VirginiaTech

CS 4604: Introduction to Database Management Systems

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Lecture #5: Entity/Relational Models---Part 1

Announcements---Project

- Goal: design a database system application with a web front-end
- Project Assignment 1 released this week
  - Total of 3 during the semester
- **Heads-up: Start thinking about groups**
  - same group for rest of the semester
  - You are free to choose your own project members
  - If you like me to assign you to a group, send me email
  - **Min size=2 members, Max size=3 members**. Anything else needs an excellent reason (and my permission)

E/R: NOT IN BOOK!

- IMPORTANT:
  - Follow only lecture slides for this topic!
  - Differences from the book:
    - More details
    - Slightly different notation

Database Design

- Requirements Analysis — *user's needs*
- Conceptual Design — *high level (E/R)*
- Logical Design — *tables (schema)*
- Schema Refinement — *normalization*
- Physical Design — *indices etc.*
- Security Design — *access controls*

Database Design

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Basic Database Terminology

- Data model : describes high-level conceptual structuring of data
  - Example: Data is set of student records, each with ID, name, address, and courses
  - Example: Data is a graph where nodes represent people and edges represent friendship relations
- Schema describes how data is to be structured and stored in a database
  - Defined during creation of the database
  - Schemas rarely change
- Data is actual "instance" of database
  - Updated continuously
  - Changes rapidly

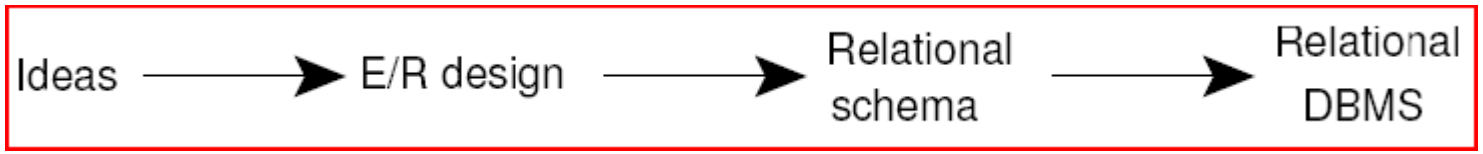
Why Learn About Database Modeling?

- The way in which data is stored is very important for subsequent access and manipulation by SQL.

- Properties of a good data model:
  - It is easy to write correct and easy to understand queries.
  - Minor changes in the problem domain do not change the schema.
  - Major changes in the problem domain can be handled without too much difficulty.
  - Can support efficient database access.

Purpose of E/R Model

- The E/R model allows us to sketch the design of a database informally.
  - Represent different types of data and how they relate to each other
- Designs are drawings called *entity-relationship diagrams*.
- Fairly mechanical ways to convert E/R diagrams to real implementations like relational databases exist.



Purpose of E/R Model

- When designing E/R diagrams,
  - forget about relations/tables!
  - only consider how to model the information you need to represent in your database.

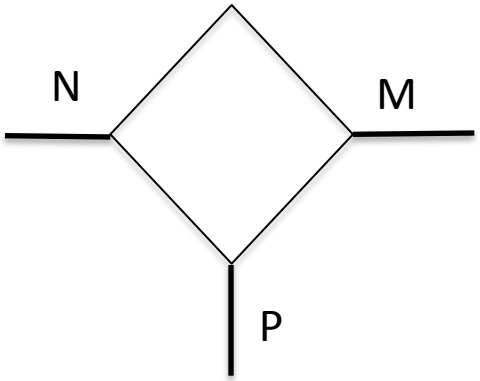
Example

- Professors advising students, Students taking courses, Students taught by professors

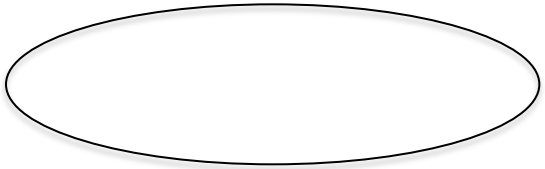
Tools

- Entities ('entity sets')

- Relationships ('rel. sets') and mapping constraints



- Attributes



Example

- Professors advising students, Students taking courses, Students taught by professors

Nouns → entity sets

Verbs → relationship sets

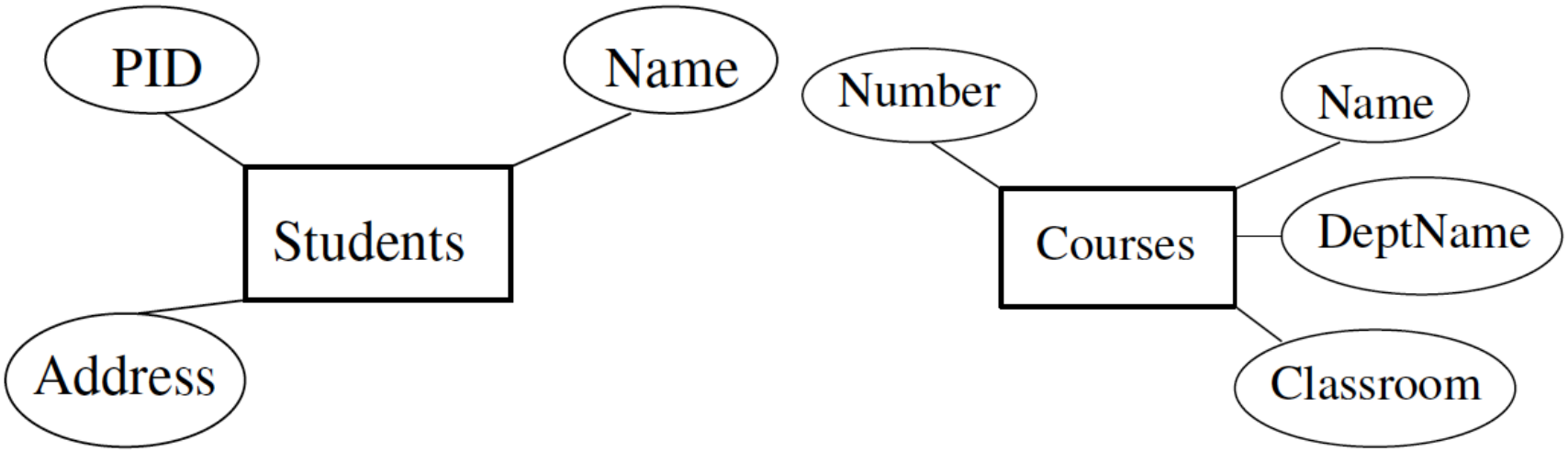
Entity Sets

- *Entity* = "thing" or objects
- *Entity set* = collection of similar entities.
  - Similar to a class in object-oriented languages.
- Attribute = property of an entity set.
  - Generally, all entities in a set have the same properties.
  - Our convention is to use 'atomic attributes' e.g. integers, character strings etc.
  - FYI: there exist
    - **multivalued** or set-valued attributes (eg., 'dependents' for EMPLOYEE)
    - **derived** attributes (eg., 15% tip)

E/R Diagrams

- In an entity-relationship diagram, each entity set is represented by a rectangle.
- Each attribute of an entity set is represented by an oval, with a line to the rectangle representing its entity set.

