# Relational Database Design: E/R-Relational Translation

Introduction to Databases

CompSci 316 Fall 2022

DUKE
COMPUTER SCIENCE

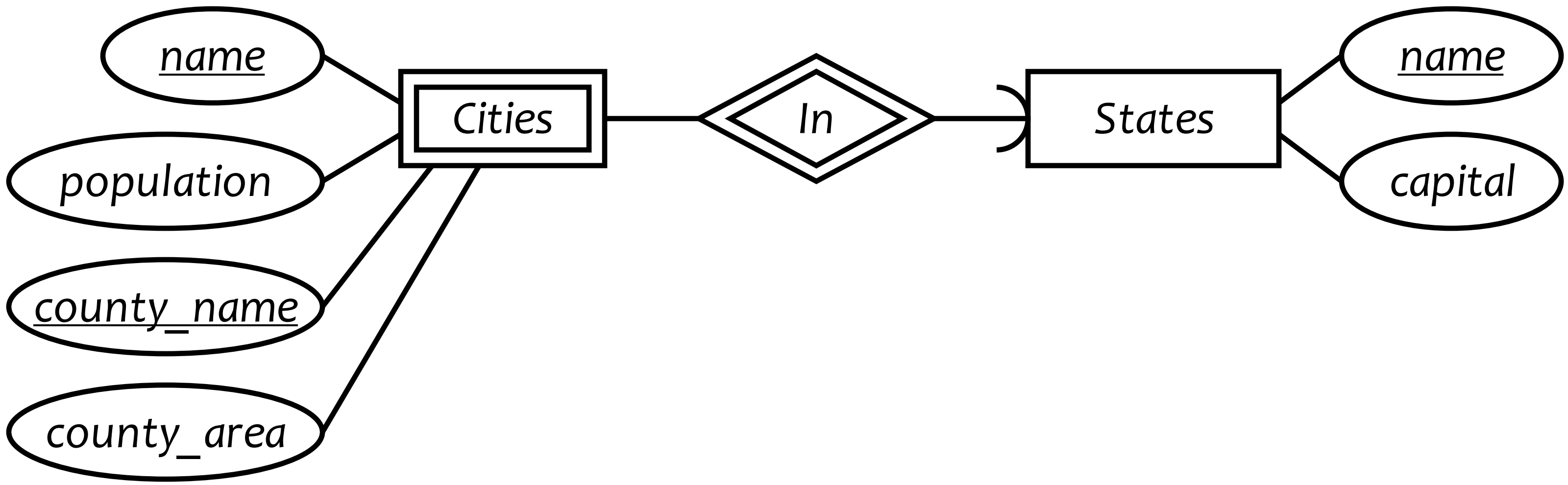
# E/R model: review

- Entity sets
  - Keys
  - Weak entity sets
- Relationship sets
  - Attributes on relationships
  - Multiplicity
  - Roles
  - Binary versus $n$-ary relationships
    - Modeling $n$-ary relationships with weak entity sets and binary relationships
  - ISA relationships

# Case study 1

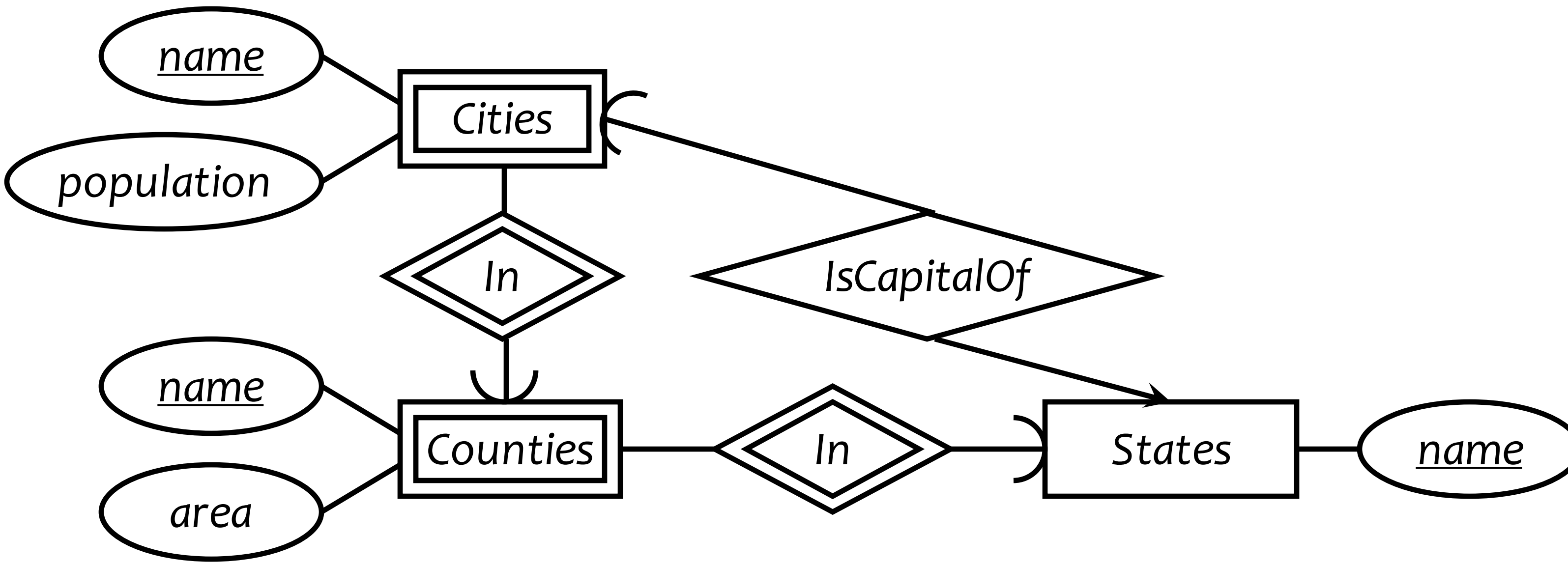
- Design a database representing cities, counties, and states
  - For states, record name and capital (city)
  - For counties, record name, area, and location (state)
  - For cities, record name, population, and location (county and state)
- Assume the following:
  - Names of states are unique
  - Names of counties are only unique within a state
  - Names of cities are only unique within a county
  - A city is always located in a single county
  - A county is always located in a single state

