Entity-Relationship Model

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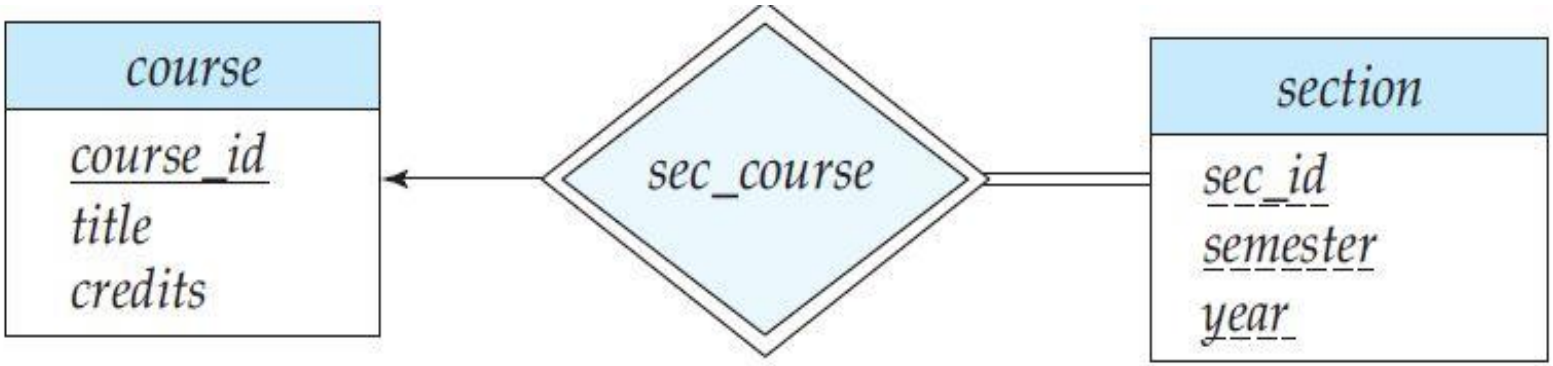
Weak and Strong Entity Sets

- An entity set that does not have sufficient attributes to form a primary key is termed a **weak entity set**.
- An entity set that has a primary key is termed a **strong (regular) entity set**.

  course: with attributes (*course_id*, *title*, *credits*)

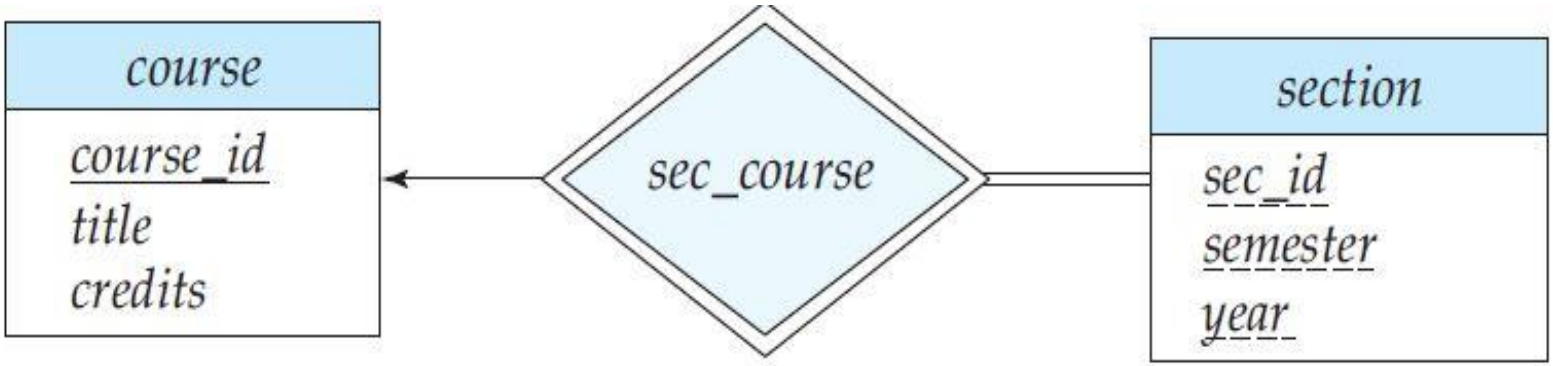
  section: with attributes (*course_id*, *sec_id*, *semester*, *year*)
- Suppose create a relationship-set *sec_course* between entity sets *section* and *course*.
- For a weak entity set to be meaningful, it must be associated with another entity set, called the **identifying** or **owner entity set**.
- Every weak entity must be associated with an identifying entity; that is, weak entity set is said to be **existence dependent** on the identifying entity set.
- The identifying entity set is said to **own** the weak entity set that it identifies.
- The relationship associating the weak entity set with the identifying entity set is called the **identifying relationship**.

