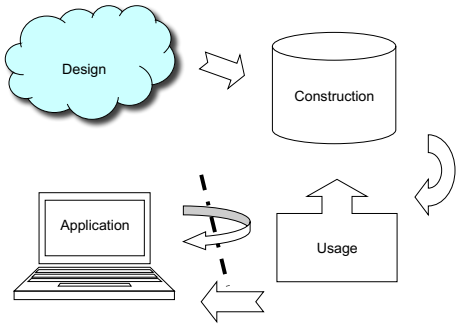
Lecture 2

Database design

The Entity-Relationship model

Course Objectives



The Entity-Relationship approach

- Design your database by drawing a picture of it – an *Entity-Relationship diagram*
  - Allows us to sketch the design of a database informally (which is good when communicating with customers)
- Use (more or less) mechanical methods to convert your diagram to relations.
  - This means that the diagram can be a formal specification as well

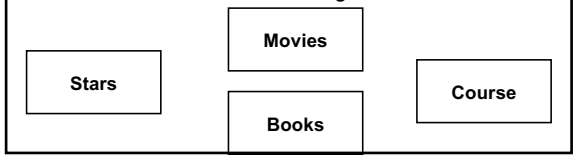
ER BASICS

E/R Model

- Three main element types:
  - Entity sets
  - Attributes, and
  - Relationships

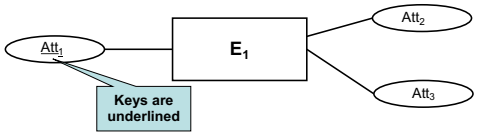
Entity Sets

- *Entity* = object that exists and distinguishable from other entities
  - course, room, person, customers, books, etc.
- *Entity set* = collection of similar entities
  - all courses, all rooms etc.
- Entities are drawn as rectangles



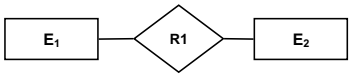
Attributes

- Entity sets have the same attributes (though not the same values)
- Attributes are drawn as ovals connected to the entity by a line.

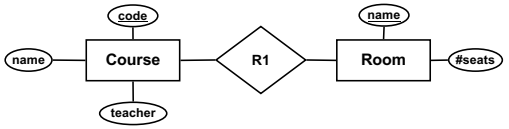


Relationships

- A relationship is an association among several entities
- Drawn as a diamond between the related entities, connected to the entities by lines.
- Note: Relationship ≠ Relation!!

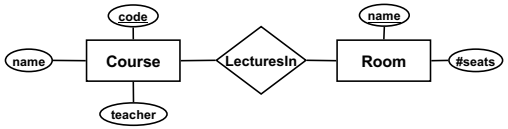


Examples:



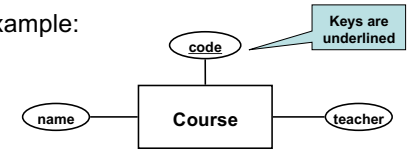
- A course has lectures in a room.
- A course is related to a room by the fact that the course has lectures in that room.
- Both entities are related through the relationship named ”R1”

Example:



- A course has lectures in a room.
- A course is related to a room by the fact that the course has lectures in that room.
- A relationship is often named with a verb form (LecturesIn)

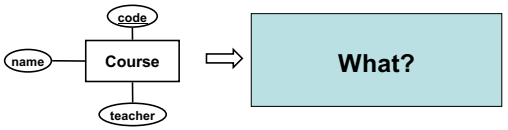
Example:



- A course has three attributes – the unique course code, a name and the name of the teacher.
- All course entities have values for these three attributes, e.g. (TDA357, Databases, Mickey).

Translation to relations

- An E-R diagram can be mechanically translated to a relational database schema.
- An entity becomes a relation, the attributes of the entity become the attributes of the relation, keys become keys.



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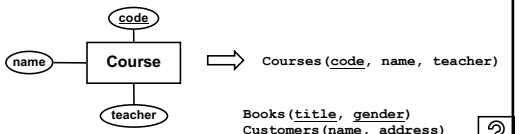


⇨ `Courses(code, name, teacher)`

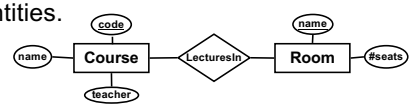
```
Books(title, gender)
Customers(name, address)
Movies(title, star, lenght)
```

A note on naming policies

- My view: A rectangle in an E-R diagram represents an entity, hence it is put in singular (e.g. Course).
  - Fits the intuition behind attributes and relationships better.
- The book: A rectangle represents an entity set, hence it is put in plural (e.g. Courses)
  - Easier to mechanically translate to relations.