# Case study 1: first design




- County area information is repeated for every city in the county
  - ☞Redundancy is bad (why?)
- State capital should really be a city
  - ☞Should "reference" entities through explicit relationships

# Case study 1: second design

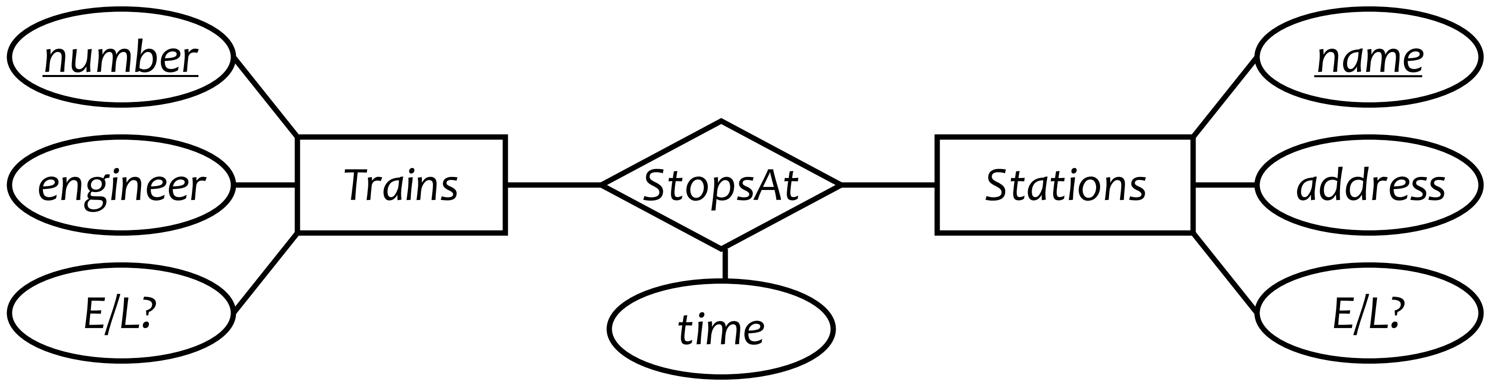



- Technically, nothing in this design prevents a city in state $X$ from being the capital of another state $Y$, but oh well…

