Relational Database Design
Part I

CPS 116

Introduction to Database Systems

Announcements (Thu. Sep. 8)

- Homework #1 is out
  - Due in 12 days, but start early—as soon as any portion has been covered
- Sign up for Gradiance
- Try our VM now
  - We can't help you on the due date if you run into last-minute installation problems
- Duke CS account created
  - Email me immediately if you still need one
- Readings: see Tentative Syllabus on course website

Relational model: review

- A database is a collection of relations (or tables)
- Each relation has a list of attributes (or columns)
- Each attribute has a domain (or type)
- Each relation contains a set of tuples (or rows)

Keys

- A set of attributes *K* is a key for a relation *R* if
  - In no instance of *R* will two different tuples agree on all attributes of *K*
    - That is, *K* is a "tuple identifier"
  - No proper subset of *K* satisfies the above condition
    - That is, *K* is minimal
- Example: *Student* (*SID*, *name*, *age*, *GPA*)
  - *SID* is a key of *Student*
  - *age* is not a key (not an identifier)
  - {*SID*, *name*} is not a key (not minimal)

Schema vs. instance

Student

SID	*name*	*age*	*GPA*
142	Bart	10	2.3
123	Milhouse	10	3.1
857	Lisa	8	4.3
456	Ralph	8	2.3

- Is *name* a key of *Student*?
  - Yes? Seems reasonable for this instance
  - No! Student names are not unique in general
- Key declarations are part of the schema

More examples of keys

- *Enroll* (*SID*, *CID*)
  - {*SID*, *CID*}
  - ☞A key can contain multiple attributes!
- *Address* (*street_address*, *city*, *state*, *zip*)
  - {*street_address*, *city*, *state*}
  - {*street_address*, *zip*}
  - ☞A relation can have multiple keys!
    - We typically pick one as the "primary" key, and underline all its attributes, e.g., *Address* (<u>*street_address*</u>, *city*, *state*, <u>*zip*</u>)

Usage of keys

7

- More constraints on data, fewer mistakes
- Look up a row by its key value
  - Many selection conditions are "key = value"
- "Pointers"
  - Example: *Enroll* (*SID*, *CID*)
    - *SID* is a key of *Student*
    - *CID* is a key of *Course*
    - An *Enroll* tuple "links" a *Student* tuple with a *Course* tuple
  - Many join conditions are "key = key value stored in another table"

Database design

8

- Understand the real-world domain being modeled
- Specify it using a database design model
  - More intuitive and convenient for schema design
  - But not necessarily implemented by DBMS
  - A few popular ones:
    - Entity/Relationship (E/R) model
    - Object Definition Language (ODL)
    - UML (Unified Modeling Language)
- Translate specification to the data model of DBMS
  - Relational, XML, object-oriented, etc.
- Create DBMS schema

Entity-relationship (E/R) model

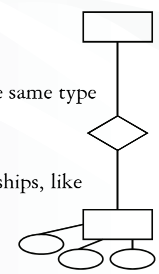
9

- Historically and still very popular
- Can think of as a "watered-down" object-oriented design model
- Primarily a design model—not directly implemented by DBMS
- Designs represented by E/R diagrams
  - We use the style of E/R diagram covered by GMUW; there are other styles/extensions
  - Very similar to UML diagrams

E/R basics

10

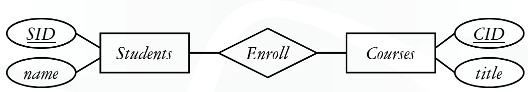
- Entity: a "thing," like an object
- Entity set: a collection of things of the same type, like a relation of tuples or a class of objects
  - Represented as a rectangle
- Relationship: an association among entities
- Relationship set: a set of relationships of the same type (among same entity sets)
  - Represented as a diamond
- Attributes: properties of entities or relationships, like attributes of tuples or objects
  - Represented as ovals



An example E/R diagram

11

- Students enroll in courses

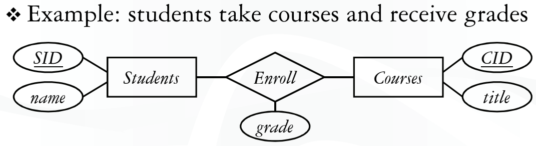


- A key of an entity set is represented by underlining all attributes in the key
  - A key is a set of attributes whose values can belong to at most one entity in an entity set—like a key of a relation

Attributes of relationships

12

- Example: students take courses and receive grades



- Where do the grades go?
  - With *Students*?
    - But a student can have different grades for multiple courses
  - With *Courses*?
    - But a course can assign different grades for multiple students
  - With *Enroll*!

13

More on relationships

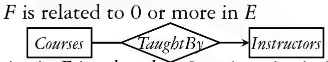
- There could be multiple relationship sets between the same entity sets
  - Example: *Students Enroll Courses*; *Students TA Courses*
- In a relationship set, each relationship is uniquely identified by the entities it connects
  - Example: Between Bart and CPS116, there can be at most one *Enroll* relationship and at most one *TA* relationship
  - ☞What if Bart took CPS116 twice and got two different grades?