Translation to relations

- A relationship between two entities is translated into a relation, where the attributes are the *keys* of the related entities.



⇨ **What?**

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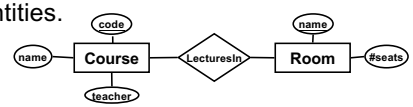


⇨

```
Courses(code, name, teacher)
Rooms(name, #seats)
LecturesIn(code, name)
```

References

```
Courses(code, name, teacher)
Teacher(name, #seats)
LecturesIn(code, name)
```

- We must ensure that the codes used in **`LecturesIn`** matches those in **`Courses`**.
  - Introduce *references* between relations.
  - e.g. the course codes used in **`LecturesIn`** *reference* those in **`Courses`**.

```
Courses(code, name, teacher)
Rooms(name, #seats)
LecturesIn(code, name)
  code  -> Courses.code
  name -> Rooms.name
```

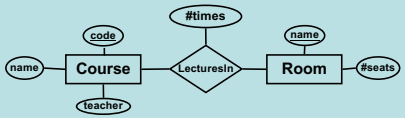
References

”Foreign” keys

- Usually, a reference points to the key of another relation.
  - E.g. **`name`** in **`LecturesIn`** references the key **`name`** in **`Rooms`**.
  - **`name`** is said to be a *foreign key* in **`LecturesIn`**.

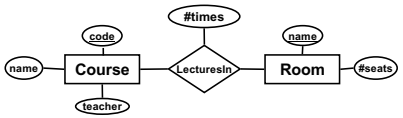
Quiz

Suppose we want to store the number of times that each course has a lecture in a certain room. How do we model this?



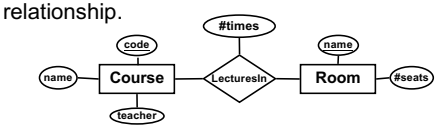
Attributes on relationships

- Relationships can also have attributes.
- Represent a property of the relationship between the entities.
  - E.g. **`#times`** is a property of the relationship between a course and a room.



Translation to relations

- A relationship between two entities is translated into a relation, where the attributes are the *keys* of the related entities, plus any attributes of the relationship.



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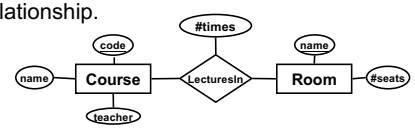
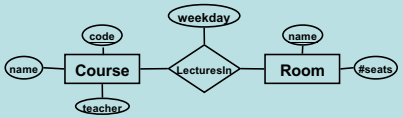


⇨

```
Courses(code, name, teacher)
Room(name, #seats)
LecturesIn(code, name, #times)
  code  -> Courses.code
  name -> Rooms.name
```

Quiz

Why could we not do the same for weekday?



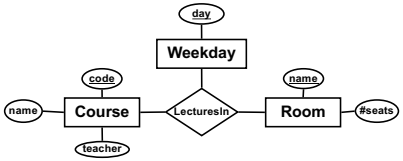
- Not a property of the relationship – a course can have lectures in a given room on several weekdays!
- A pair of entities are either related or not.

Relationship (non-)keys

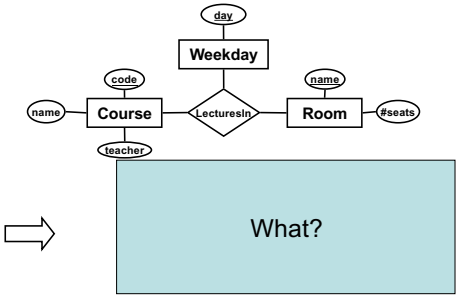
- Relationships have no keys of their own!
  - The ”key” of a relationship is the combined keys of the related entities
  - Follows from the fact that entities are either related or not.
  - If you at some point think it makes sense to put a key on a relationship, it should probably be an entity instead.

Multiway relationships

- A course has lectures in a given room on different weekdays.

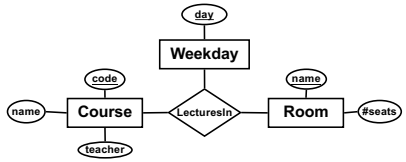


- Translating to relations:



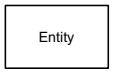
What?

