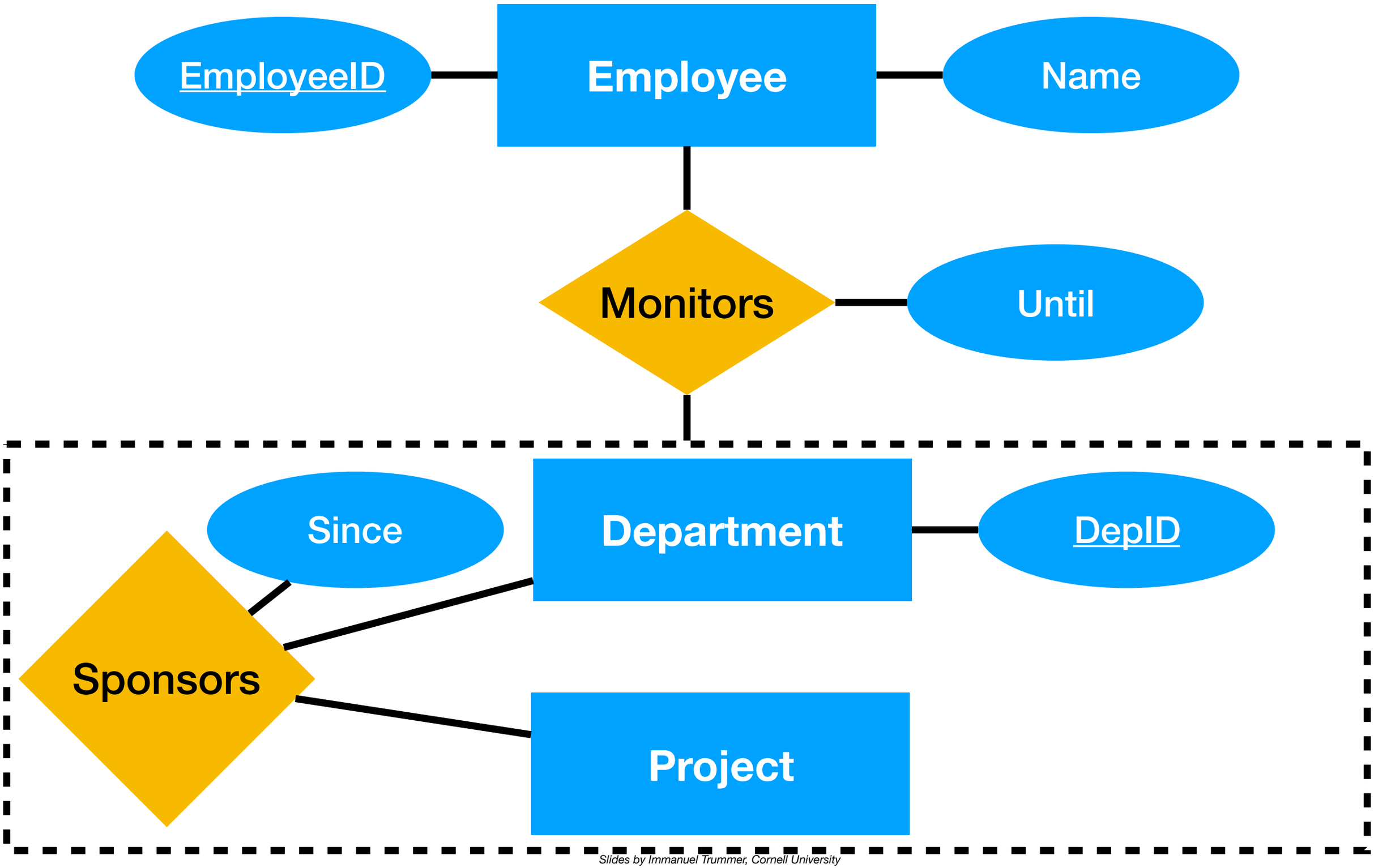
Weak Entity Example



Aggregation

- Models **relationship of a relationship**
- Surround relationship with dashed rectangle
- Now connect dashed rectangle with other items

Aggregation Example

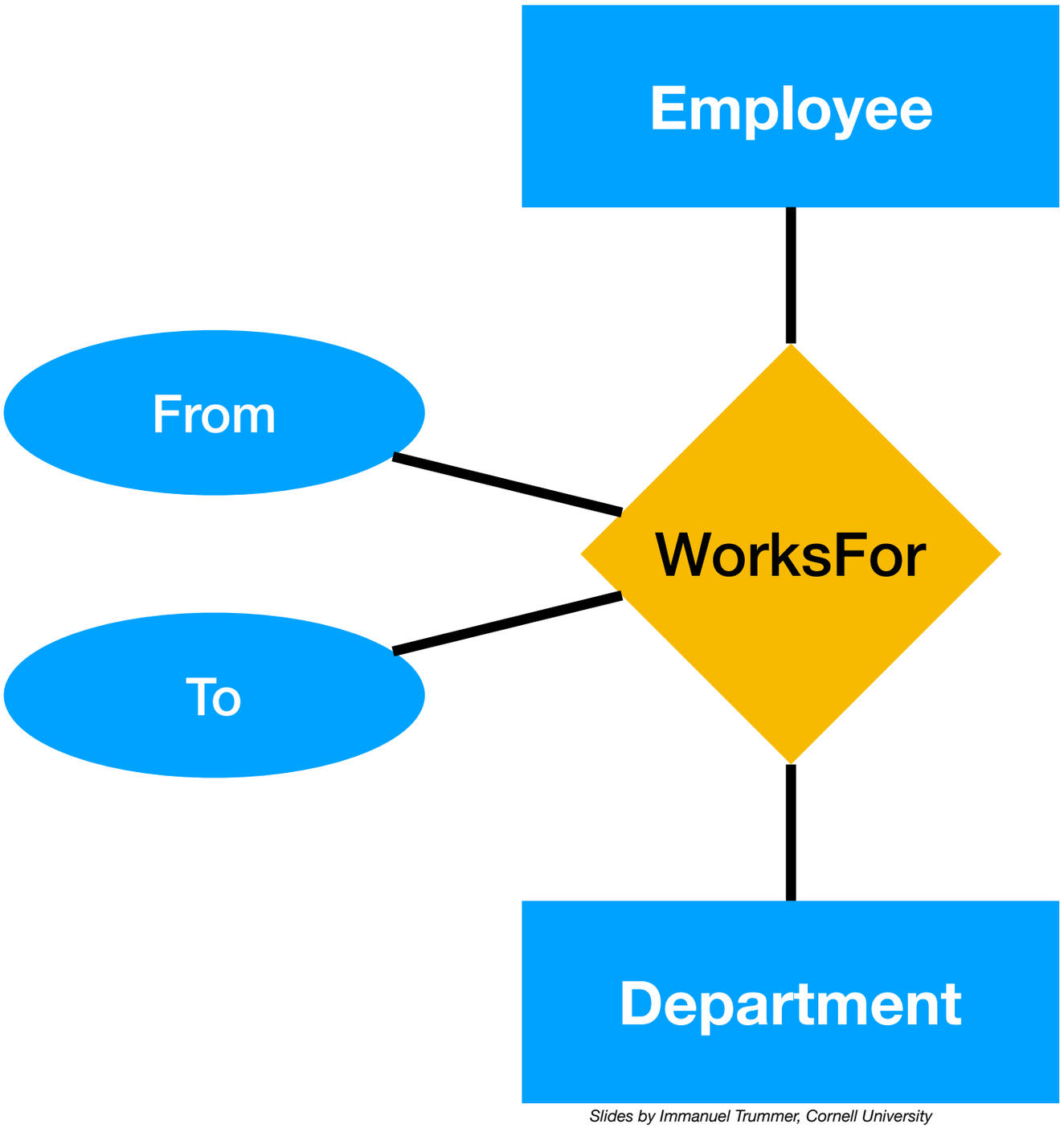


Why Not Use Ternary Relationship ... ?