# Case study 2

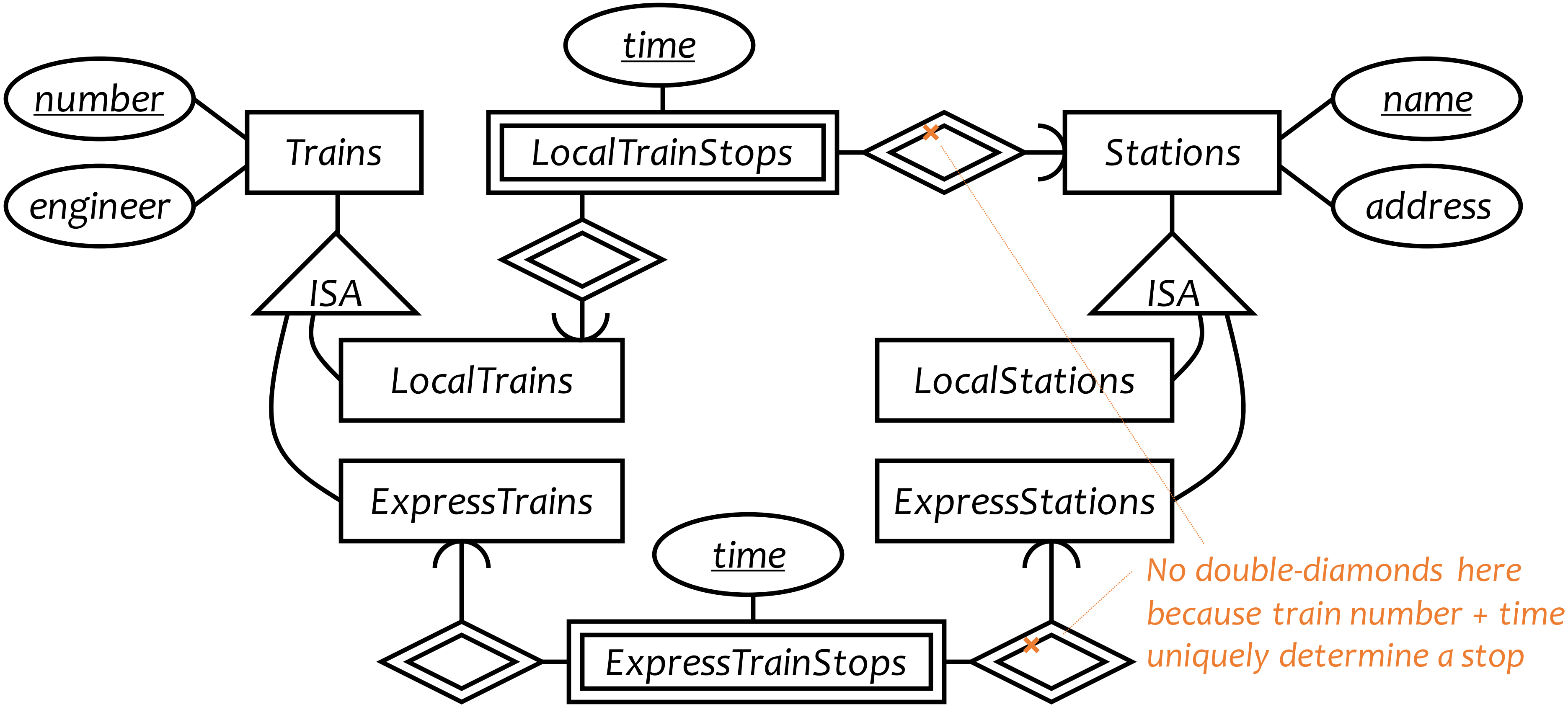
- Design a database consistent with the following:
  - A station has a unique name and an address, and is either an express station or a local station
  - A train has a unique number and an engineer, and is either an express train or a local train
  - A local train can stop at any station
  - An express train only stops at express stations
  - A train can stop at a station for any number of times during a day
  - Train schedules are the same every day

# Case study 2: first design




- Nothing in this design prevents express trains from stopping at local stations
  - ☞We should capture as many constraints as possible
- A train can stop at a station only once during a day
  - ☞We should not introduce unintended constraints

# Case study 2: second design




Is the extra complexity worth it?

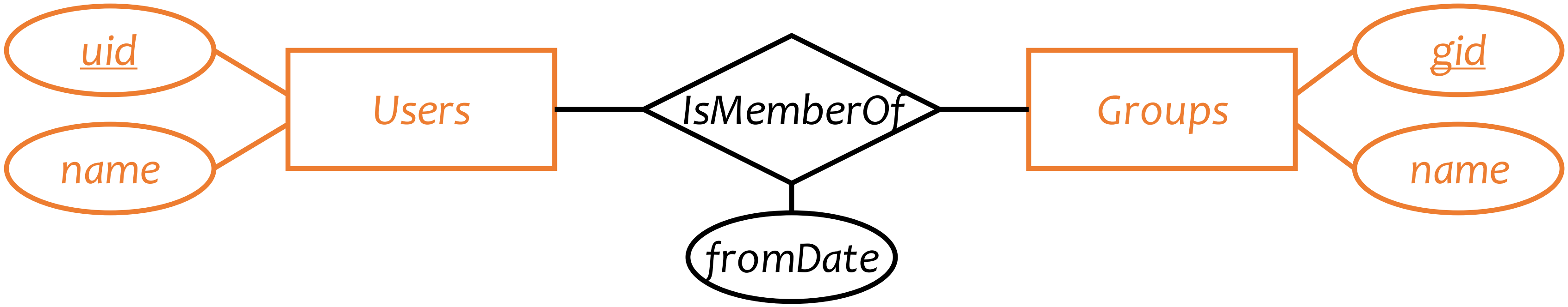
# Database design steps: review

- Understand the real-world domain being modeled
- Specify it using a database design model (e.g., E/R)
- Translate specification to the data model of DBMS (e.g., relational)
- Create DBMS schema