14

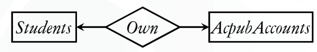
Multiplicity of relationships

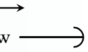
- *E* and *F*: entity sets
- Many-many: Each entity in *E* is related to 0 or more entities in *F* and vice versa
  - Example:

- Many-one: Each entity in *E* is related to 0 or 1 entity in *F*, but each entity in *F* is related to 0 or more in *E*
  - Example:



- One-one: Each entity in *E* is related to 0 or 1 entity in *F* and vice versa
  - Example:

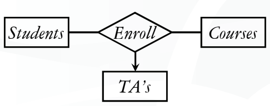


- "One" (0 or 1) is represented by an arrow →
- "Exactly one" is represented by a rounded arrow 

15

N-ary relationships

- Example: Each course has multiple TA's; each student is assigned to one TA

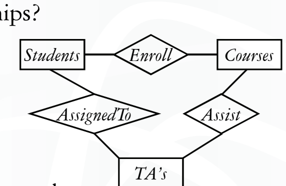


- Meaning of an arrow into *E*: Pick one entity from each of the other entity sets; together they must be related to either 0 or 1 entity in *E*

16

N-ary versus binary relationships

- Can we model *n*-ary relationships using just binary relationships?

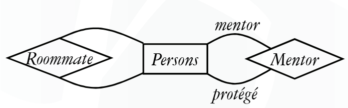


- No; for example:
  - Bart takes CPS116 and CPS114
  - Lisa TA's CPS116 and CPS114
  - Bart is assigned to Lisa in CPS116, but not in CPS114

17

Roles in relationships

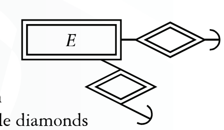
- An entity set may participate more than once in a relationship set
- ☞ May need to label edges to distinguish roles
- Examples
  - People mentor others; label needed
  - People are roommates of each other; label not needed



18

Weak entity sets

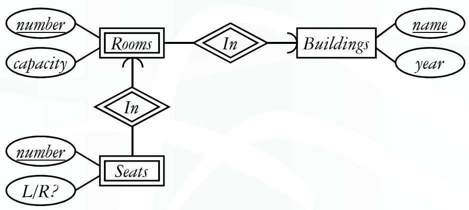
- Sometimes, the key of an entity set *E* comes not completely from its own attributes, but from the keys of other (one or more) entity sets
  - *E* must link to them via many-one (or one-one) relationship sets
  - Example: *Rooms* inside *Buildings* are partly identified by *Buildings*' name
  - *E* is called a weak entity set
    - Denoted by double rectangle
    - The relationship sets through which *E* obtains its key are drawn as double diamonds



Weak entity set examples

19

❖ Seats in rooms in buildings

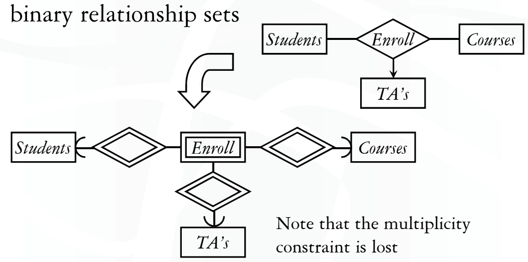


❖ Why must double diamonds be many-one/one-one?
- With many-many, we would not know which entity provides the key value!

Modeling *n*-ary relationships

20

❖ An *n*-ary relationship set can be replaced by a weak entity set (called a connecting entity set) and *n* binary relationship sets



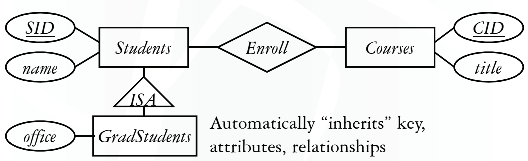
Note that the multiplicity constraint is lost

ISA relationships

21

❖ Similar to the idea of subclasses in object-oriented programming: subclass = special case, fewer entities, and possibly more properties
- Represented as a triangle (direction is important)

❖ Example: Graduate students are students, but they also have offices



Automatically "inherits" key, attributes, relationships

Summary of E/R concepts

22

❖ Entity sets
- Keys
- Weak entity sets

❖ Relationship sets
- Attributes of relationships
- Multiplicity
- Roles
- Binary versus *n*-ary relationships
  - Modeling *n*-ary relationships with weak entity sets and binary relationships
- ISA relationships

Case study 1

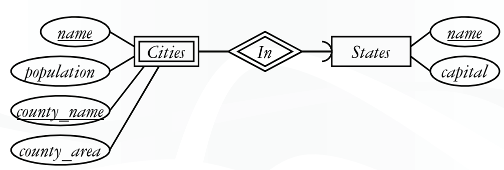
23

❖ 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

24

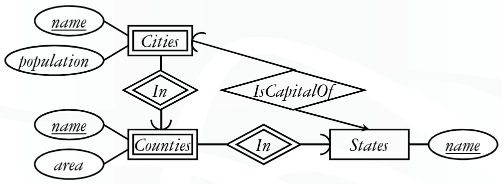


❖ County area information is repeated for every city in the county
  ☞Redundancy is bad (why?)

❖ State capital should really be a city
  ☞Should "reference" entities through explicit relationships

25

Case study 1: second design



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

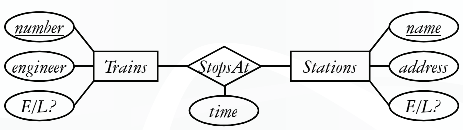
26

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 everyday

27

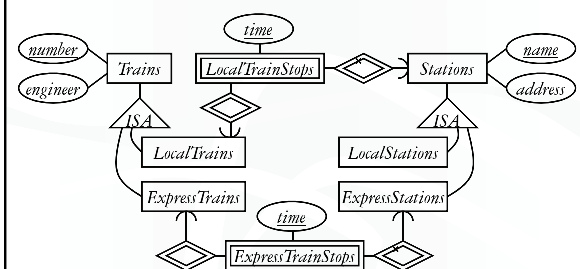
Case study 2: first design



- 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 constraints

28

Case study 2: second design



Is the extra complexity worth it?