Weak Entity Set



- **Identifying entity set** for *section* is *course*
- Relationship *sec_course* : associates *section* entities with their corresponding *course* entities, is the **identifying relationship**
- A weak entity type normally has a **partial key (discriminator)**, which is the attribute that can uniquely identify weak entities that are *related to the same owner entity*.
- The primary key of a weak entity set is formed by the primary key of the identifying entity set, plus the weak entity set's discriminator.

Weak Entity Set



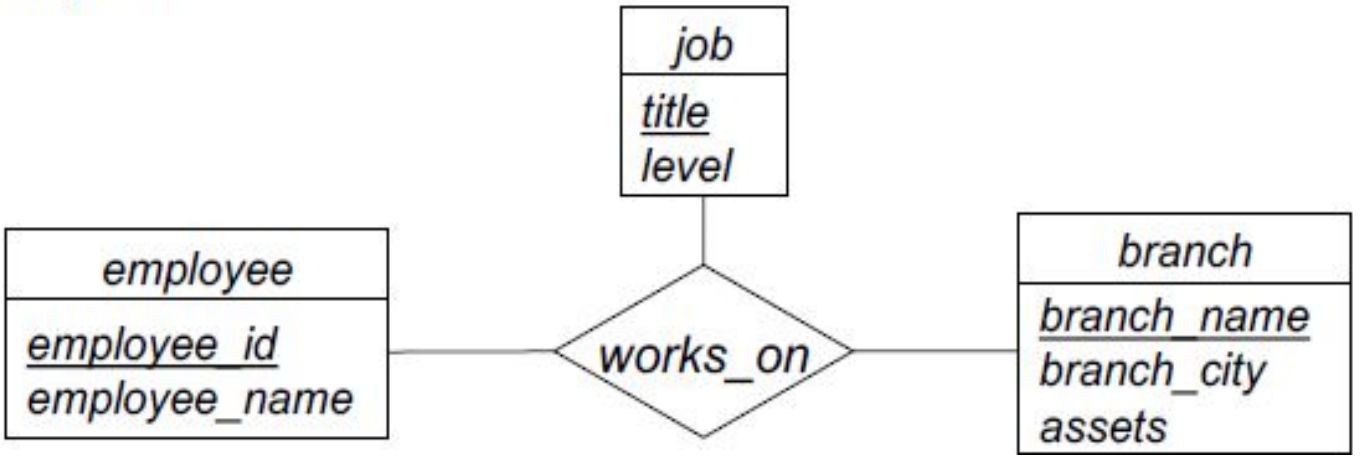
- A weak entity type always has a ***total participation constraint*** (existence dependency) with respect to its identifying relationship because a weak entity cannot be identified without an owner entity.

Whether every existence dependency results in a weak entity type ?

- **DRIVER_LICENSE entity cannot exist unless it is related to a PERSON entity, even though it has its own key (License_number) and hence is not a weak entity.**

N-ary Relationships

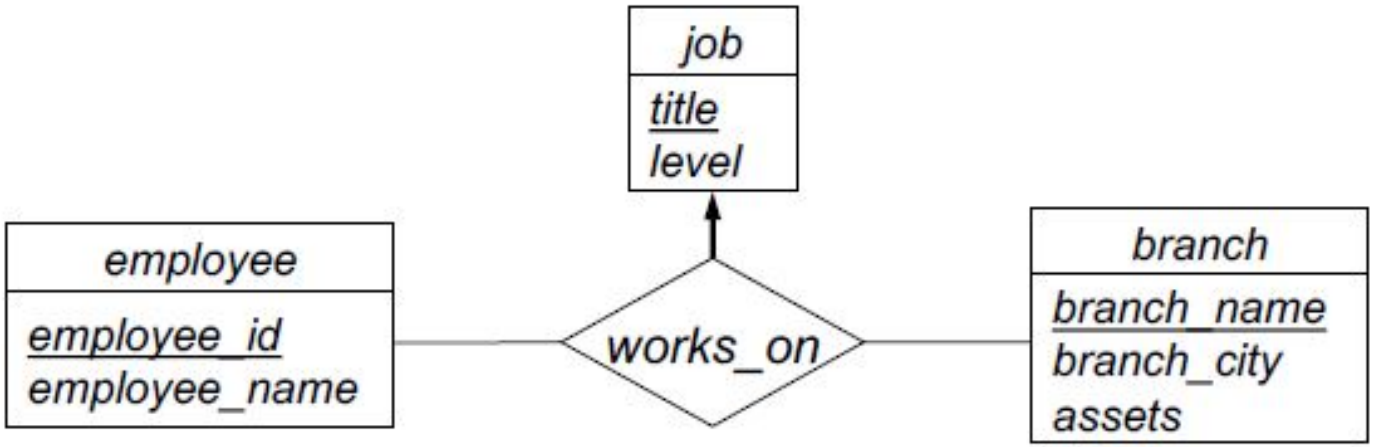
- We can specify relationships of degree > 2 in E-R model
- For example:



- Employees are assigned to jobs at various branches
- **Many-to-many mapping:** any combination of employee, job, and branch is allowed
- An employee can have several jobs at one branch

N-ary Mapping Cardinalities

- We can specify *some* mapping cardinalities on the relationships with degree > 2



- Each combination of employee and branch can only be associated with one job:
- Each employee can have only one job at each branch

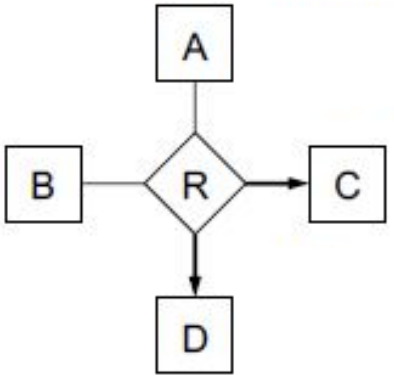
N-ary Mapping Cardinalities

- For degree > 2 relationships, we only allow at most one edge with an arrow.

  Reason: multiple arrows on N-ary relationship-set is ambiguous.
  - Interpreted in two ways.
- Relationship-set R associating entity-sets $A_1, A_2, \ldots, A_n$
  - No arrows on edges $A_1, A_2, \ldots, A_i$
  - Arrows are on edges to $A_{i+1}, A_{i+2}, \ldots, A_n$

- **Meaning 1** (the simpler one):
  - A particular combination of entities in $A_1, A_2, \ldots, A_i$ can be associated with at most one set of entities in $A_{i+1}, A_{i+2}, \ldots, A_n$
  - Primary key of R is union of primary keys from set $\{A_1, A_2, \ldots, A_i\}$

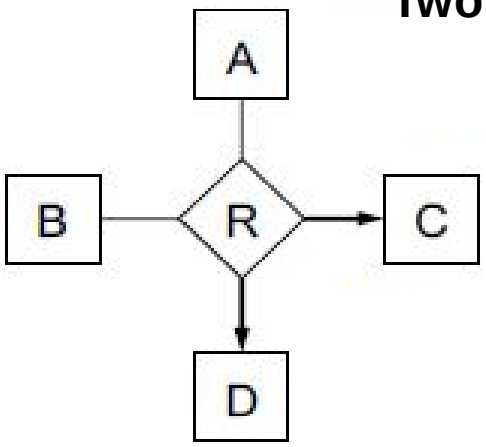
Primary key (a, b)



(a_1, b_2, c_3, d_1)
(a_2, b_3, c_1, d_2)
(a_1, b_3, c_2, d_2)
~~(a_1, b_2, c_3, d_1)~~

N-ary Mapping Cardinalities

- Relationship-set R associating entity-sets $A_1, A_2, \ldots, A_n$
  - No arrows on edges $A_1, A_2, \ldots, A_i$ and Arrows are on edges to $A_{i+1}, A_{i+2}, \ldots, A_n$
- **Meaning 2** (the insane one):
  - For each entity-set A_k $(i < k \leq n)$, a particular combination of entities from all other entity-sets can be associated with at most one entity in A_k
  - R has a candidate key for each arrow in N-ary relationship-set
  - For each k $(i < k \leq n)$, another candidate key of R is union of primary keys from entity-sets $\{A_1, A_2, \ldots, A_i\}$



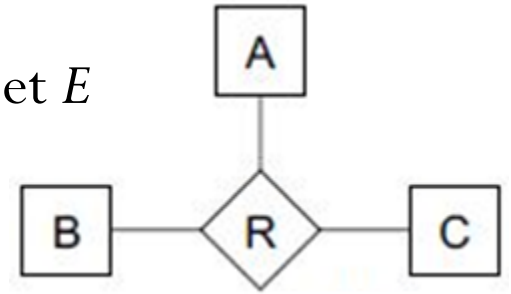
Two candidate key
(a, b, c)
(a, b, d)

1. (a_1, b_2, c_3, d_5)
2. (a_3, b_4, c_3, d_2)
3. (a_1, b_2, c_1, d_4)
4. (a_3, b_4, c_5, d_7)
5. ~~(a_1, b_2, c_3, d_6)~~
6. ~~(a_3, b_4, c_5, d_2)~~

Can these allowed in Meaning 1 ?