☞Next: translating E/R design to relational schema

# Translating entity sets

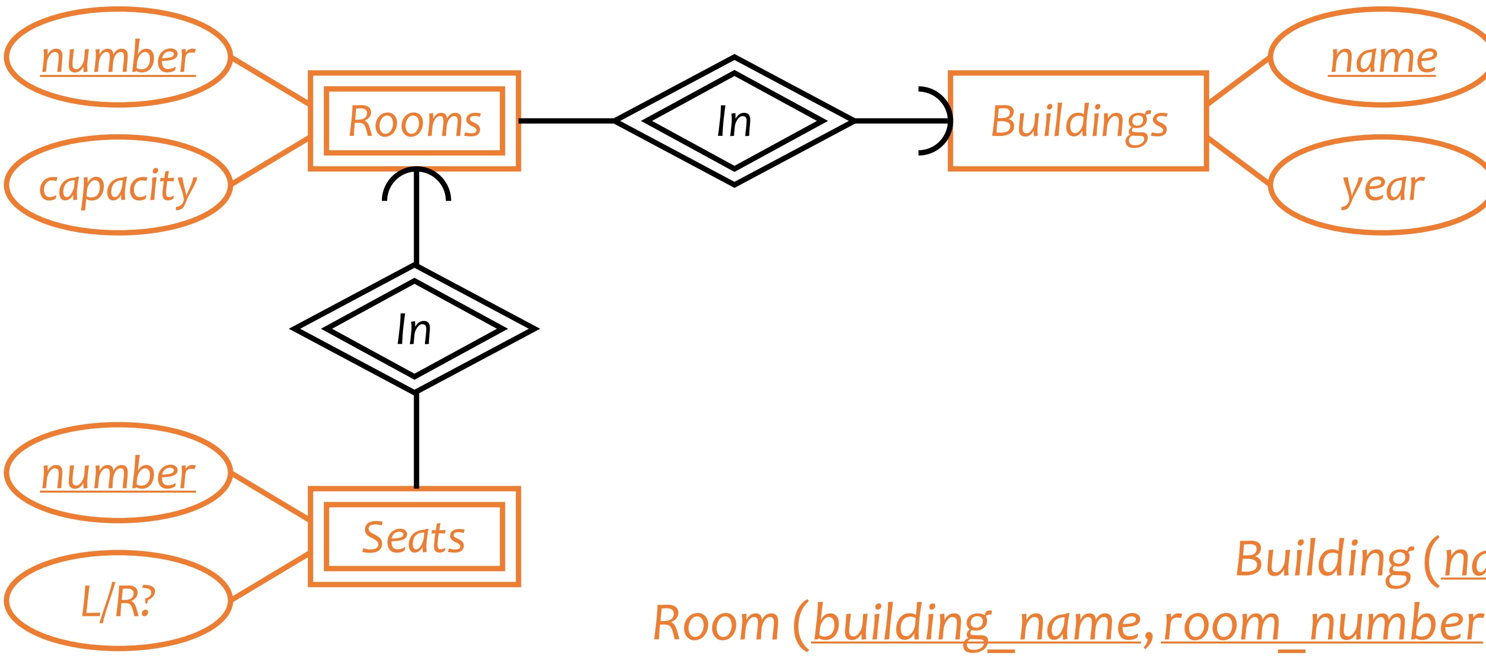
- An entity set translates directly to a table
  - Attributes → columns
  - Key attributes → key columns




*User (<u>uid</u>, name)*   *Group (<u>gid</u>, name)*

# Translating weak entity sets

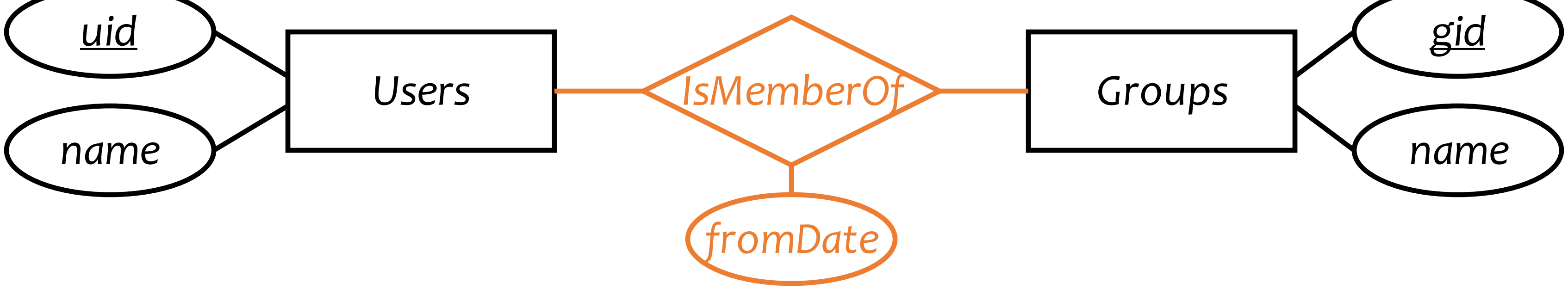
- Remember the "borrowed" key attributes
- Watch out for attribute name conflicts




Building (name, year)
Room (building_name, room_number, capacity)
Seat (building_name, room_number, seat_number, left_or_right)

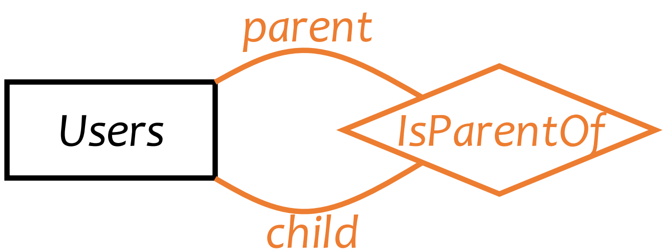
# Translating relationship sets

- A relationship set translates to a table
  - Keys of connected entity sets → columns
  - Attributes of the relationship set (if any) → columns
  - Multiplicity of the relationship set determines the key of the table