Design Choices: Entities vs. Attributes

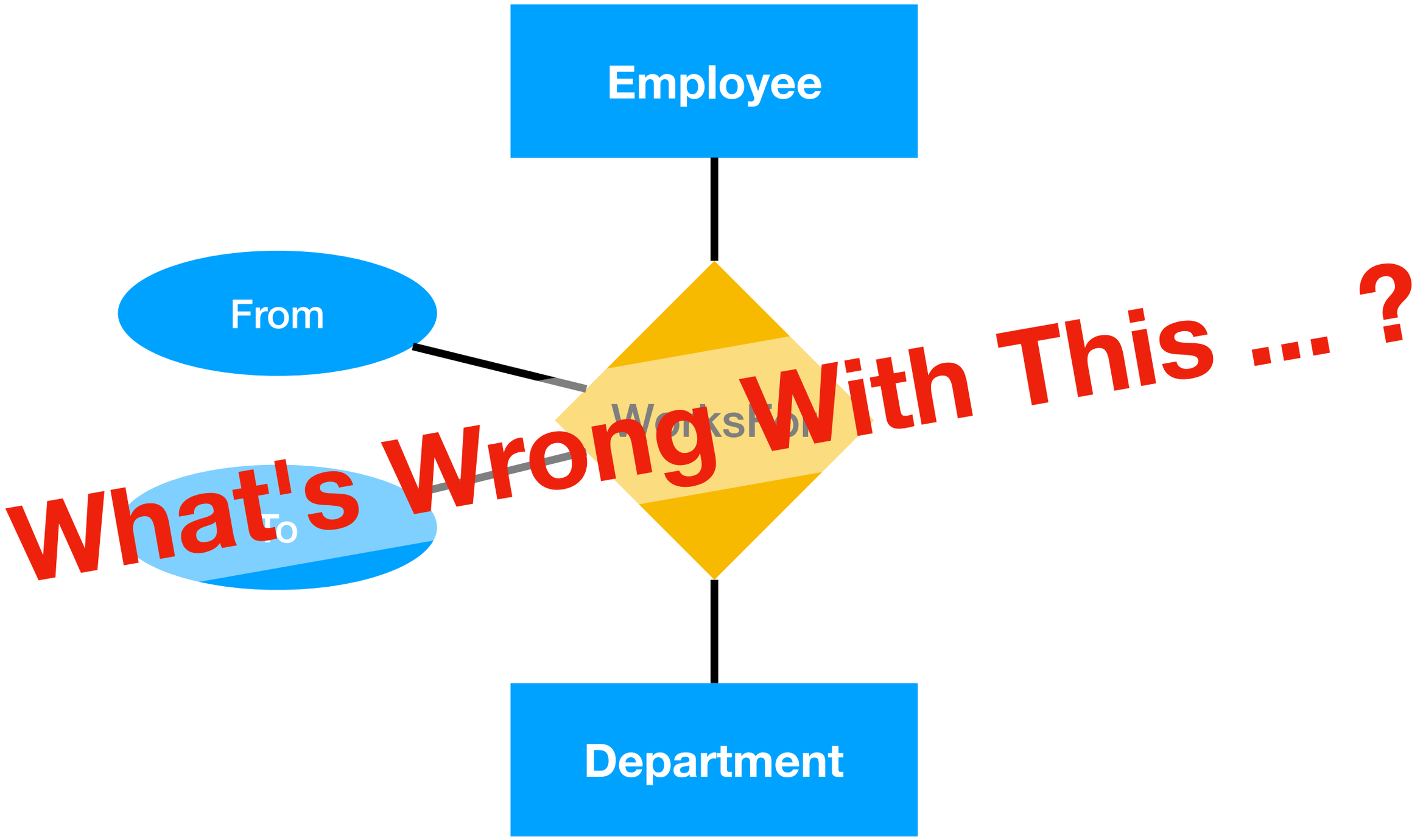
- Often can choose between **entities and attributes**
  - E.g., model address as attribute or connected entity?
- Use entity if employees can have **multiple** addresses
  - Attribute values cannot be set valued
- Model as entity if we want to **structure** address further
  - Can model components as attributes

Subtleties of ER Diagrams



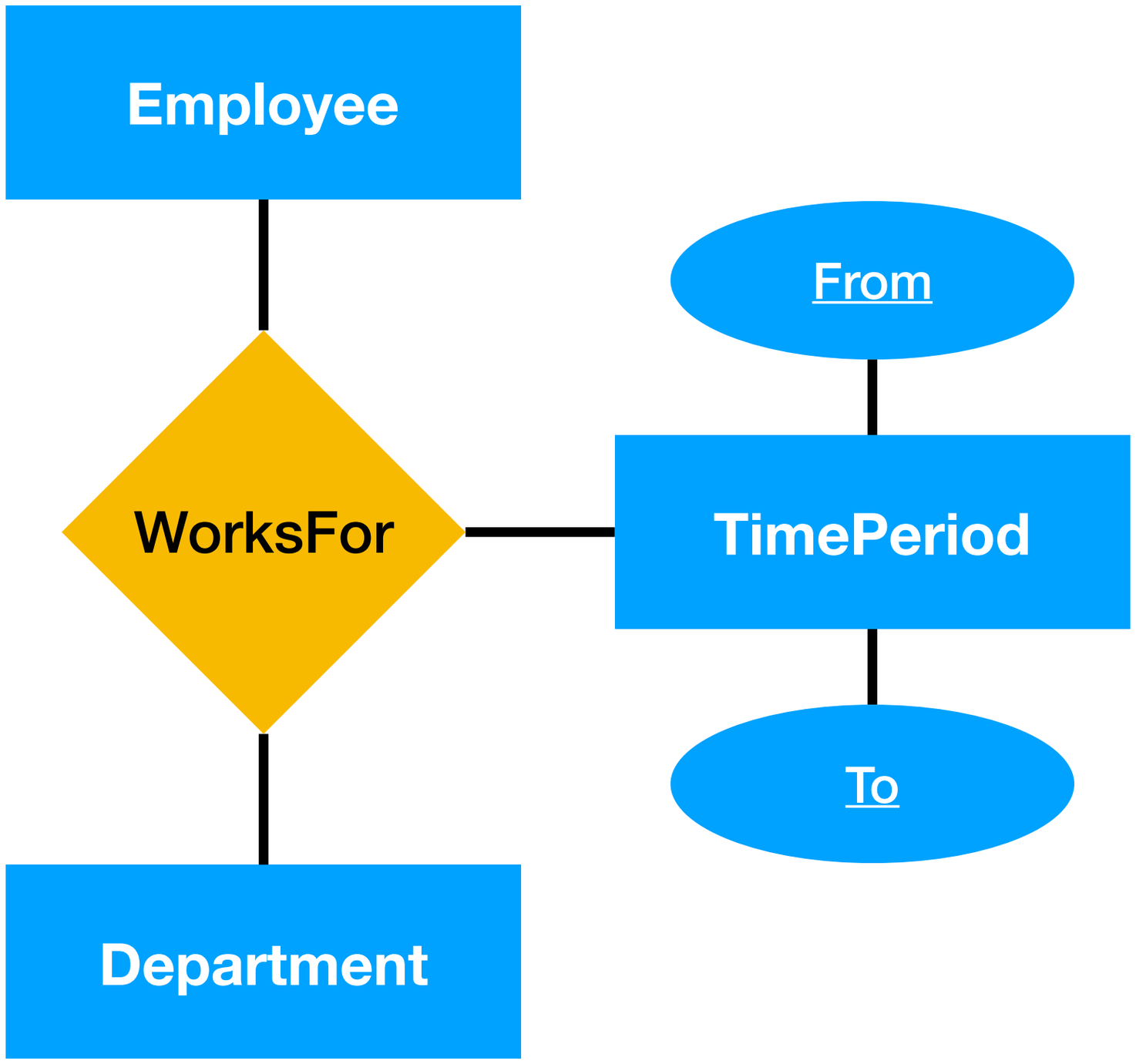
Slides by Immanuel Trummer, Cornell University