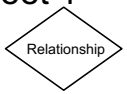
- Translating to relations:




```
Courses(code, name, teacher)
Rooms(name, #seats)
Weekdays(day)
LecturesIn(code, name, day)
  code  -> Courses.code
  name -> Rooms.name
  day   -> Weekdays.day
```

ER Cheatsheet 1





ENTITY = noun/thing
- Exist on their own
- Have their own keys

RELATIONSHIP = verb
- Only exist in relation to an entity
- No own keys, only foreign keys
- Reference the entity keys with ->

```
Course(code, name, teacher)
Room(name, #seats)
Weekday(day)
```

```
HasLecturesIn(code,name,day,#times)
   code -> Course.code
   name -> Room.name
   day -> Weekday.day
```

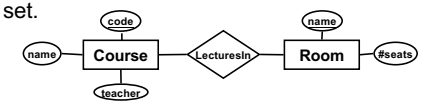
Both entities and relationships can have attributes!

attribute key

CARDINALITY

Many-to-many relationships

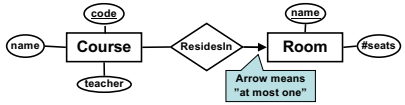
- Many-to-many (n-to-n, many-many) relationships
  - Each entity in either of the entity sets can be related to any number of entities of the other set.



  - A course can have lectures in many rooms.
  - Many courses can have lectures in the same room.

Many-to-one relationships

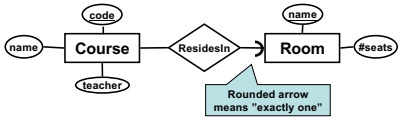
- Many-to-one (n-to-1, many-one) relationships
  - Each entity on the ”many” side can only be related to (at most) one entity on the ”one” side.



  - Courses have all their lectures in the same room.
  - Many courses can share the same room.

Many-to-”exactly one”

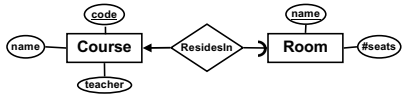
- All entities on the ”many” side *must* be related to one entity on the ”one” side.
  - This is also known as ***total participation***



  - All courses have all their lectures in some room.
  - Many courses can share the same room.

One-to-one relationships

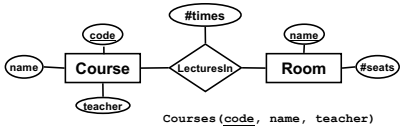
- One-to-one (1-to-1, one-one) relationships
  - Each entity on either side can only be related to (at most) one entity on the other side.



  - Courses have all their lectures in the same room.
  - Only one course in each room.
  - Not all rooms have courses in them.

Translating multiplicity

- A *many-to-many* relationship between two entities is translated into a relation, where the attributes are the *keys* of the related entities, and any attributes of the relation.

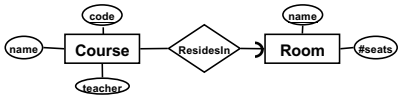


⇨

```
Courses(code, name, teacher)
Rooms(name, #seats)
LecturesIn(code, name, #times)
  code  -> Courses.code
  name -> Rooms.name
```

Translating multiplicity

- A *X-to-”exactly one”* relationship between two entities is translated as part of the ”many”-side entity.



⇨ What?

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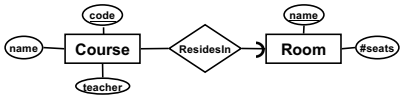
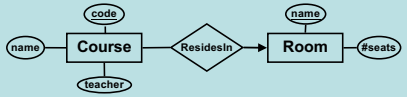


⇨

```
Courses(code, name, teacher, room)
  room -> Rooms.name
Rooms(name, #seats)
```

Quiz

How do we translate an *X-to-one* (meaning "at most one") relationship?




```
Courses(code, name, teacher, room)
Room(name, #seats)
```

or

```
Courses(code, name, teacher)
Room(name, #seats)
ResidesIn(code, room)
```

?

Aside: the NULL symbol

- Special symbol NULL means either
  - we have no value, or
  - we don't know the value
- Use with care!
  - Comparisons and other operations won't work.
  - May take up unnecessary space.

Translation comparison

```
Courses(code, name, teacher)
Rooms(name, #seats)
ResidesIn(code, room)
```

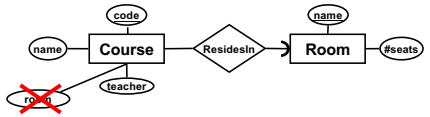
Note that "room" is not a key here (why not?)