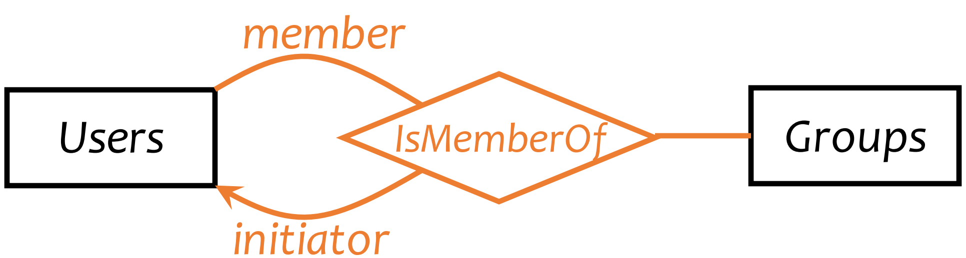



*Member (<u>uid</u>, <u>gid</u>, fromDate)*

# More examples



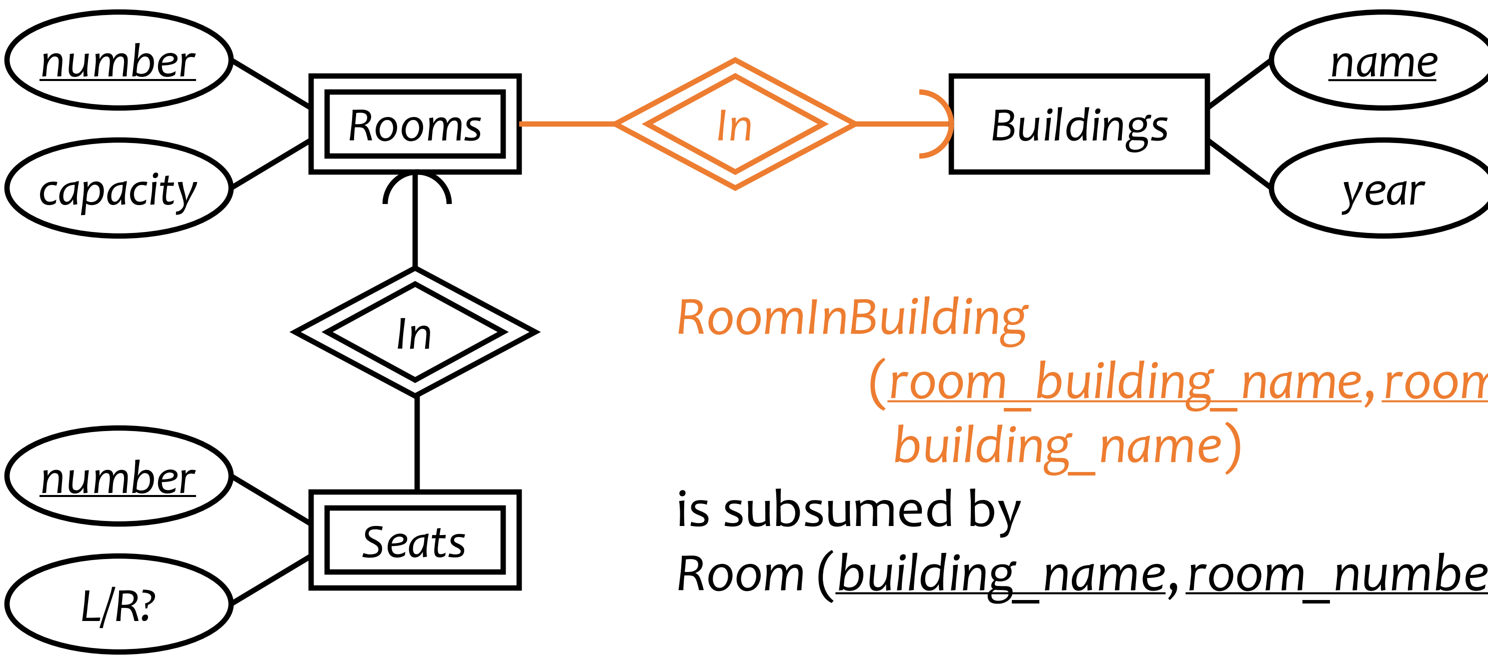

*Parent (parent_uid, child_uid)*




*Member (uid, initiator_uid, gid)*

# Translating double diamonds?

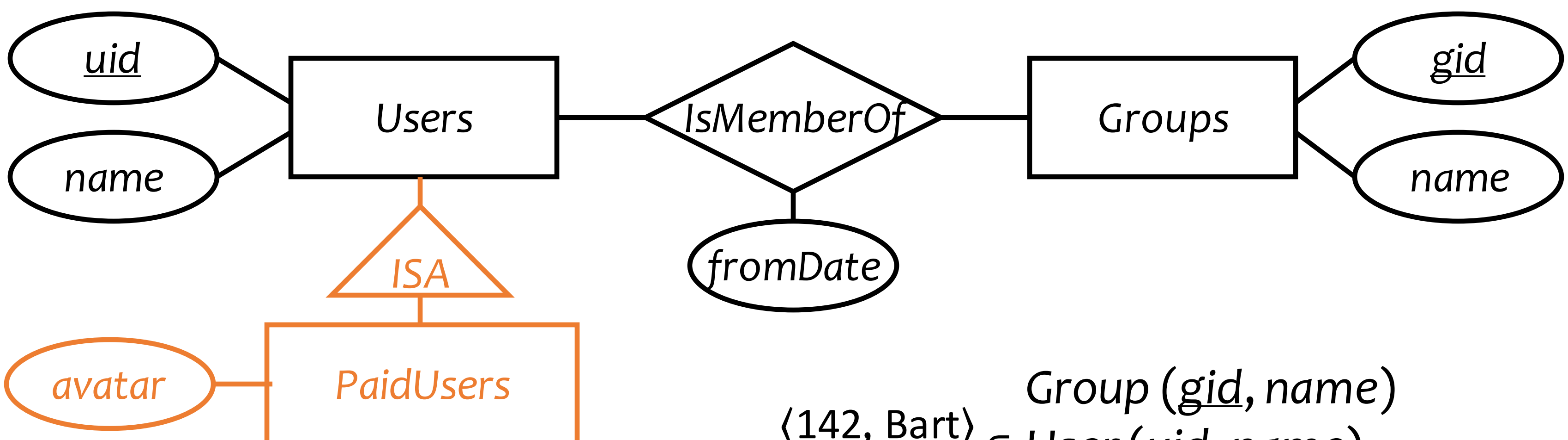
- Recall that a double-diamond (supporting) relationship set connects a weak entity set to another entity set
- No need to translate because the relationship is implicit in the weak entity set's translation




*RoomInBuilding*
(*<u>room_building_name</u>*, *<u>room_number</u>*, *building_name*)