Example: Entity Sets

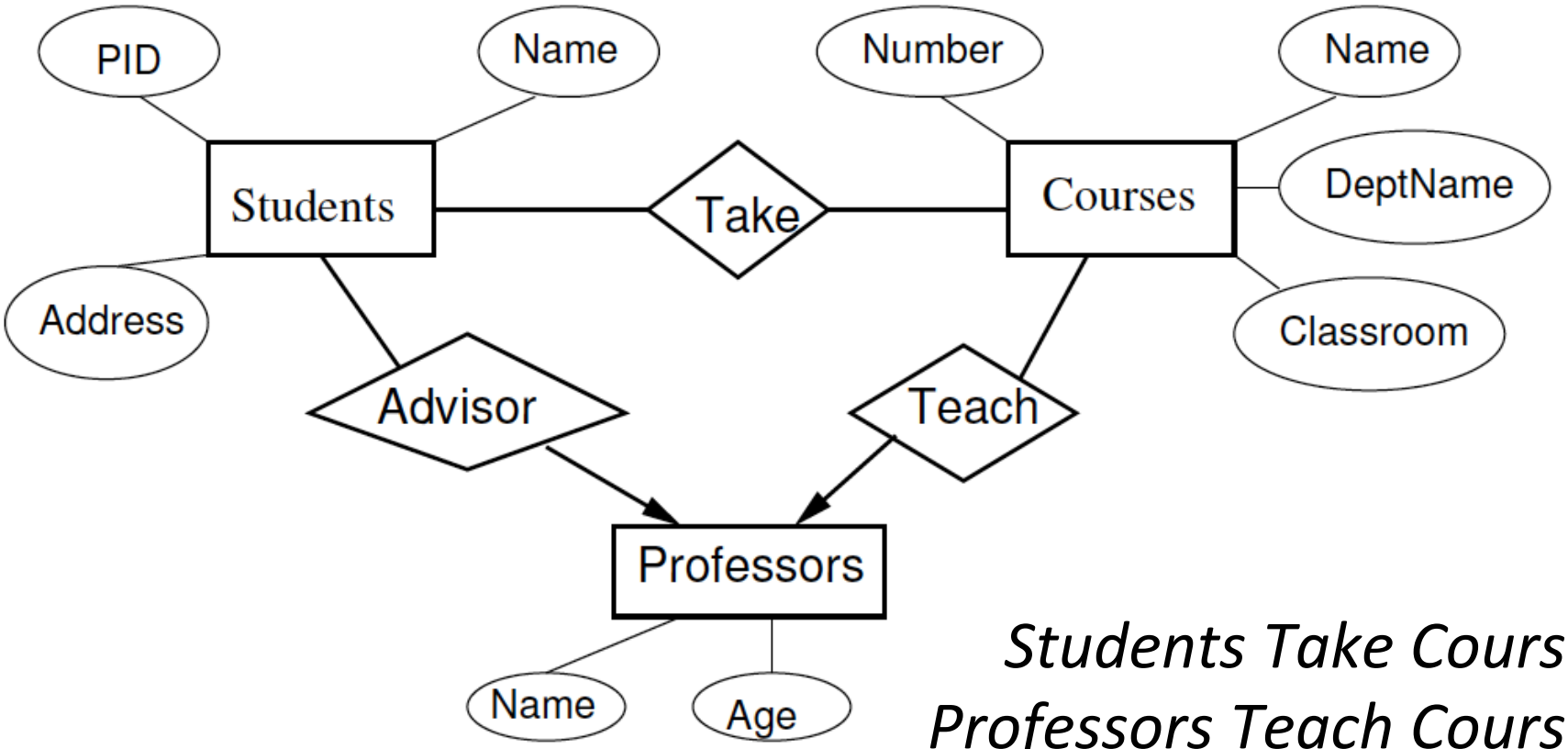


Relationships

- A relationship connects two or more entity sets.
- It is represented by a diamond, with lines to each of the entity sets involved.

- Don't confuse 'Relationships' with 'Relations'!

Example: Relationships



Students Take Courses

Professors Teach Courses

Professors Advise Students

Instance of an E/R Diagram

- An E/R is NOT an implementation of the DB
  - Just a notation for specifying structure

- Still useful to think of instance of an E/R Diagram === the particular data stored in a database

Instance of an Entity Set

- For each entity set, the instance stores a specific set of entities
- Each entity is a tuple containing specific values for each attribute
- Example: Instance of Entity set Students

Name	*PID*	*Address*
Hermione Grainger	HG	Gryffindor Tower
Draco Malfoy	DM	Slytherin Tower
Harry Potter	HP	Gryffindor Tower
Ron Weasley	RW	Gryffindor Tower

Instance of a Relationship

- Example: Instance of relationship Takes (no DeptName)

Student	*PID*	*Address*	*CourseName*	*Enrollment*	*Grade*
Hermione Grainger	HG	Gryffindor	Potions	∞	A-
Draco Malfoy	DM	Slytherin	Potions	∞	B
Harry Potter	HP	Gryffindor	Potions	∞	A
Ron Weasley	RW	Gryffindor	Potions	∞	C

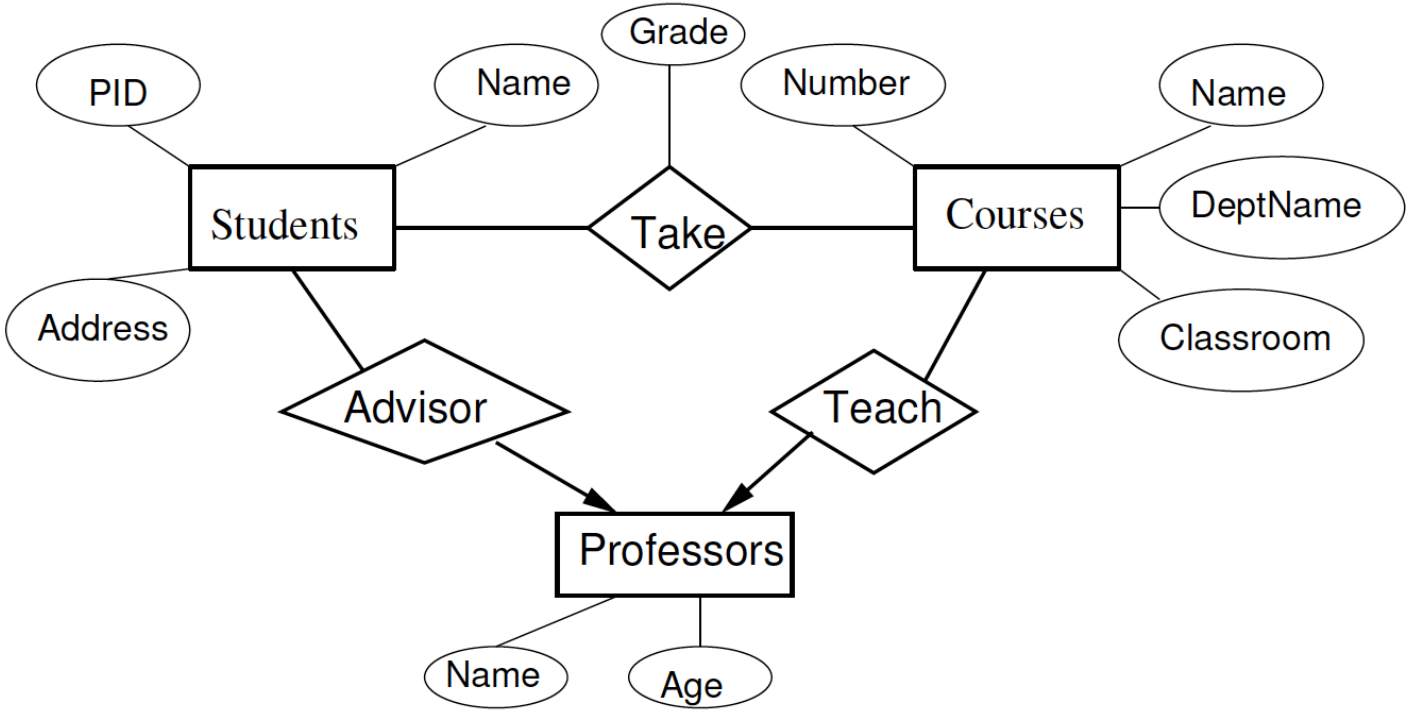
- Relationship R between (entity sets) E and F
  - Relates some *entities* in E to some *entities* in F

Instance of a Relationship

- Instance is a set of pairs of tuples (e; f) where e is in E and f is in F
  - Instance need not relate every tuple in E with every tuple in F
  - Relationship set for R: the pairs of tuples (e; f) related by R
- (Conceptually) An instance of R is simply the 'concatentation' of the attribute lists for all pairs of tuples (e; f) in the relationship set for R
- 'Tuples' in R have two components, one from E and one from F

Attributes for a Relationship

- Question: What is Grade an attribute of?
- Such an attribute is a property of the entity-pairs in the relationship



Many-Many Relationships

- In a *many-many* relationship, an entity of either set can be connected to many entities of the other set.

Many-One Relationships

- Some binary relationships are *many -one* from one entity set to another .
- Each entity of the first set is connected to at most one entity of the second set.
- But an entity of the second set can be connected to zero, one, or many entities of the first set.

One-One Relationships

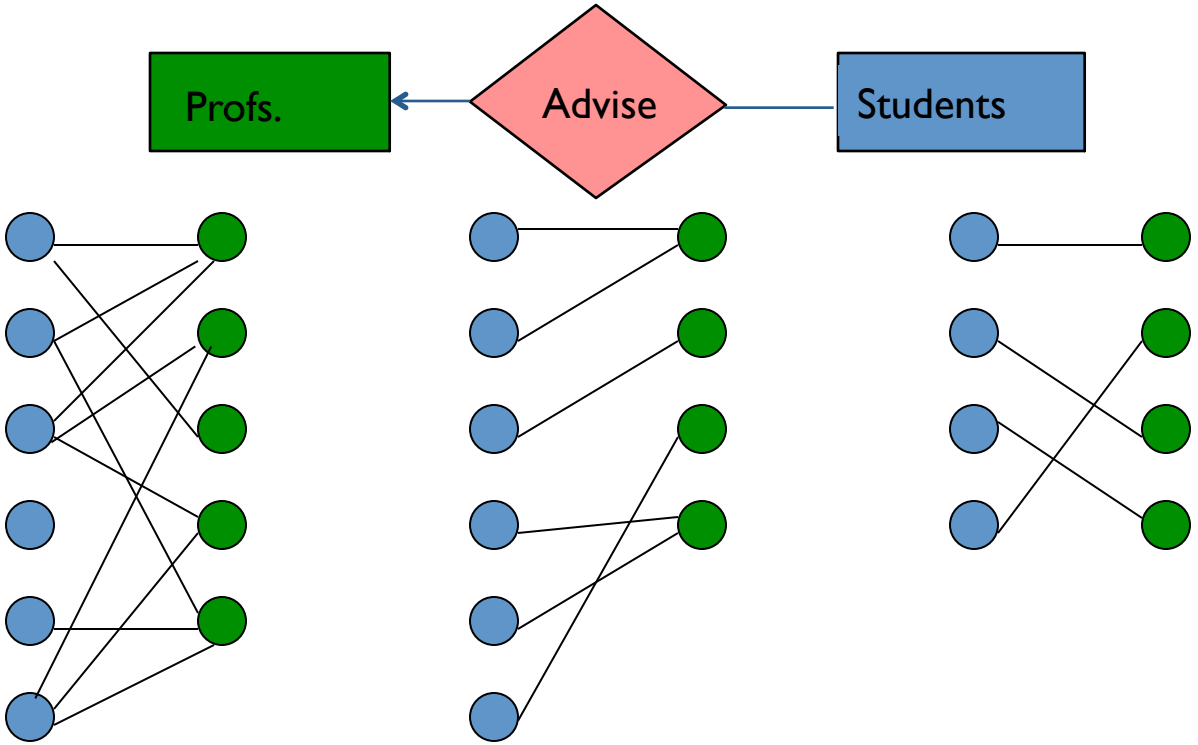
- In a one-one relationship, each entity of either entity set is related to at most one entity of the other set.