Subtleties of ER Diagrams

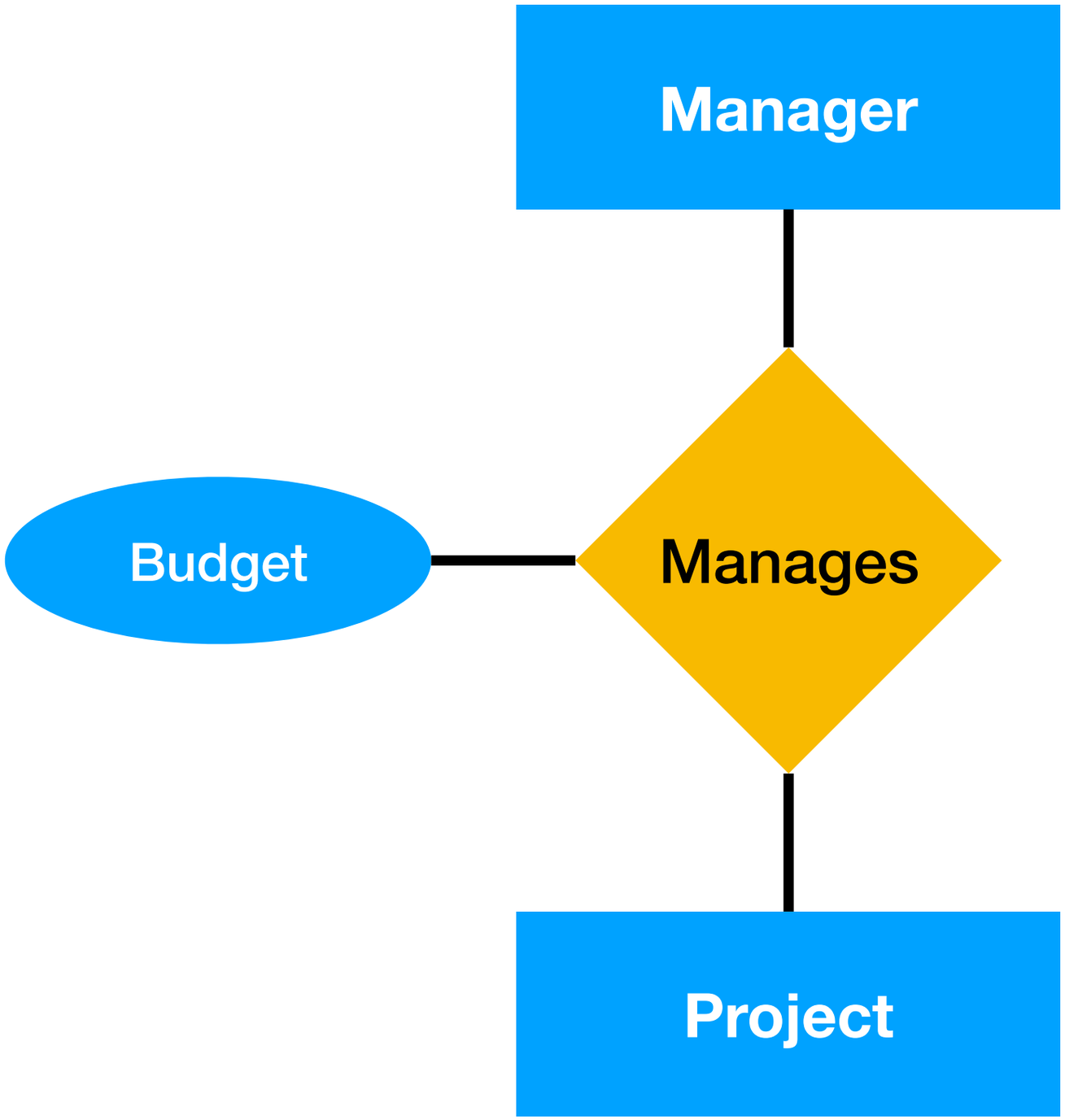


Slides by Immanuel Trummer, Cornell University

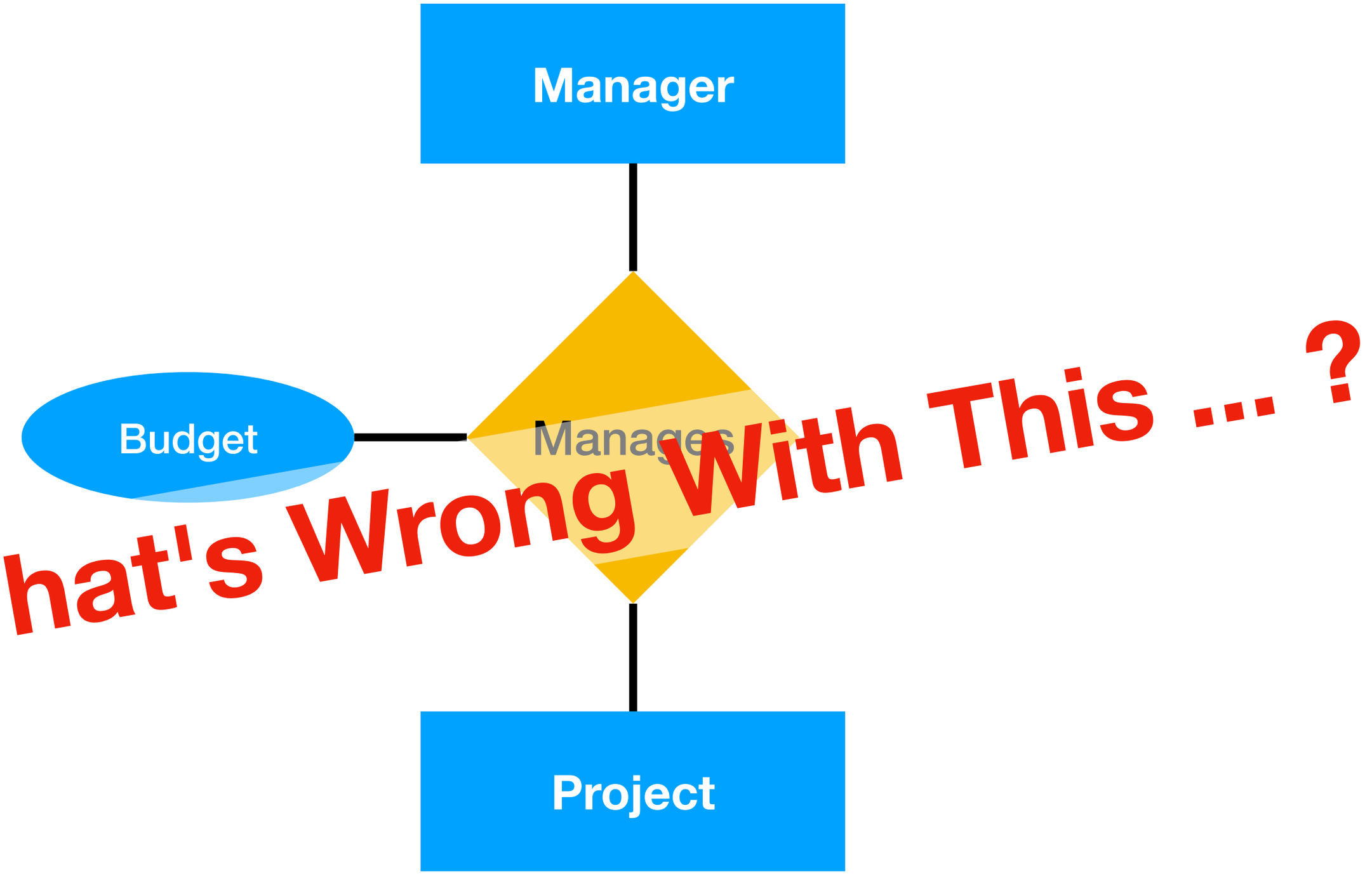
Better Representation



Subtleties of ER diagrams II

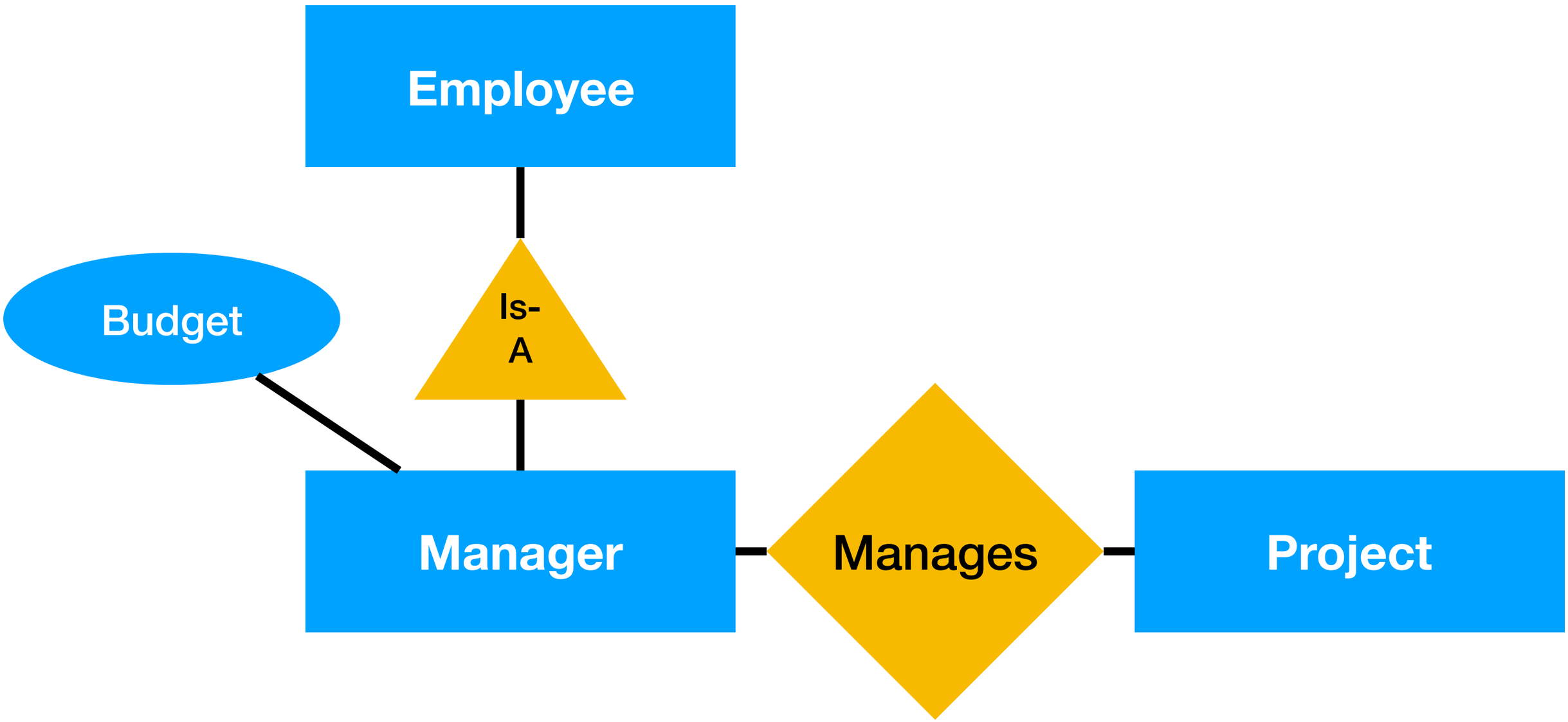


Subtleties of ER diagrams II



Slides by Immanuel Trummer, Cornell University