is subsumed by
*Room* (*<u>building_name</u>*, *<u>room_number</u>*, *capacity*)

# Translating subclasses & ISA: approach 1

- Entity-in-all-superclasses approach ("E/R style")
    - An entity is represented in the table for each subclass to which it belongs
    - A table includes only the attributes directly attached to the corresponding entity set, plus the inherited key




*Group* ($\underline{gid}$, *name*)

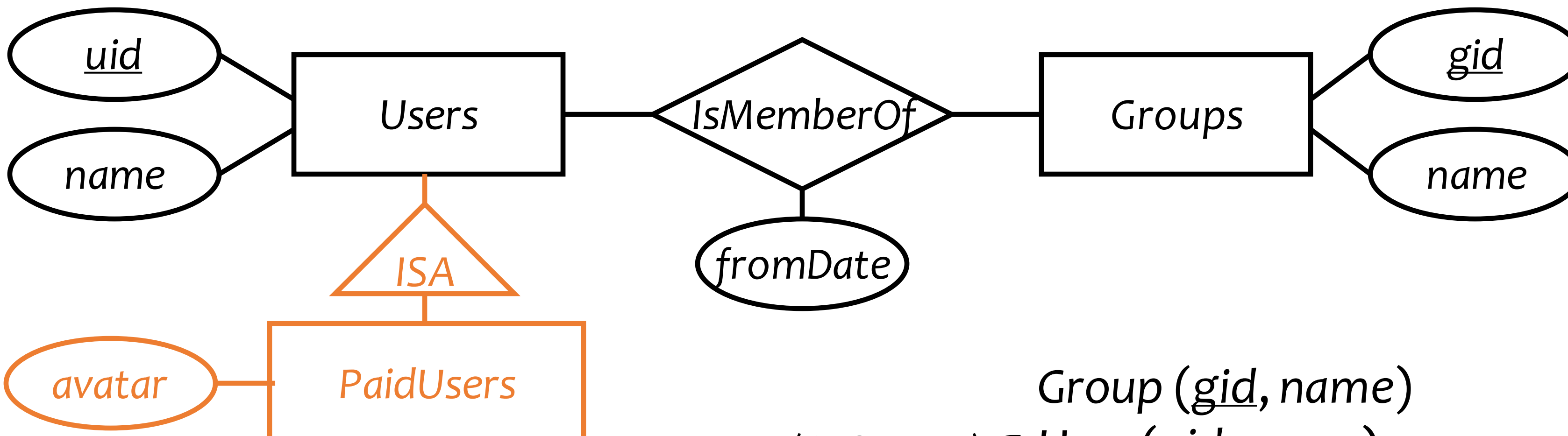
⟨142, Bart⟩ ⟨456, Ralph⟩ ∈ *User* ($\underline{uid}$, *name*)

*Member* ($\underline{uid}$, $\underline{gid}$, *from_date*)