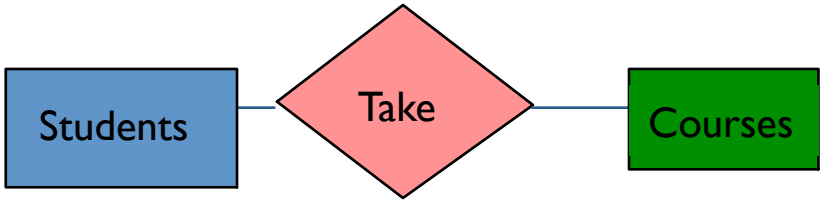
- The schema defines the multiplicity of relationships. Don't use the instances of the schema to determine multiplicity.

Representing "Multiplicity"

- Show a many-one relationship by an arrow entering the "one" side.
- Show a one-one relationship by arrows entering both entity sets.

Different kinds of relationships





Exactly one

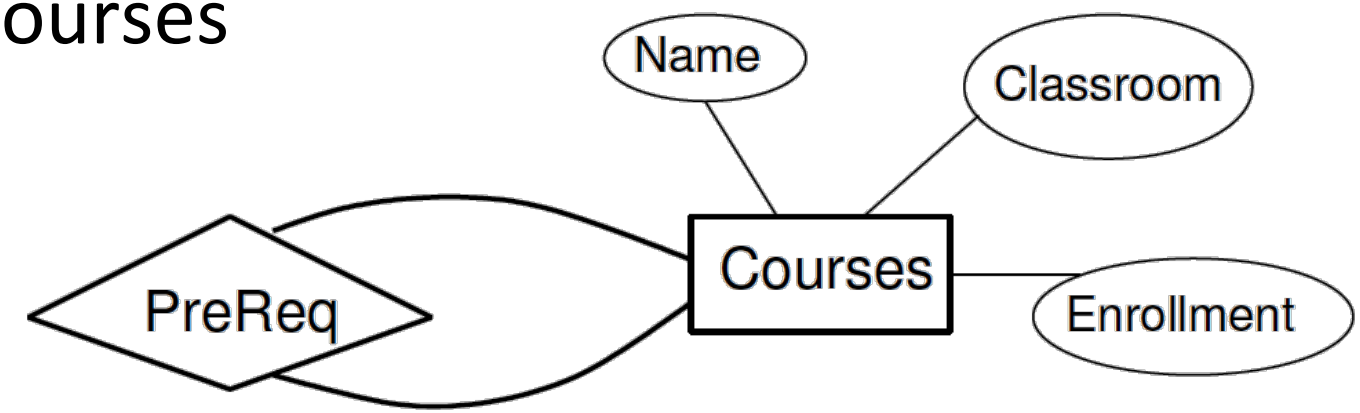
- In some situations, we can also assert "exactly one," i.e., each entity of one set must be related to exactly one entity of the other set. To do so, we use a rounded arrow.

Example: Exactly One

- Consider *Best-course* between *Profs* and *Courses*.
- Some courses are not the best-course of any professor, so a rounded arrow to *Profs* would be inappropriate.
- But a professor has to have a best-course

Roles in Relationships

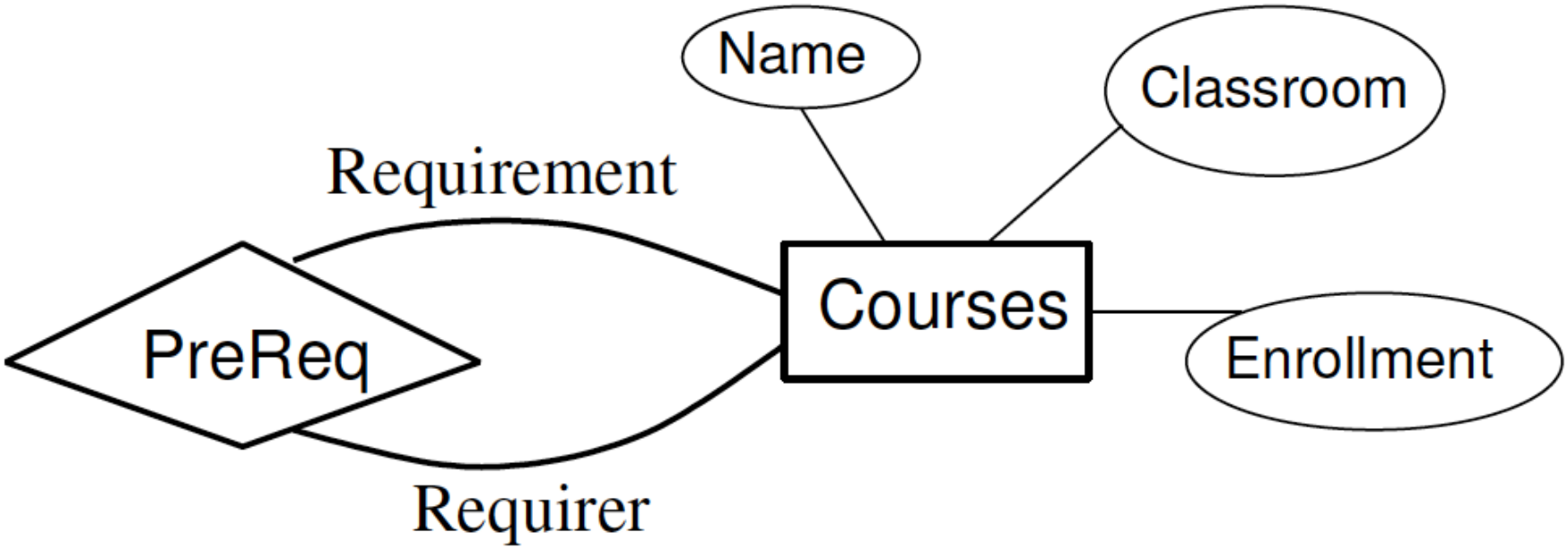
- Can the same entity set appear more than once in the same relationship?
- Prerequisite relationship between two Courses



- But which course is the pre-req?