- Safe translation - no NULLs anywhere.
- May lead to duplication of the course code.
- May lead to more *joins*.
- Default translation rule, use unless you have a good reason not to.

```
Courses(code, name, teacher, room)
Rooms(name, #seats)
```

- Will lead to NULLs for courses that have no room.
- Can sometimes be preferred when *not* having a room is an uncommon exception to the rule.
- Reduces the need for *joins*.

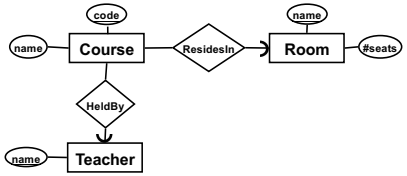
Bad E-R design



- Room is a related entity – not an attribute as well!
- E-R modelling error #1 – don't do this!!

Attribute or related entity?

What about teacher? Isn't that an entity?



Quiz!

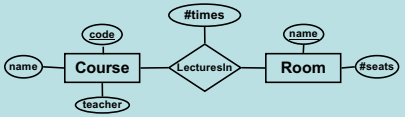
When should we model something as an entity in its own right (as opposed to an attribute of another entity)?

At least one of the following should hold:

- Consists of more than a single (key) attribute
- Used by more than one other entity
- Part of an X-to-many relation as the many side
- Generally entity-ish, is important on its own

Quiz!

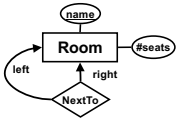
- Translate this E-R diagram to relations




```
Courses(code, name, teacher)
Rooms(name, #seats)
LecturesIn(course, room, #times)
  course -> Courses.code
  room   -> Rooms.name
```

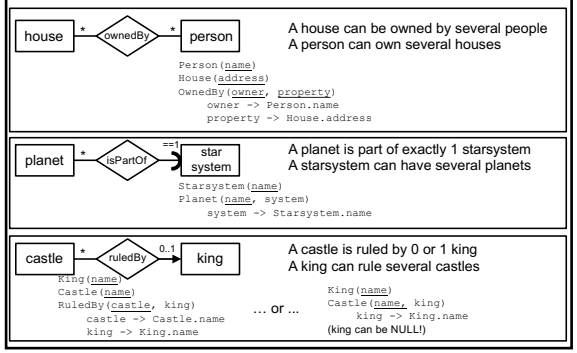
Relationships to ”self”

- A relationship can exist between entities of the same entity set.
- Use *role* annotations for attributes.




```
Rooms(name, #seats)
NextTo(left, right)
  left  -> Rooms.name
  right -> Rooms.name
```

ER Cheatsheet 2



Break! In part 2:

weak entities, subclasses,
”multivalued” and ”flag” attributes

Subclassing and weak entities

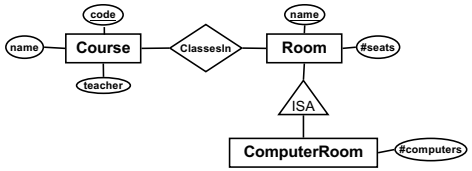
SPECIAL RELATIONSHIPS

Subclassing

- Subclass = sub-entity = special case.
- A subclass is a subset of an entity set.
- More attributes and/or relationships.
- A subclass shares the key of its parent.

- Drawn as an entity connected to the superclass by a special triangular relationship called *ISA.* Triangle points to superclass.
  - ISA = ”is a”

Example:



– A computer room *is a* room.
– Not all rooms are computer rooms.
– Computer rooms share the extra property that they have a number of computers.

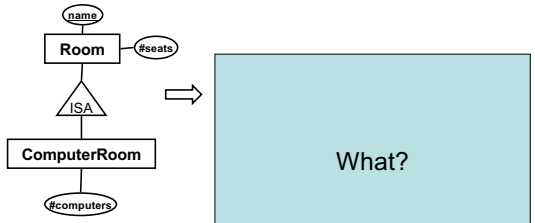
Subclass/Superclass Hierarchy

- We assume that subclasses form a tree hierarchy.
  – A subclass has only one superclass.
  – Several subclasses can share the same superclass.
    - E.g. Computer rooms, lecture halls, chemistry labs etc. could all be subclasses of Room.

Translating ISA to relations

- Standard approach:
  – An ISA relationship is a standard one-to-”exactly one” relationship. Each subclass becomes a relation with the key attributes of the superclass included.
  – Also known as the E-R approach.