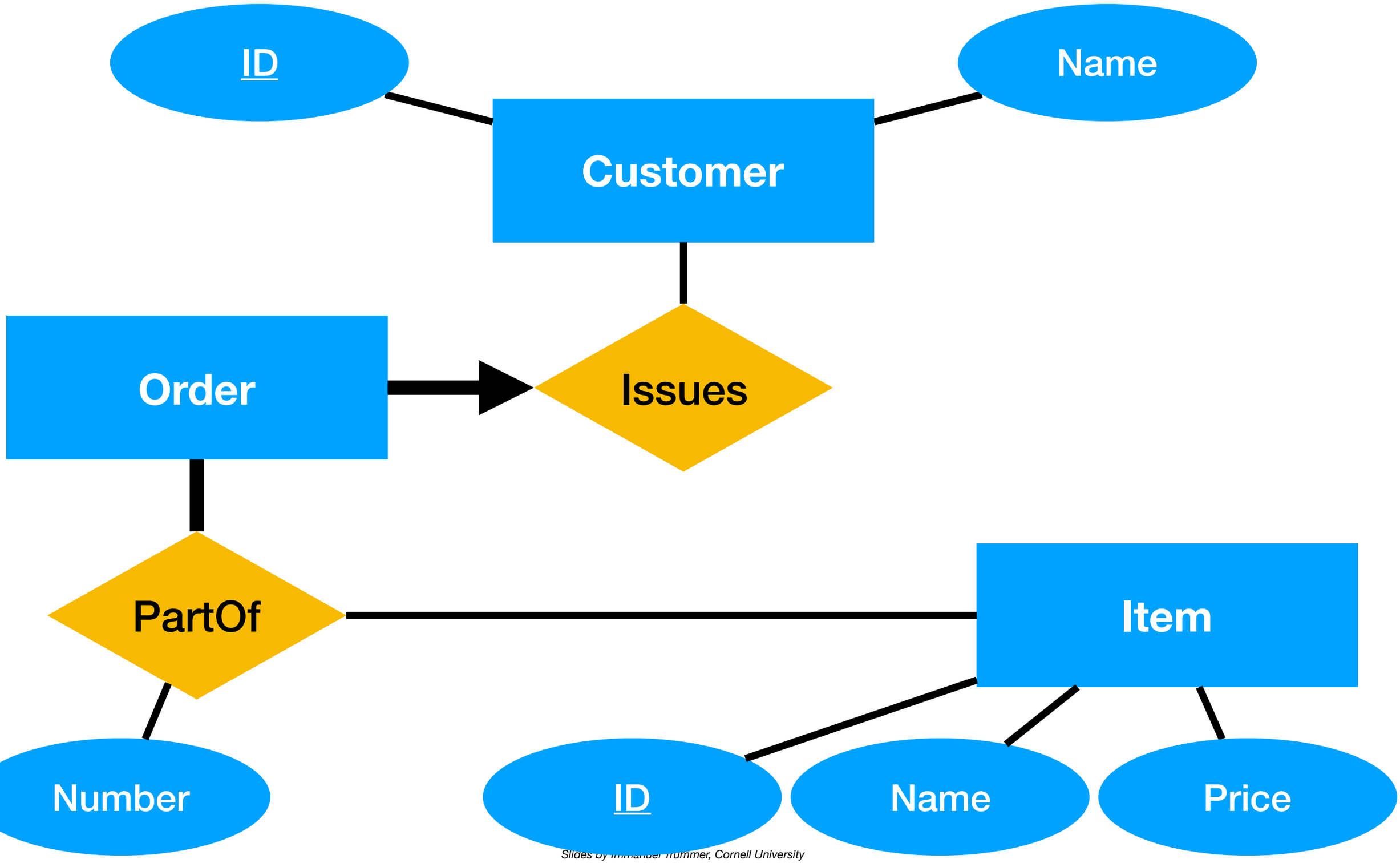
Better Representation



Exercise

- Draw an ER diagram describing the following situation
- Customers have an ID (unique) and a name
- Each order is associated with exactly one customer
- An order consists of at least one item
- Items have an ID (unique), a name, and a price

Solution


ID
Name
Customer