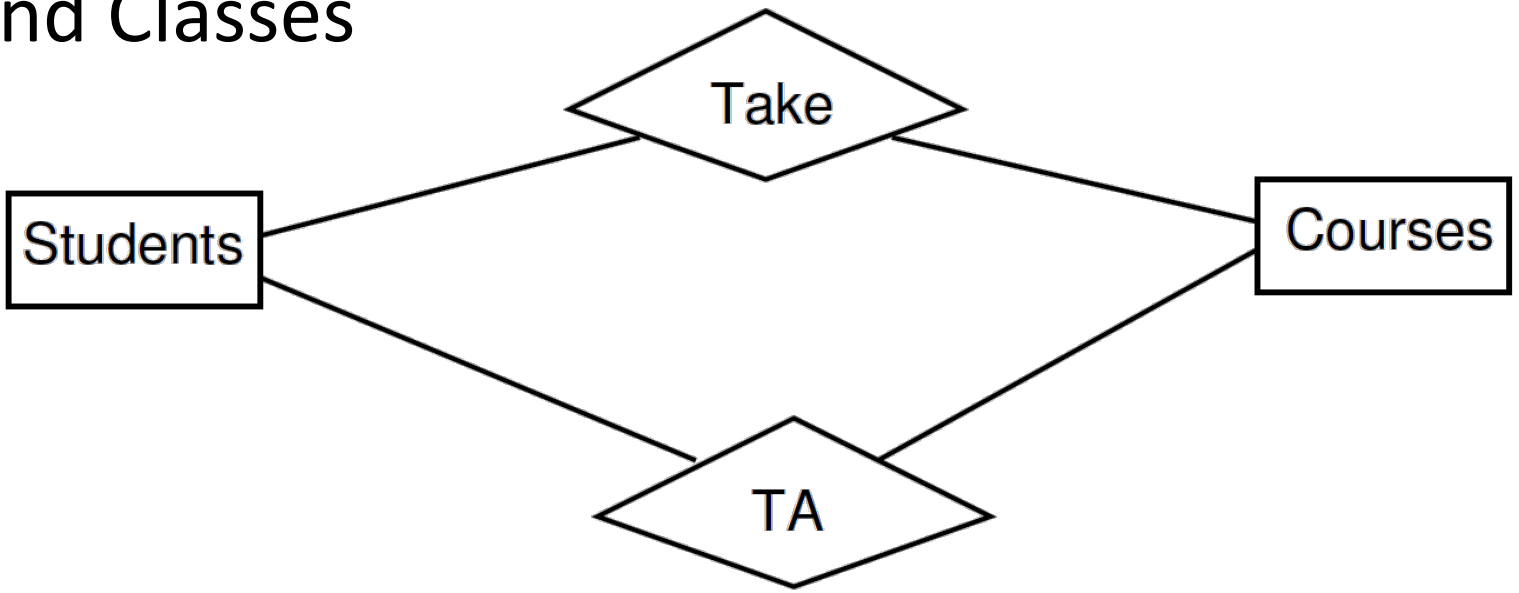
Roles in Relationships

- Label the connecting lines with the *role* of the entity

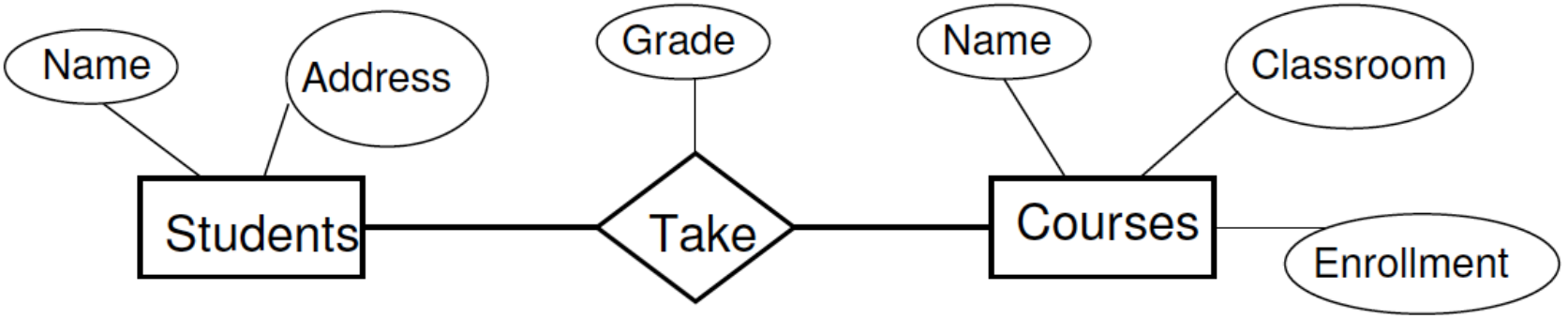


Parallel Relationships

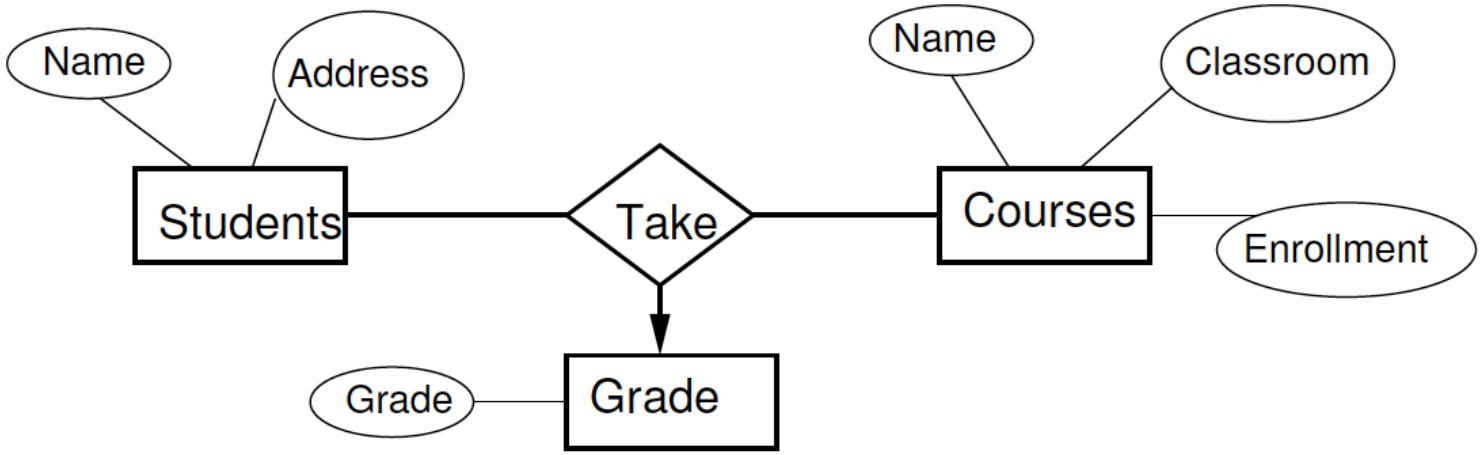
- Can there be more than one relationship between the same pair of entities?
- TA and Take relationship between Students and Classes



Are Attributes on Relationships Needed



- Attribute on relationship → Attribute to an entity and make relationship multi-way



Entity vs. attribute

- Entity EMPLOYEE (w/ emp#, name, job_code, ...)
- Q: How about ‘spouse’ - entity or attribute?

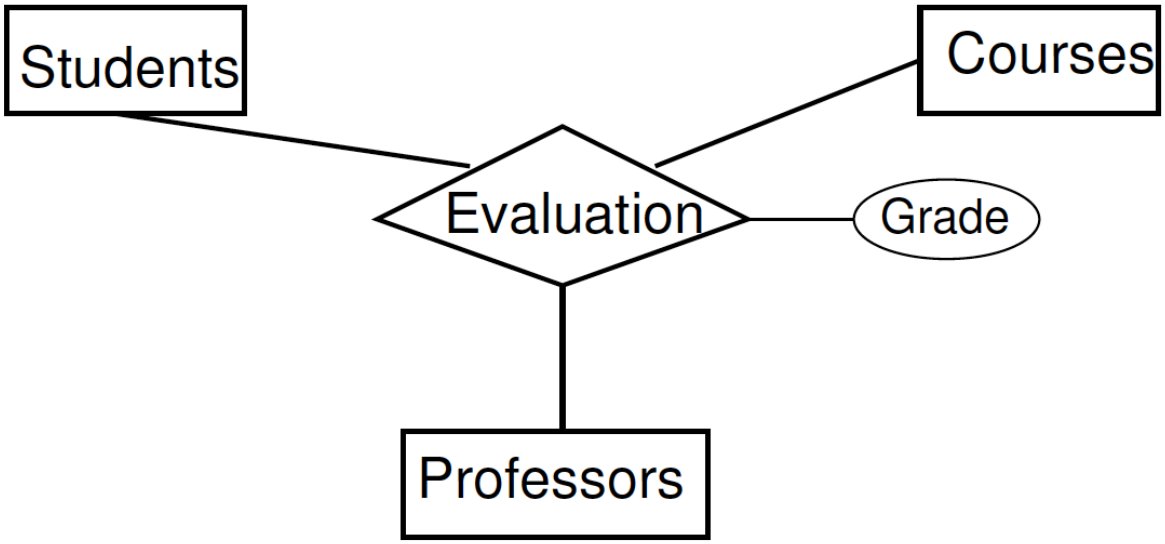
- Q: How about ‘dependents’ ?

Entity vs. attribute

- Entity EMPLOYEE (w/ emp#, name, job_code, ...)
- Q: How about ‘spouse’ - entity or attribute?
- A: probably, ‘attribute’ is enough
- Q: How about ‘dependents’?
- A: Entity - we may have many dependents

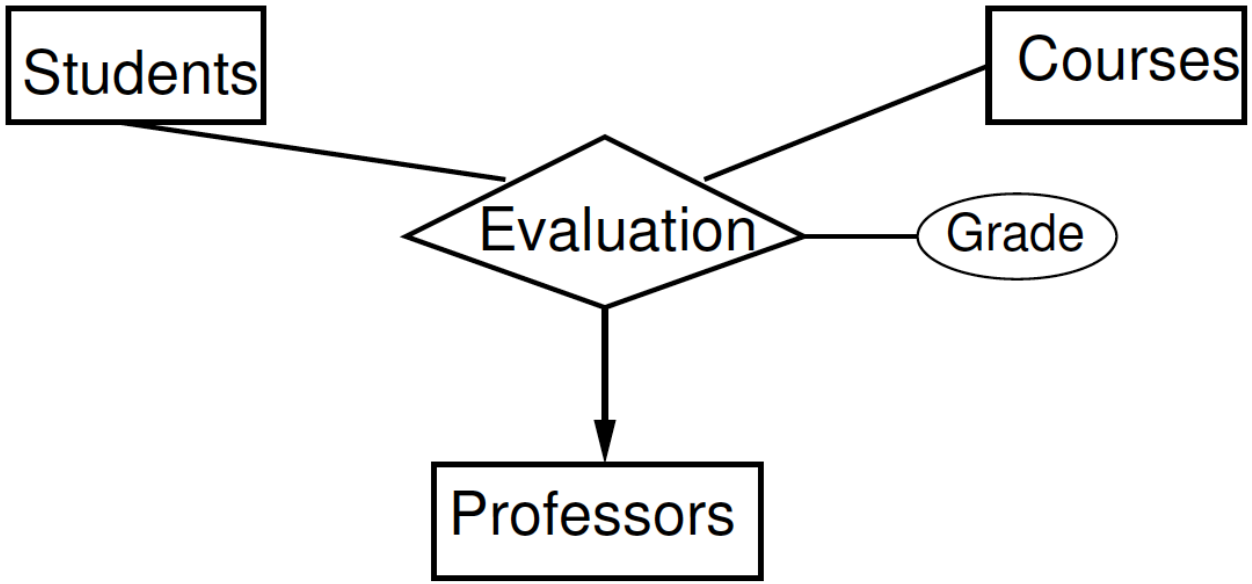
Multi-way Relationships

- Relationships may connect more than 2 entity sets
- >= 1 professor can teach a course but each student evaluates each professor separately
- Three-way Evaluation relationship between Students, Professors, and Classes