⟨456, ☺⟩ ∈ *PaidUser* ($\underline{uid}$, *avatar*)

# Translating subclasses & ISA: approach 2

- Entity-in-most-specific-class approach ("OO style")
  - An entity is only represented in one table (the most specific entity set to which the entity belongs)
  - A table includes the attributes attached to the corresponding entity set, plus all inherited attributes




Group (gid, name)

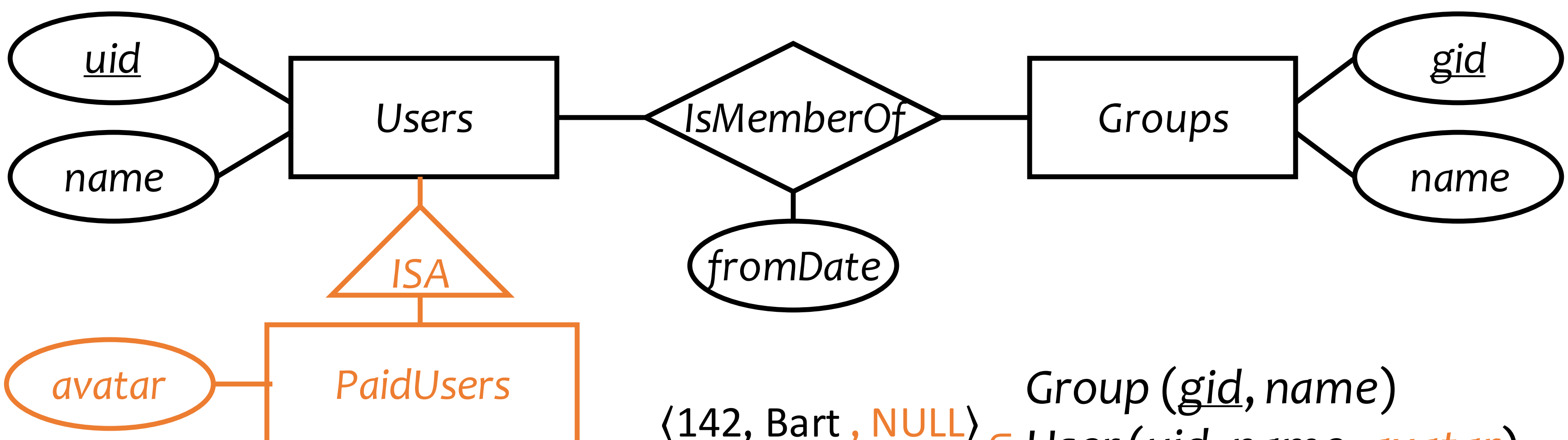
⟨142, Bart⟩ ∈ User (uid, name)

Member (uid, gid, from_date)

⟨456, Ralph, ☺⟩ ∈ PaidUser (uid, name, avatar)

# Translating subclasses & ISA: approach 3

- All-entities-in-one-table approach ("NULL style")
  - One relation for the root entity set, with all attributes found in the network of subclasses (plus a "type" attribute when needed)
  - Use a special NULL value in columns that are not relevant for a particular entity




⟨142, Bart , NULL⟩
⟨456, Ralph, ☺⟩ ∈ *User* (<u>*uid*</u>, *name*, *avatar*)

*Group* (<u>*gid*</u>, *name*)