Order
Issues
PartOf
Item
Number
ID
Name
Price

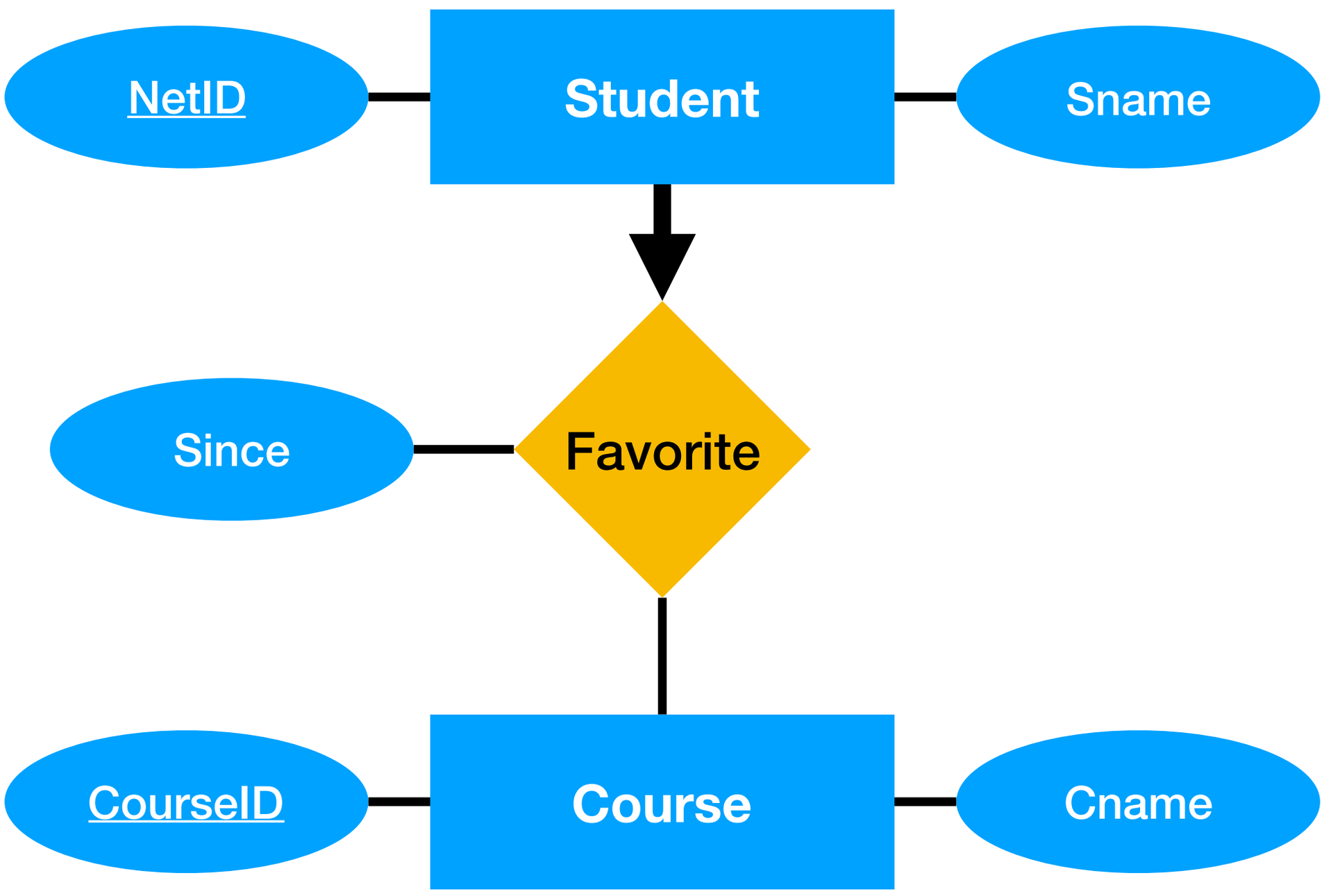
ER diagrams as Relations

- Need to **translate** ER diagrams to relations
- Introduce **relations** for entity types
- Each entity becomes **row** in relation
- Properties are represented as **columns**
- Underlined attributes part of **primary key**