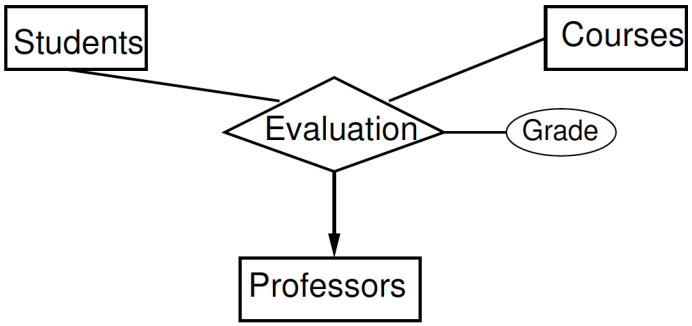
Multi-way Relationships

- >= 1 professor can teach a course but each student taught by at most one professor, and each student only evaluates that professor
- Add arrow directed towards Professors



Multiplicity in Multiway Relationships

- An arrow pointing to an entity set E => if we select an entity from each of the other entity sets, the selected entities are related to at most one entity in E



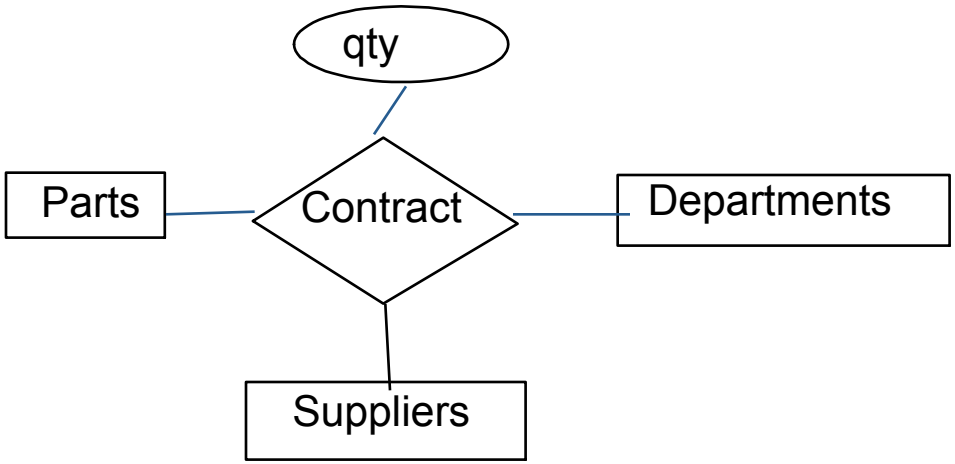
Student	*Course*	*Professor*	*Grade*
Hermione Grainger	Potions	Snape	F-
Draco Malfoy	Potions	Snape	A*
Harry Potter	Potions	Lupin	A+
Ron Weasley	Potions	Lupin	B+

- E/R diagram forbids connections between “Hermione Grainger”, “Potions" and two different professors.

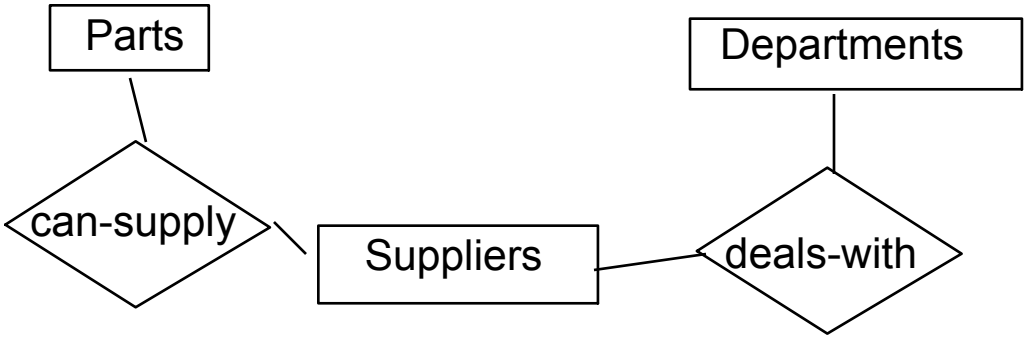
Binary vs Ternary Rel.

- Can a ternary rel. be replaced by binary rels?

Attempt 1

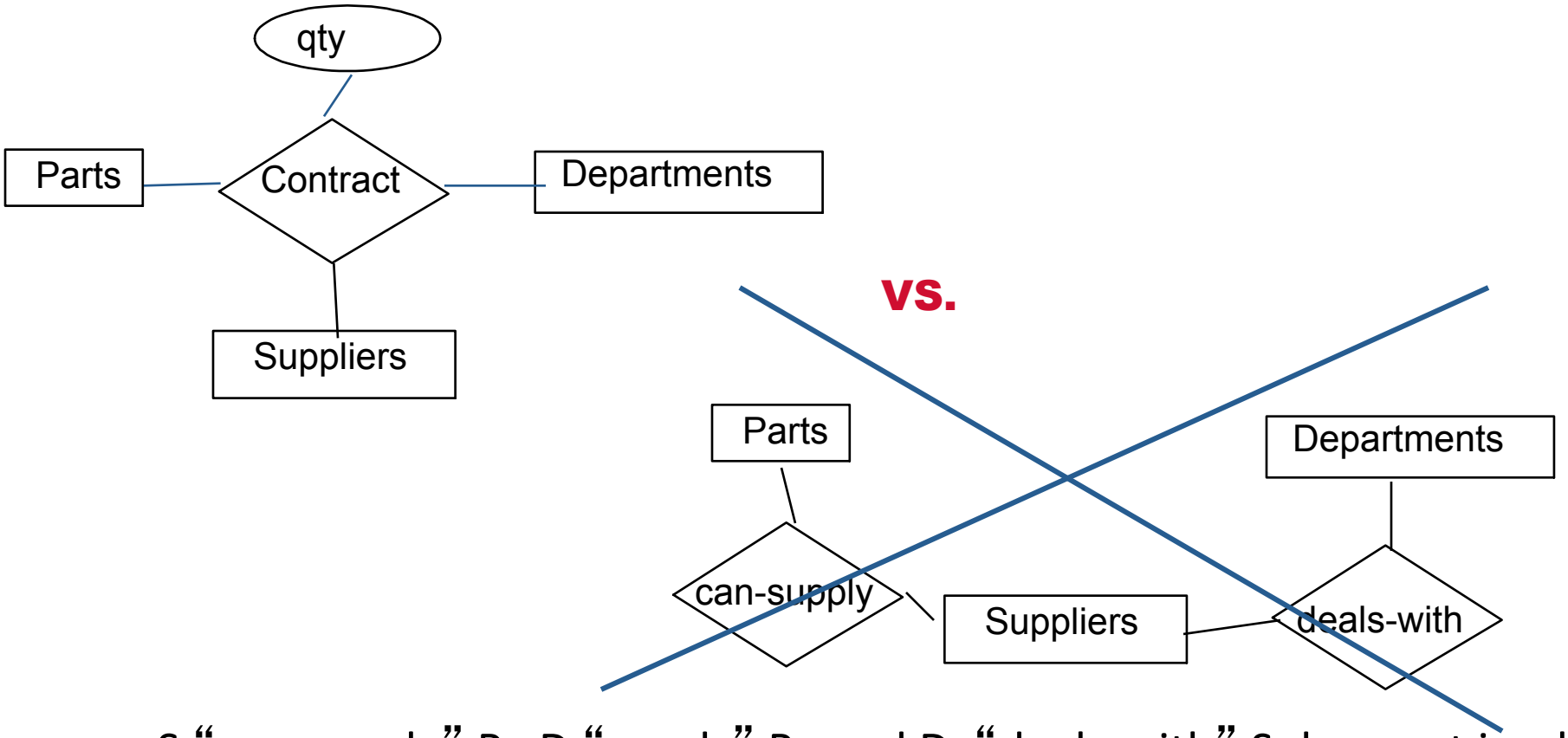


vs.



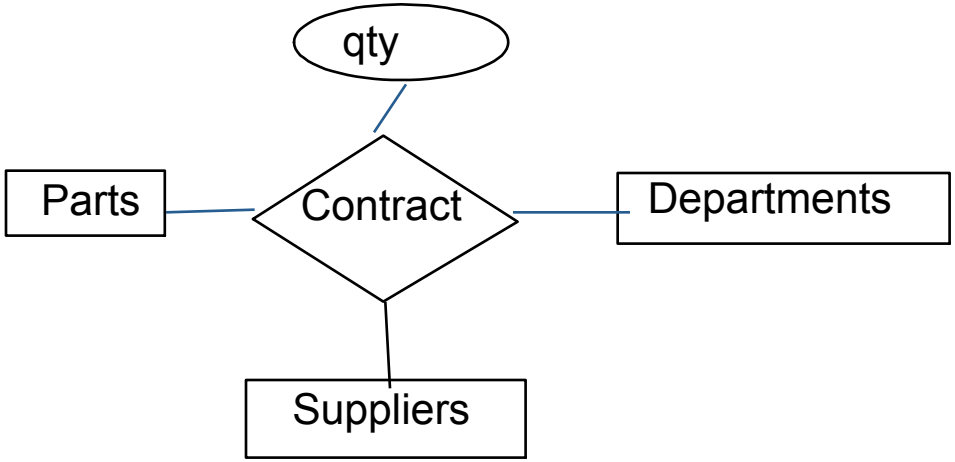
Is this OK?