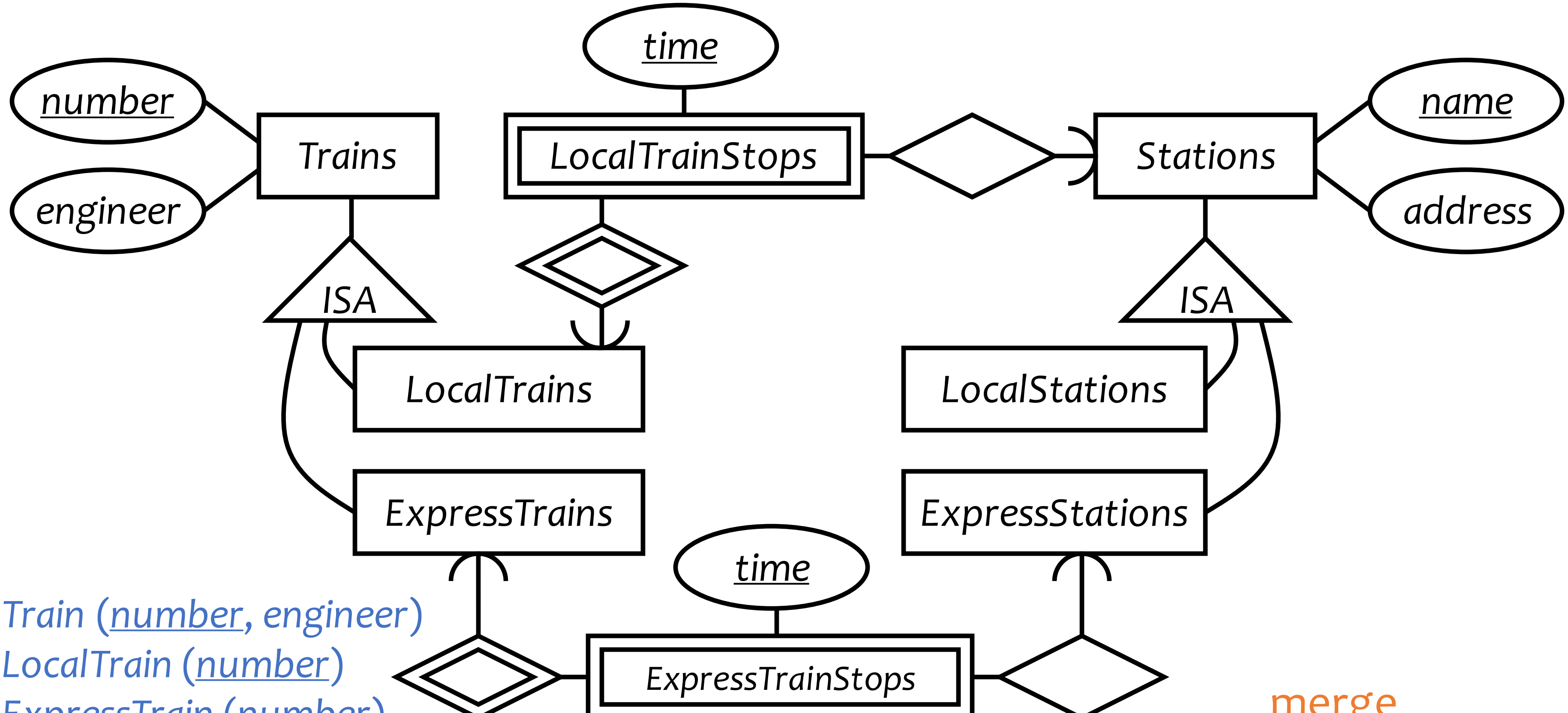
*User* (<u>*uid*</u>, *name*, *avatar*)

*Member* (<u>*uid*</u>, <u>*gid*</u>, *from_date*)

# Comparison of three approaches

- Entity-in-all-superclasses
  - *User* (<u>*uid*</u>, *name*), *PaidUser* (<u>*uid*</u>, *avatar*)
  - Pro: All users are found in one table
  - Con: Attributes of paid users are scattered in different tables
- Entity-in-most-specific-class
  - *User* (<u>*uid*</u>, *name*), *PaidUser* (<u>*uid*</u>, *name*, *avatar*)
  - Pro: All attributes of paid users are found in one table
  - Con: Users are scattered in different tables
- All-entities-in-one-table
  - *User* (<u>*uid*</u>, [*type*, ]*name*, *avatar*)
  - Pro: Everything is in one table
  - Con: Lots of NULL's; complicated if class hierarchy is complex

# A complete example




Train (number, engineer)
LocalTrain (number)
ExpressTrain (number)

Station (name, address)
LocalStation (name)
ExpressStation (name)

merge

LocalTrainStop (local_train_number, time)
LocalTrainStopsAtStation (local_train_number, time, station_name)

merge

ExpressTrainStop (express_train_number, time)
ExpressTrainStopsAtStation (express_train_number, time, express_station_name)

# Simplifications and refinements

*Train* (*<u>number</u>*, *engineer*), *LocalTrain* (*<u>number</u>*), *ExpressTrain* (*<u>number</u>*)
*Station* (*<u>name</u>*, *address*), *LocalStation* (*<u>name</u>*), *ExpressStation* (*<u>name</u>*)
*LocalTrainStop* (*<u>local_train_number</u>*, *station_name*, *<u>time</u>*)
*ExpressTrainStop* (*<u>express_train_number</u>*, *express_station_name*, *<u>time</u>*)

- Eliminate *LocalTrain* table
  - Redundant: can be computed as
    $$\pi_{number}(Train) - ExpressTrain$$
  - Slightly harder to check that *local_train_number* is indeed a local train number
- Eliminate *LocalStation* table
  - It can be computed as $\pi_{number}(Station) - ExpressStation$

# An alternative design

*Train* (*<u>number</u>*, *engineer*, *type*)

*Station* (*<u>name</u>*, *address*, *type*)

*TrainStop* (*<u>train_number</u>*, *station_name*, *<u>time</u>*)

- Encode the type of train/station as a column rather than creating subclasses
- What about the following constraints?
  - Type must be either “local” or “express”
  - Express trains only stop at express stations
  - ☞They can be expressed/declared explicitly as database constraints in SQL (as we will see later in course)
- Arguably a better design because it is simpler!

# Design principles


- KISS
    - Keep It Simple, Stupid
- Avoid redundancy
    - Redundancy wastes space, complicates modifications, promotes inconsistency
- Capture essential constraints, but don't introduce unnecessary restrictions
- Use your common sense
    - Warning: mechanical translation procedures given in this lecture are no substitute for your own judgment
- Practice ethical design
    - Your database design influences everything built around it and can have profound effects on real people

http://ungenius.files.wordpress.com/2010/03/thehomer.jpg