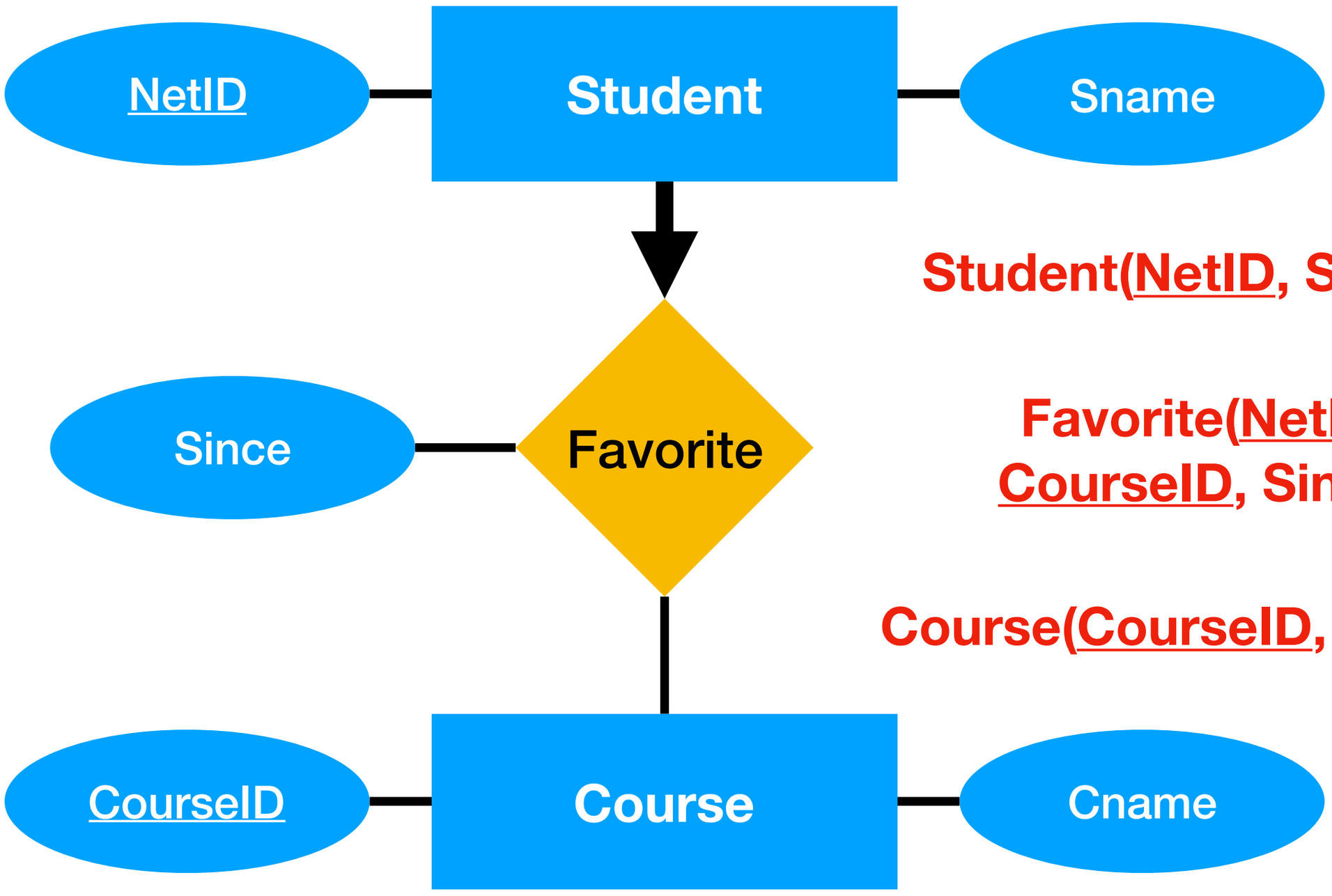
Translating Relationships

- Generic method: introduce relation capturing relationships
  - Columns store **primary keys** of all connected entities
  - Row represents **relationship** between specific entities
  - **Primary key** combines primary keys of entities
  - Additional **attributes** become columns as well

Example



Example



Student(NetID, Sname)

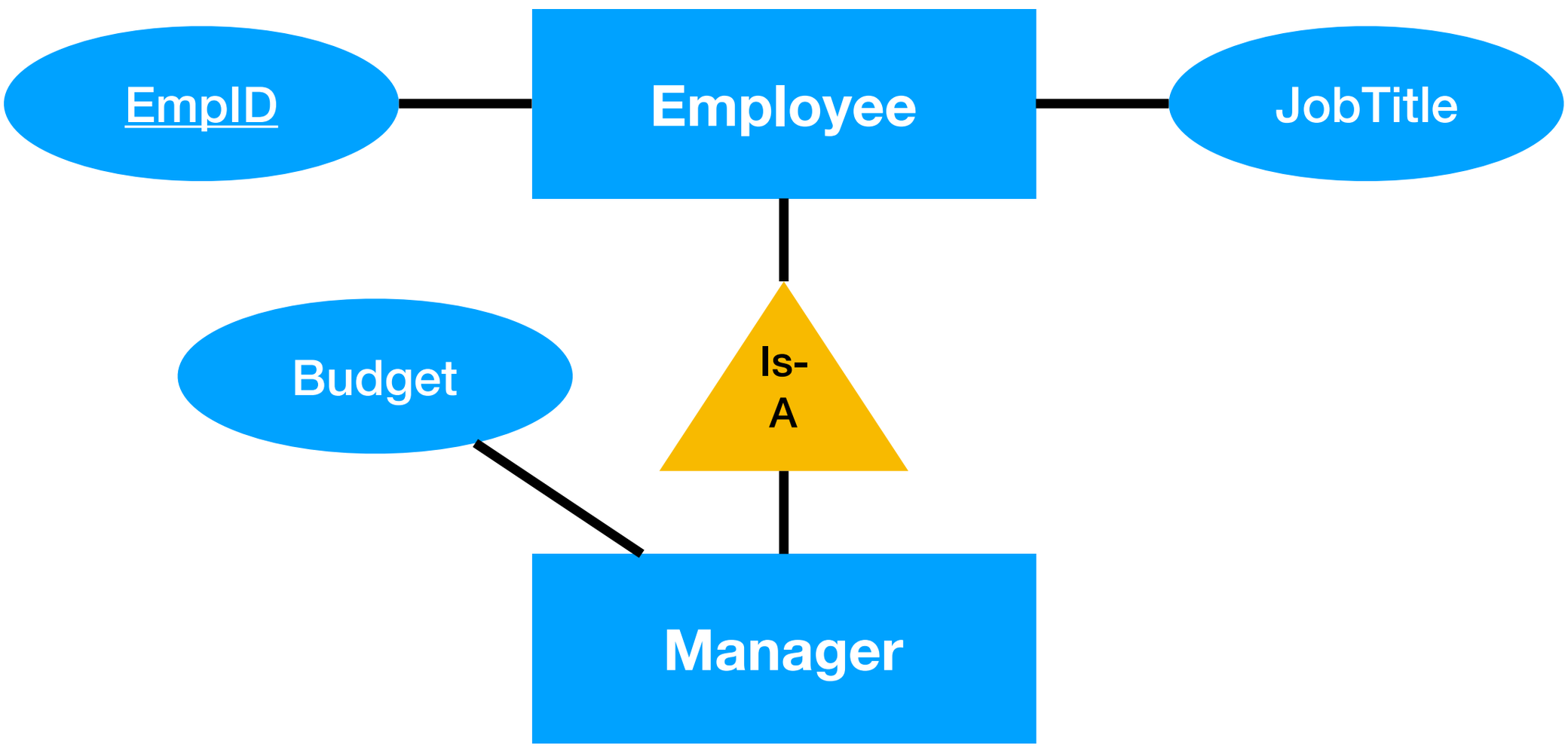
Favorite(NetID, CourseID, Since)

Course(CourseID, Cname)

Translating Sub-Classes

- Entities of sub-class may have **additional attributes**
- Can be represented in **multiple different ways**
  - **Separate relations** for superclass and sub-class
  - Introduce **multiple relations** linking key to attributes
  - Use relation for **sub-class**, set unused attributes to null