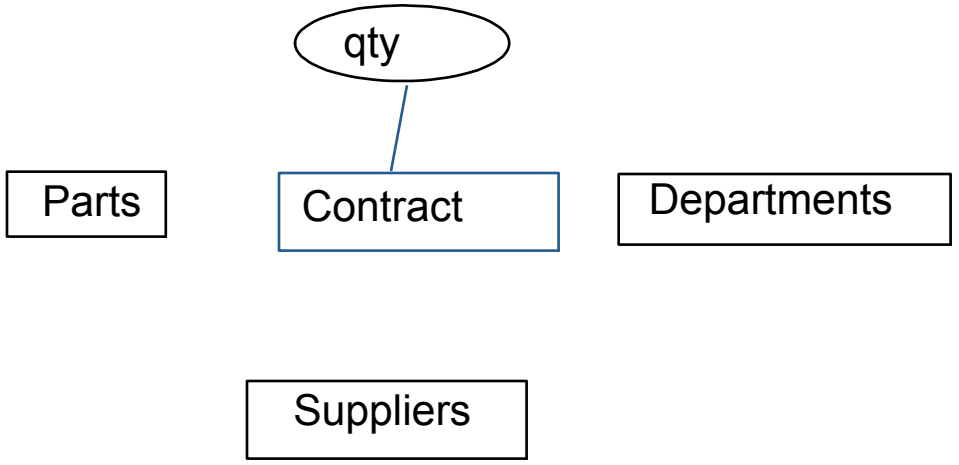
Attempt 1: contd.



- S "can-supply" P, D "needs" P, and D "deals-with" S does not imply that D has agreed to buy P from S.
- How do we record *qty*?

Attempt 2


qty
Parts
Contract
Departments
Suppliers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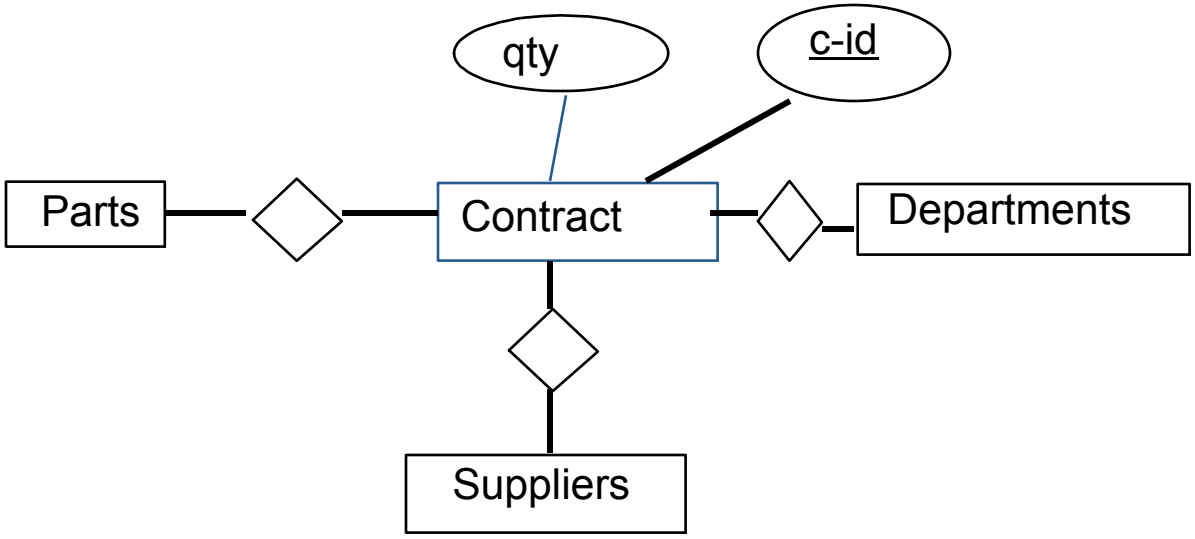
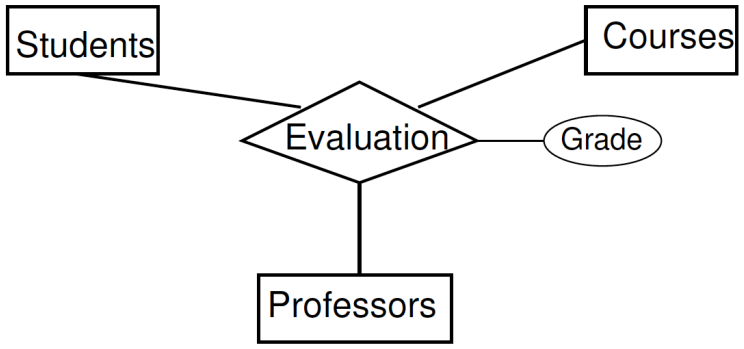
Attempt 2: contd



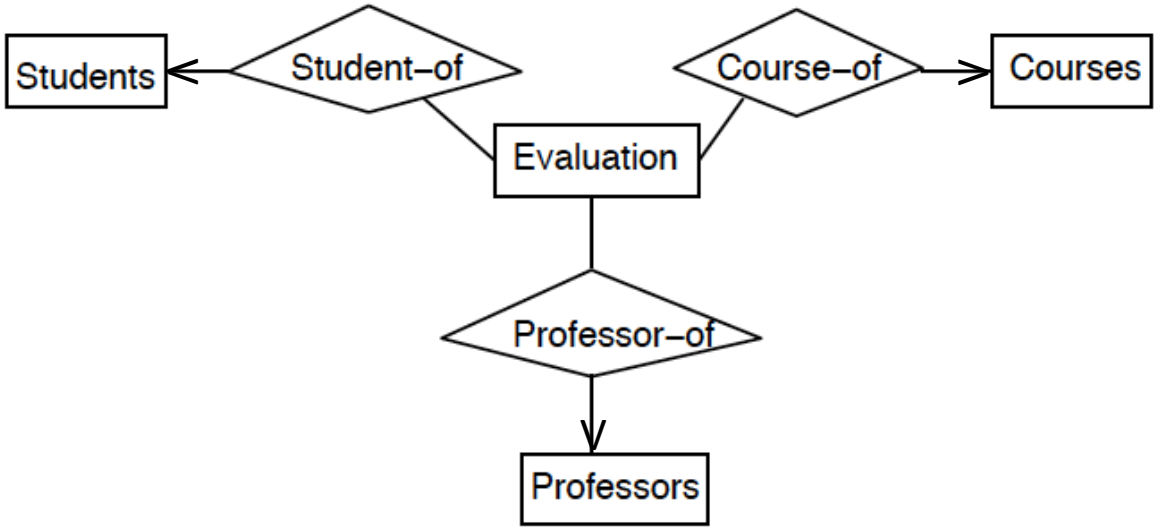
Converting Multiway to Binary

- It is easy to convert a multiway relationship to multiple binary relationships
  - Create a new connecting entity set. Think of its entities as the tuples in the relationship set for the multiway relationship
  - Introduce relationships from the connecting entity set to each of the entities in the original relationship
  - If an entity set plays > 1 role, create a relationship for each role

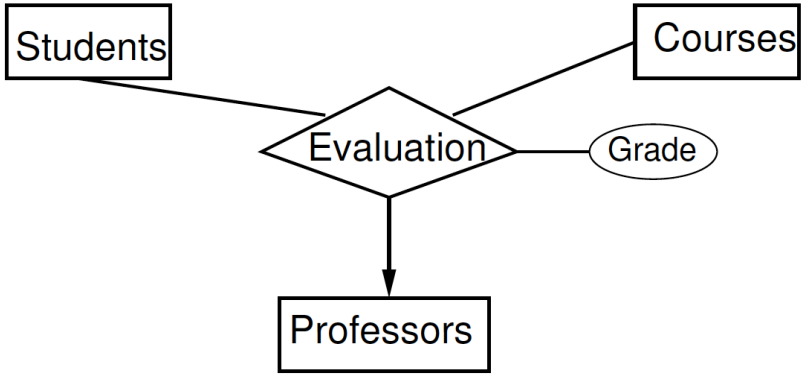
Converting Multiway to Binary



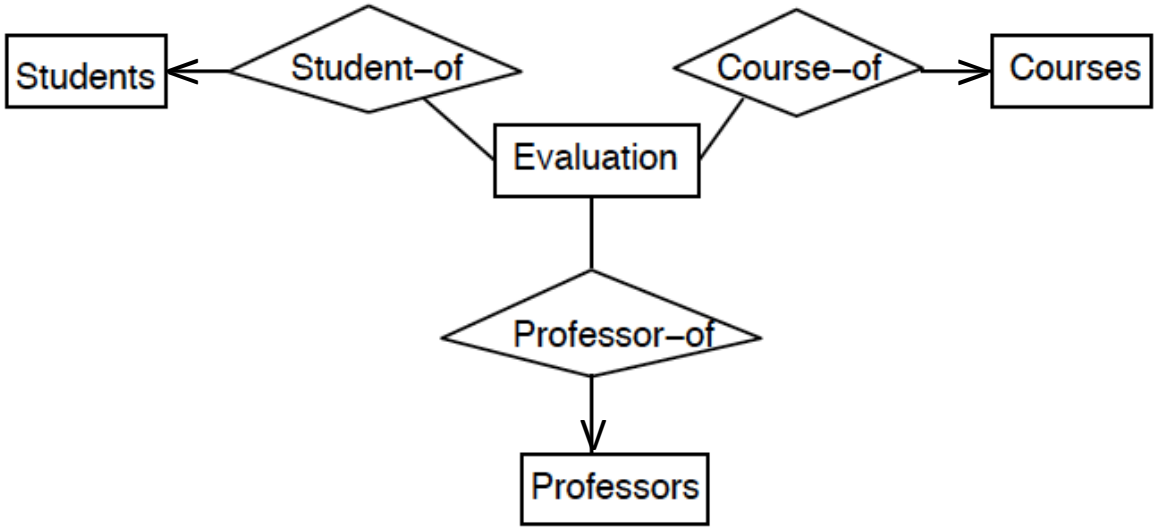
Equivalent:



Converting Multiway to Binary



Not exactly equivalent, but can be made so by additional FDs.