The E-R approach:



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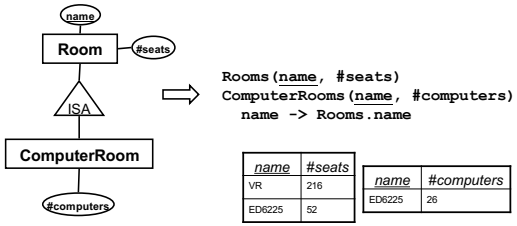


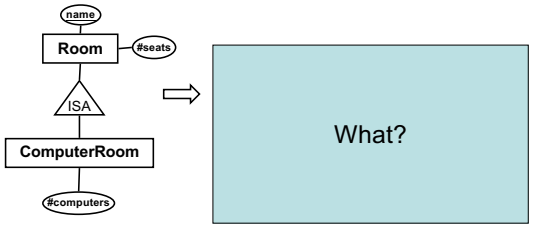
name	*#seats*
VR	216
ED6225	52

name	*#computers*
ED6225	26

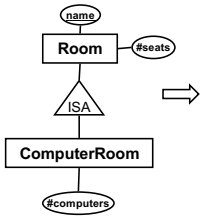
Alternate ISA translations

- Two alternate approaches
  – *NULLs:* Join the subclass(es) with the superclass. Entities that are not part of the subclass use NULL for the attributes that come from the subclass.
  – *Object-oriented:* Each subclass becomes a relation with all the attributes of the superclass included. An entity belongs to either of the two, but not both.

The NULLs approach:



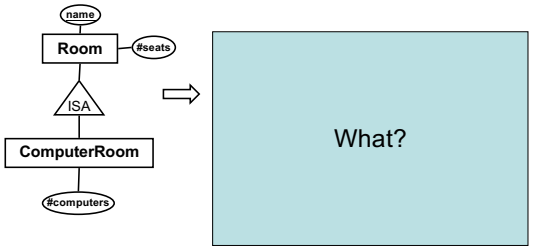
The NULLs approach:



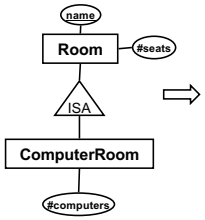
`Rooms(name, #seats, #computers)`

name	*#seats*	*#computers*
VR	216	NULL
ED6225	52	26

The object-oriented (OO) approach:



The object-oriented (OO) approach:



`Rooms(name, #seats)`
`ComputerRooms(name, #seats, #computers)`

name	*#seats*
VR	216

name	*#seats*	*#computers*
ED6225	52	26

Comparison – E-R

- E-R approach
  - Always works.
  - Use unless you have a good reason not to.

Comparison – OO

- OO approach
  - Good when searching for general information about entities in a subclass only.
    - *"List the number of seats in all computer rooms"*
  - Does *not* work if superclass has any relationships.
    - An entity belonging to the subclass does not belong to the superclass as well, so foreign keys would have no single table to refer to.

Comparison – NULLs

- NULLs approach
  - Could save space in situations where most entities in the hierarchy are part of the subclass (e.g. most rooms have computers in them).
  - Reduces the need for *joins.*
  - Not suited if subclass has any relationships.
    - Would lose the constraint that only the entities in the subclass can participate in the relationship.

Weak entities

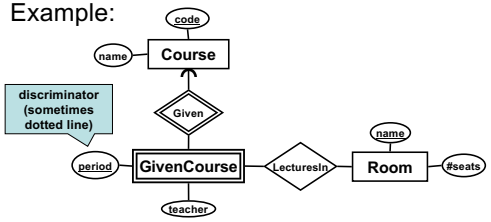
- Some entities depend on other entities.
  - A course is an entity with a code and a name.
  - A course does not have a teacher, rather it has a teacher for each time the course is given.
  - We introduce the concept of a given course, i.e. a course given in a particular period. A given course is a *weak entity*, dependent on the entity course. A given course has a teacher.

Weak entities

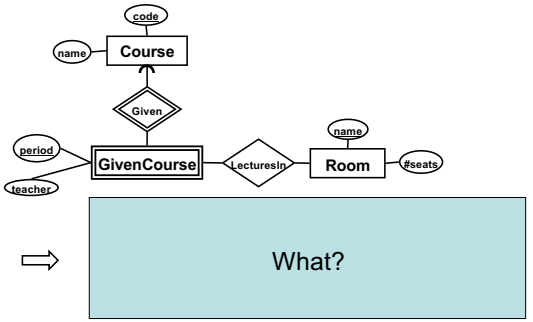
- A *weak entity* is an entity that depends on another entity for help to be ”uniquely” identified.
  - E.g. an airplane seat is identified by its number, but is not uniquely identified when we consider other aircraft. It depends on the airplane it is located in.
- Drawn as a rectangle with double borders.
- Related to its *supporting entity* by a *supporting relationship*, drawn as a diamond with double borders. This relationship is always many-to-”exactly one”.