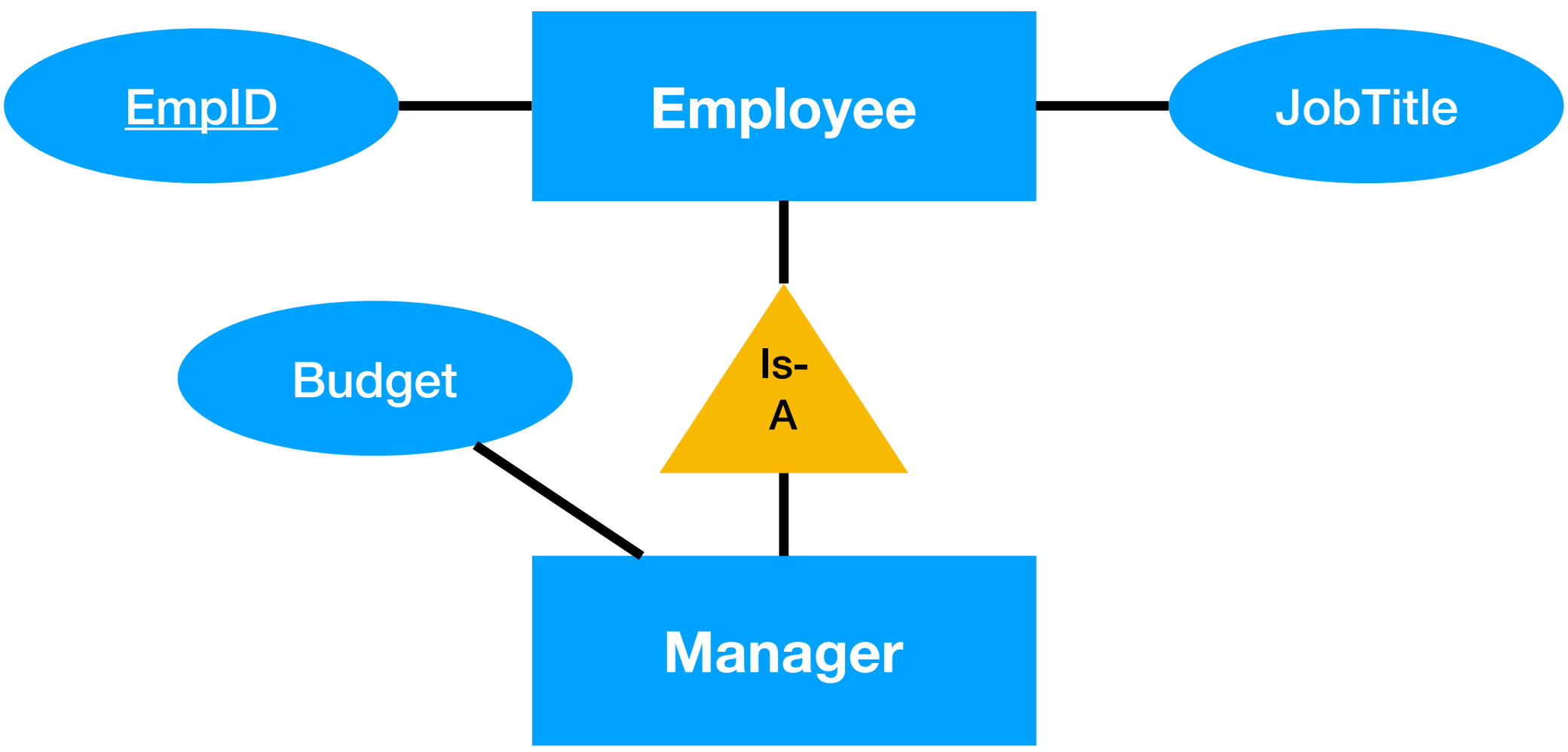
Sub-Classing Example



Employee(EmpID, JobTitle)

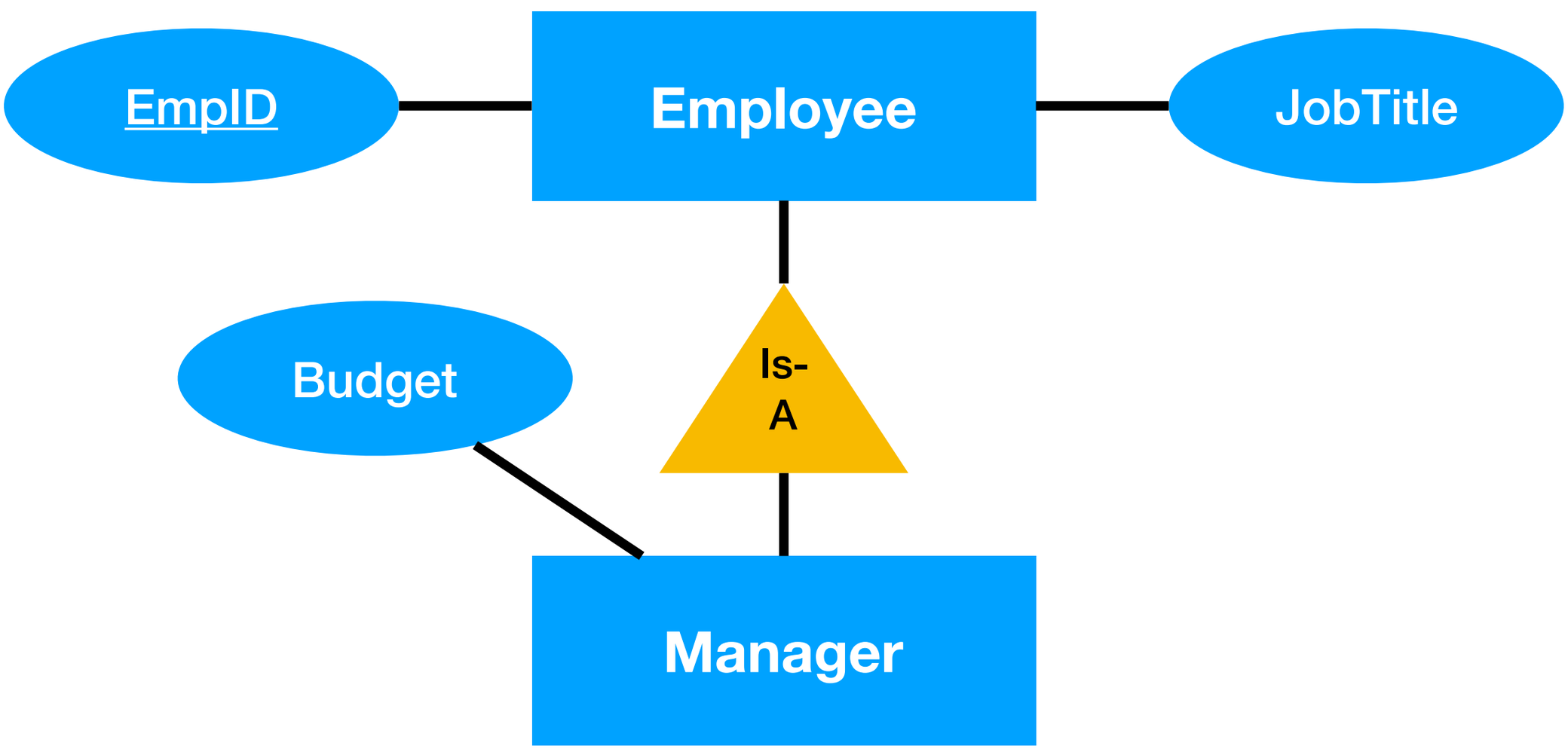
Manager(EmpID, JobTitle, Budget)

Sub-Classing Example



JobTitles(EmpID, JobTitle)
Budgets(EmpID, Budget)