Example of the Conversion

- Instance of Evaluation (ternary) relationship before conversion:

Student	*Course*	*Professor*	*Grade*
Hermione Grainger	Potions	Snape	F-
Draco Malfoy	Potions	Snape	A*
Harry Potter	Potions	Lupin	A+
Ron Weasley	Potions	Lupin	B+

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- **After**

Evaluation entity set

Eval_Id	*Grade*
e1	F-
e2	A*
e3	A+
e4	B+

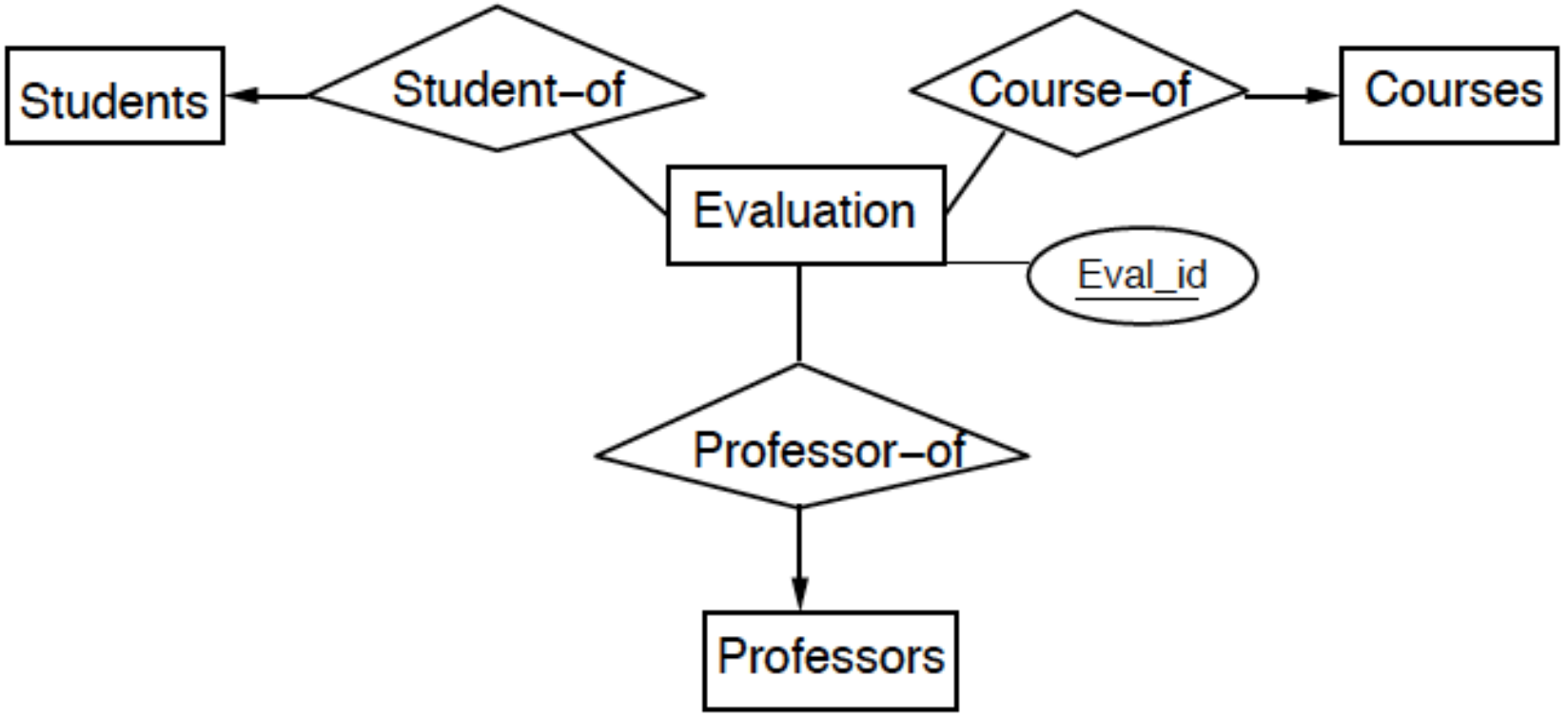
Student_of entity set

Eval_Id	Student
e1	Hermione Grainger
e2	Draco Malfoy
e3	Harry Potter
e4	Ron Weasley

Details of the Conversion

- Create an entity in the new Evaluation entity set for each instance (row) in the ternary Evaluation relationship.
- In the Student_of relationship, relate each entity in the Evaluation entity set with the corresponding student entity.
- How many students can the Student_of relationship relate an Evaluation entity to?
  - Only one!
- Therefore, the multiplicity of Student_of is many-to-one from Evaluation to Student.

Conversion


Students
Student–of
Course–of
Courses
Evaluation
Eval_id
Professor–of
Professors

Subclasses: Example

- University Employees, Handout 2 (will be released next week)

All employees have a unique ID. In addition to professors, universities also employ staff. The university pays all its employees a salary. Professors come in three flavors: 9-month appointees, calendar year appointees, and research professors. Each 9-month appointee and research professor has a grant that pays part of the employee's salary. Calendar year and 9-month professors teach classes while research professors do not.

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Someone from staff IS A employee
A Professor IS A employee
A Research Professor IS A Professor
A Teacher IS A Professor
A 9-month appointee IS A ??

Subclasses: Example

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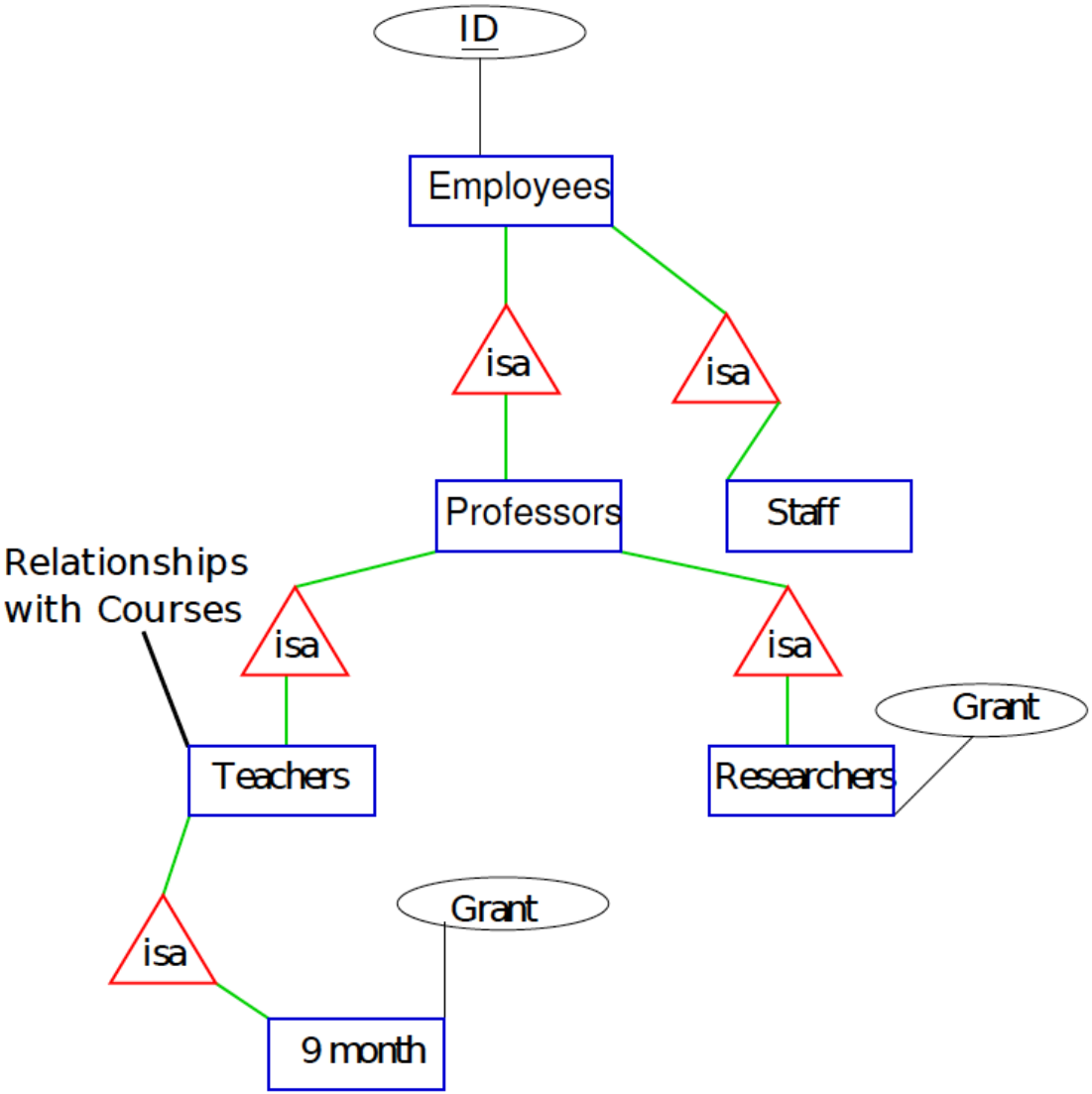
Subclasses: Example