Weak entities in E-R diagrams

Example:

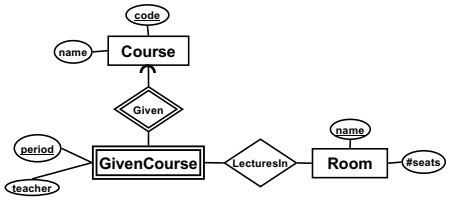


Translating to relations:



What?

Translating to relations:

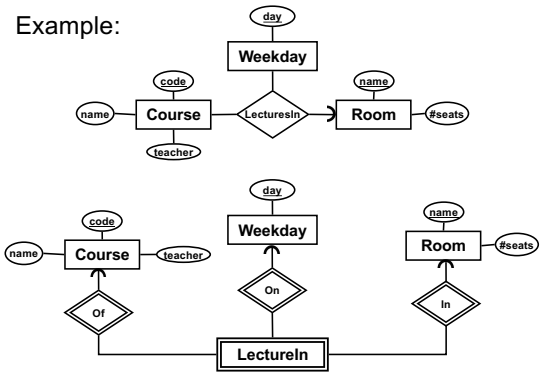



```
Courses(code, name)
GivenCourses(course, period, teacher)
  course -> Courses.code
LecturesIn(course, period, room)
  (course, period) -> GivenCourses.(course, period)
  room             -> Rooms.name
Rooms(name, #seats)
```

Multiway relationships as WEs

- Multiway relationships can be transformed away using weak entities
  - Subtitute the relationship with a weak entity.
  - Insert supporting relationships to all entities related as ”many” by the original relationship.
  - Insert ordinary many-to-one relationships to all entities related as ”one” by the original relationship.

Example:



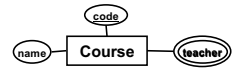
What’s the point?

- Usually, relationships work just fine, but in some special cases, you need a weak entity to express all multiplicity constraints correctly.
- A weak entity is needed when a **part** of an entity’s key is a foreign key.

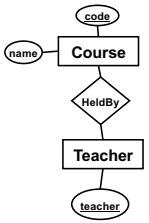
“Multivalued” attributes and “flag” attributes

THINGS NOT TO DO…

”Multivalued” attributes




```
Courses(code,name)
HeldBy(code,teacher)
  code -> Courses.code
```

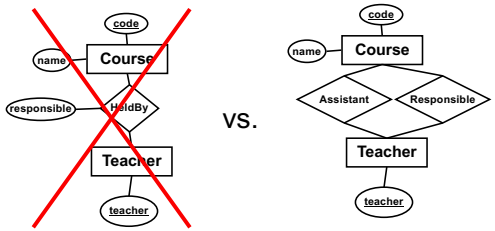



```
Courses(code,name)
Teachers(teacher)
HeldBy(code,teacher)
  code    -> Courses.code
  teacher -> Teachers.teacher
```

”Multivalued” attributes

- Inflexible if you later want more attributes on teachers.
- No guarantees against e.g. spelling errors of teacher names.
  - less flexible to insert a constraint on what values are allowed than to use an extra table.
- Tables are cheap – references are cheap
  - No reason NOT to use an entity.
- Rule of thumb: Don’t use multivalued attributes!!

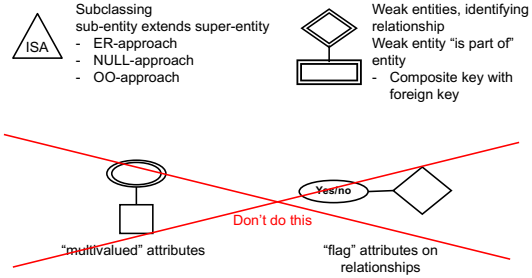
”Flag” attributes on relationships



”Flag” attributes on relationships

- Less intuitively clear.
- Inflexible if later you need more roles.
- Tables are cheap, union of two tables is a cheap operation (O(1)) – filtering can be expensive (O(n))!
- Only benefit: automatic mutual exclusion (a teacher can only be *either* responsible *or* an assistant).
  - If important, can be recovered via assertions (costly).
- Rule of thumb: Don’t use flag attributes on relationships!

ER cheatsheet 3



Next time, lecture 3

Functional Dependencies
BCNF
3NF