Sub-Classing Example



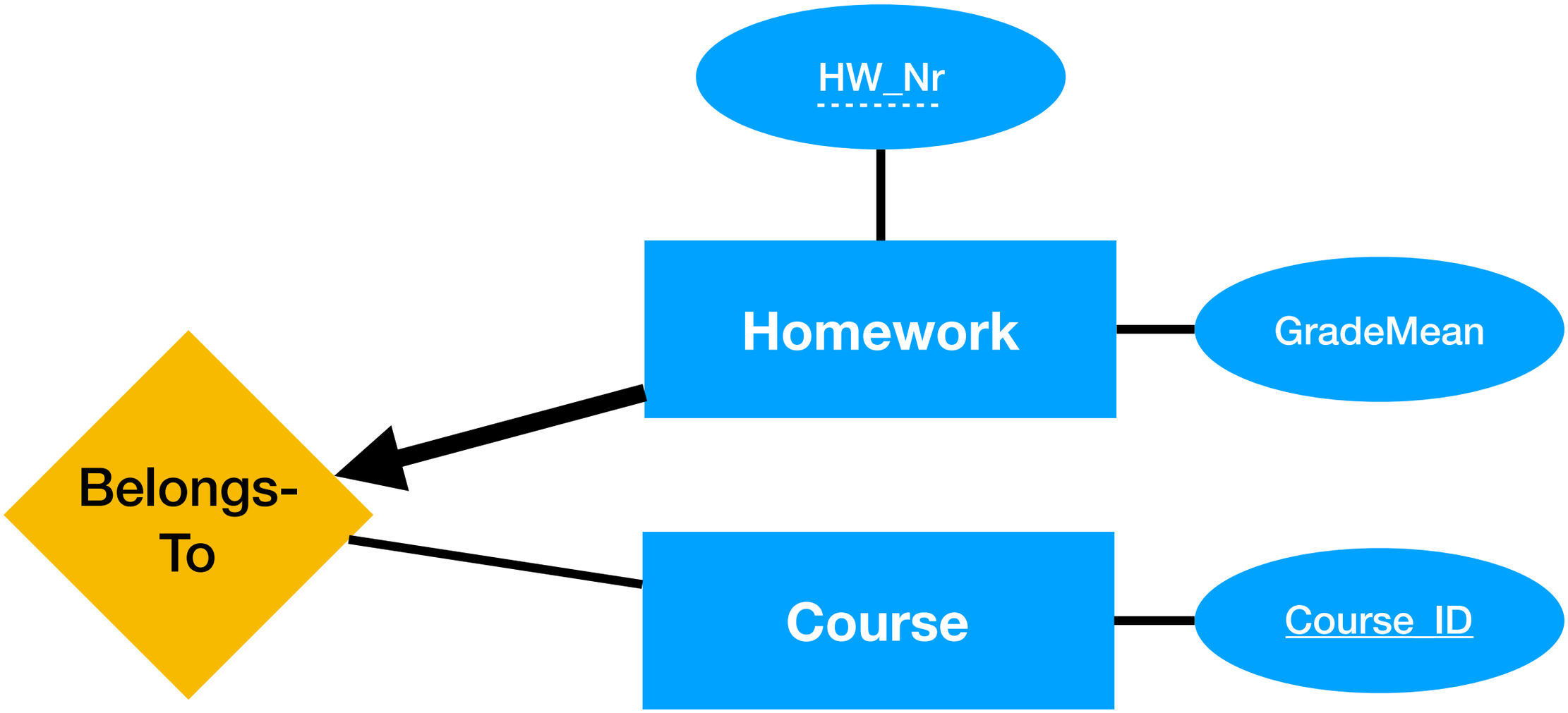
EmployeeOrManager(EmpID, JobTitle, Budget)

Slides by Immanuel Trummer, Cornell University

Translating Weak Entities

- Introduce **new relation** for storing weak entities
- Add **foreign key columns referencing owner** entity
- In SQL: **cascading delete** depending on owner

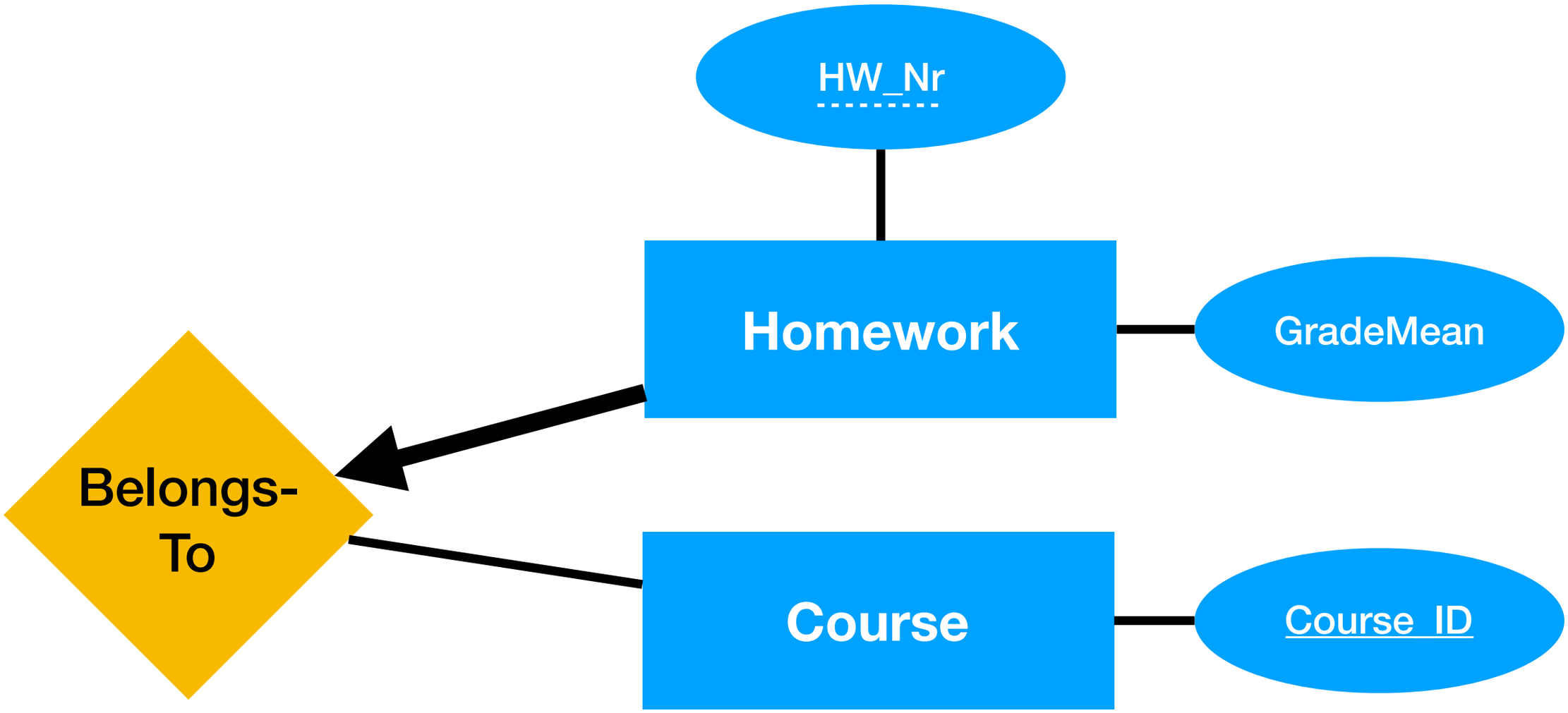
Weak Entities Example



Homeworks(HwNr, CourseID, GradeMean)

Slides by Immanuel Trummer, Cornell University

Weak Entities Example



Create table Homeworks(HwNr int, courseID int, gradeMean numeric,
primary key(HwNr, courseID),
foreign key (courseID) references courses on delete cascade)

ER diagrams in Practice

- **Lots of tools** available for drawing ER diagrams
  - https://dbmstools.com/categories/database-diagram-tools/postgresql
  - Many of them **export automatically** SQL statements
- Precise visualization may differ, **concepts are similar**

MusicBrainz Database: Simplified Schema