- University Employees, Handout 2



Subclasses in the E/R Model

- A subclass of an entity set E is an entity set F such that
  - each entity in F is an entity in E
  - the entity set F must have at least one attribute or participate in at least one relationship that E does not
- Connect E to F using an *isa* relationship denoted by a triangle
- Convention is to draw E above F
- Each *isa* relationship is one-one but we do not draw the arrows.
- The set of *isa* relationships must form a tree.

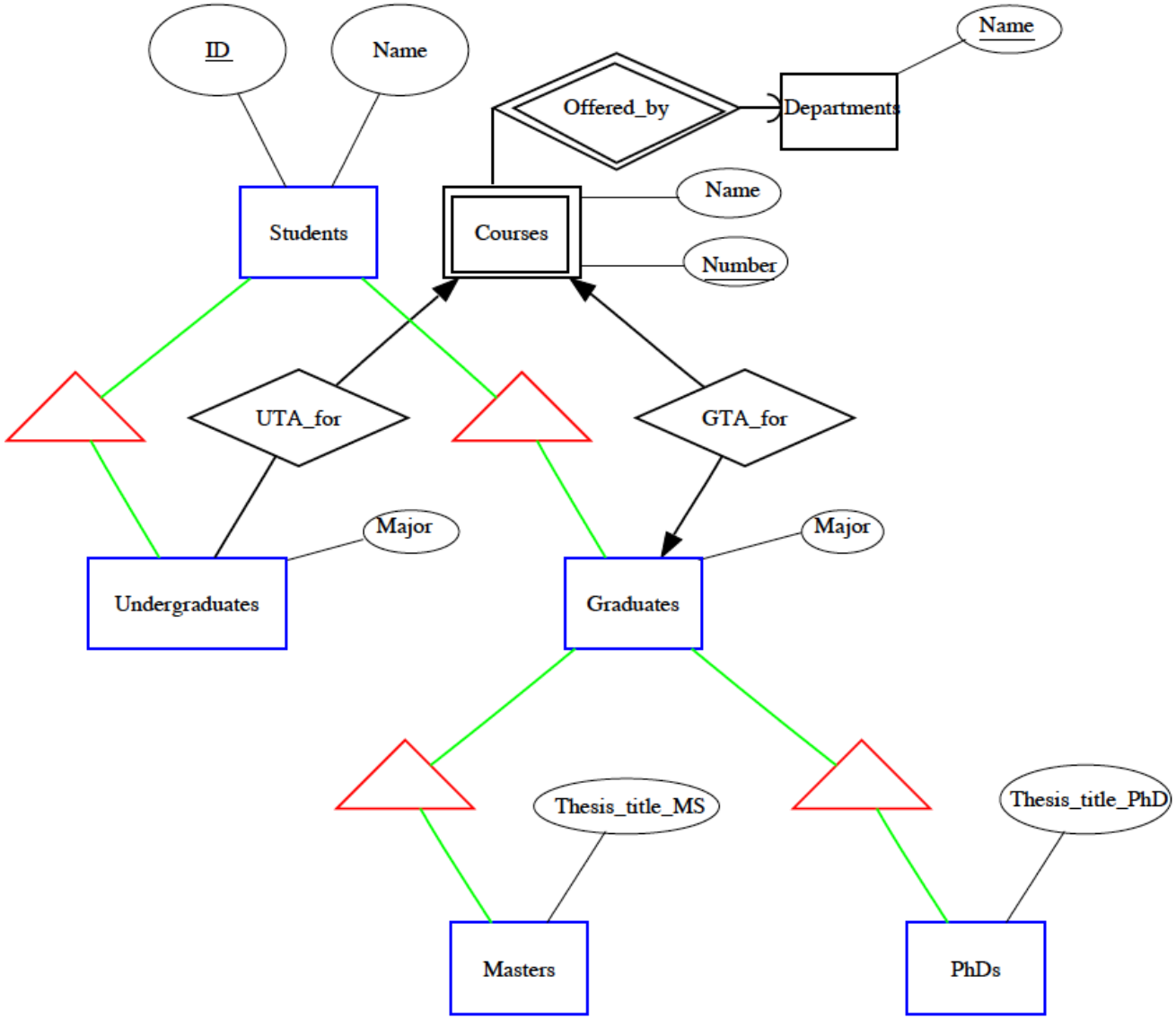
Subclasses: Example

- University Students, Handout 2

Students enrolled in a university can be either undergraduates or graduates. Graduate students can be enrolled either in a Masters or a Ph.D. program. Each graduate student must submit a thesis. The thesis can be uniquely identified by its title. Each student can be a TA for at most one course. Furthermore, a course can have at most one graduate student as a TA (it may have multiple undergraduate TAs).

Subclasses: Example

- University Students, Handout 2

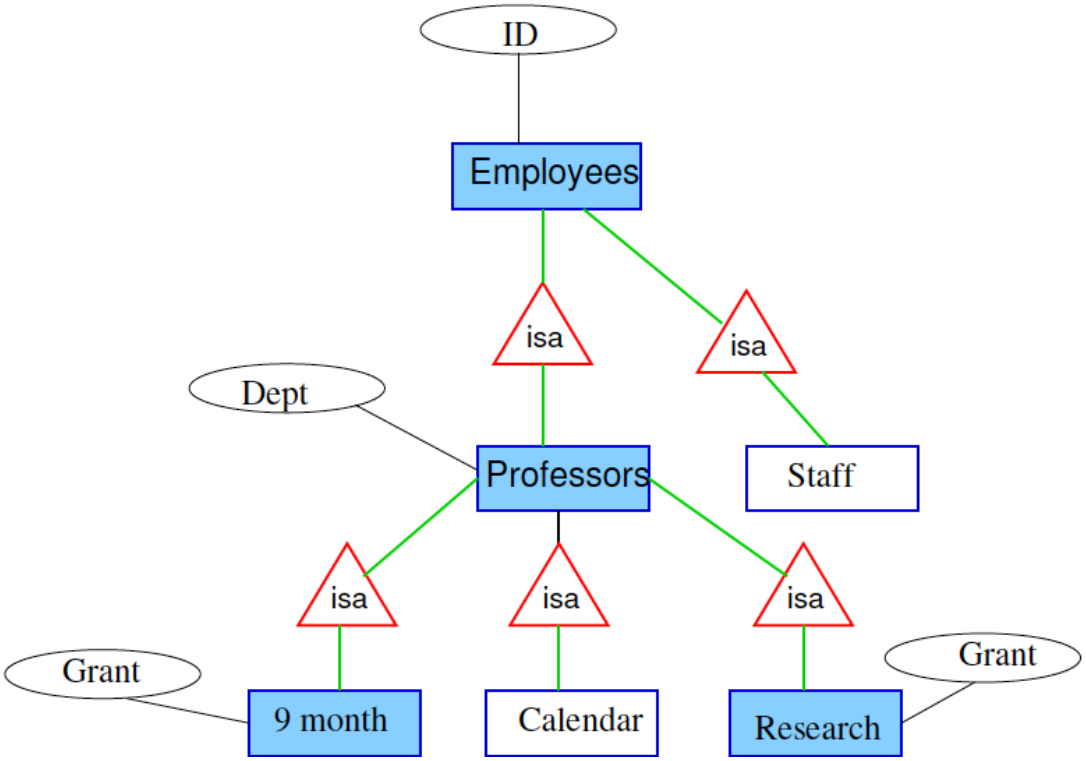


E/R vs. OO Subclasses

- In object-oriented programming languages, each object is in only one class.
  - A subclass inherits variables and methods from the superclasses.
- In an E/R diagram, an entity has components in all the subclasses to which it belongs
  - If an entity *e* has a component in an subclass, then *e* has a component in the superclass
  - Does *e* have a component in the root?
  - The attributes of *e* are the union of the attributes of its components
  - *e* participates in all the relationships its components participate in

Components of an Entity

- Prof. Fingers InMany Pies has a 9-month appointment, teaches in one semester every year, and does not teach in the other semester.
- In the other semesters, his research grant pays his salary.
- Which entity sets does he have components in? (using a different *isa* hierarchy than before)



Components of an Entity

- How do we represent students enrolled in combined Bachelors-Masters programs?
- Such a student has components in multiple entity sets

Components of an Entity

- Such a student has components in multiple entity sets