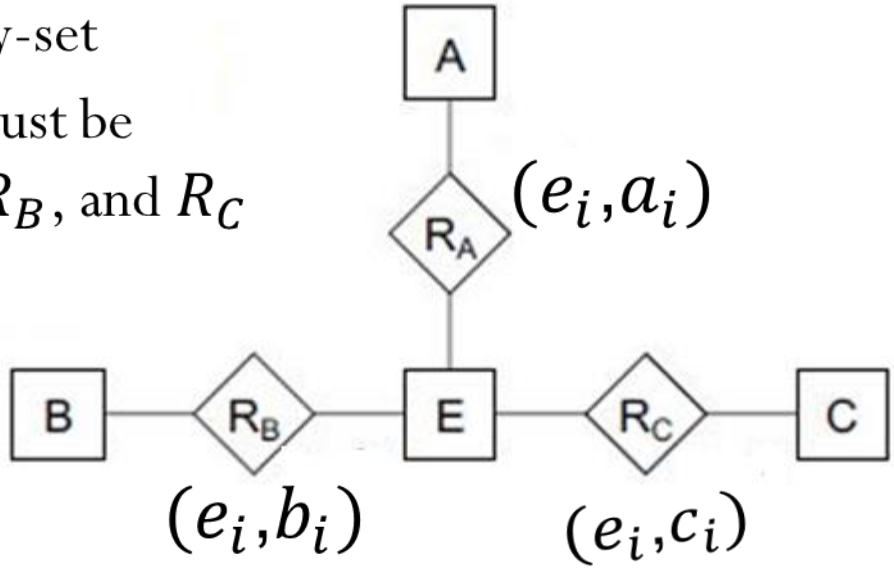
Binary vs. N-ary Relationships

- Often have only binary relationships in DB schemas
- For degree > 2 relationships, *could* replace with binary relationships
  - Replace N-ary relationship-set with a new entity-set *E*
    - Create an identifying attribute for *E*
    - e.g. an auto-generated ID value



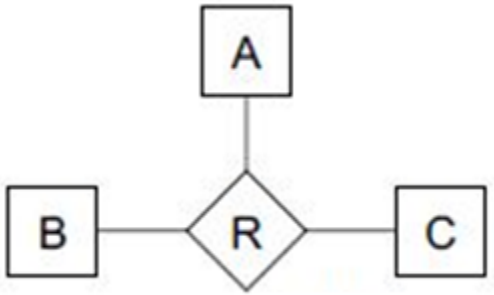
(a_i, b_i, c_i)

  - Create a relationship-set between *E* and each other entity-set
  - Relationships in *R* must be represented in R_A, R_B, and R_C



Binary vs. N-ary Relationships

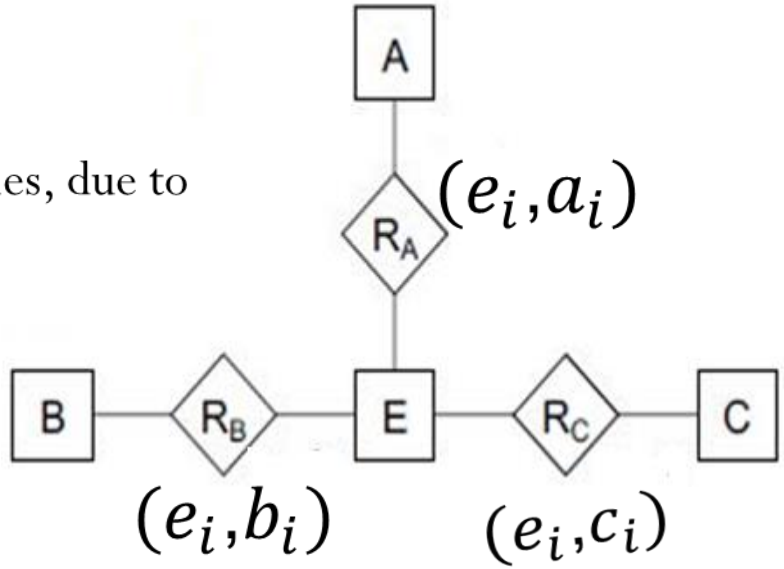
- **Are these representations identical?**
- **Example:** Want to represent a relationship between entities a_5, b_1 and c_2
  - How many relationships can we actually have between these three entities?



(a_i, b_i, c_i)

- **Ternary relationship set:**
  - Can only store one relationship between a_5, b_1 and c_2, due to primary key of R

- **Alternate approach:**
  - Can create many relationships between these entities, due to the entity-set E !
    - $(a_5, e_1), (b_1, e_1), (c_2, e_1)$
    - $(a_5, e_2), (b_1, e_2), (c_2, e_2)$
    - …



- **Can't constrain in exactly the same ways**

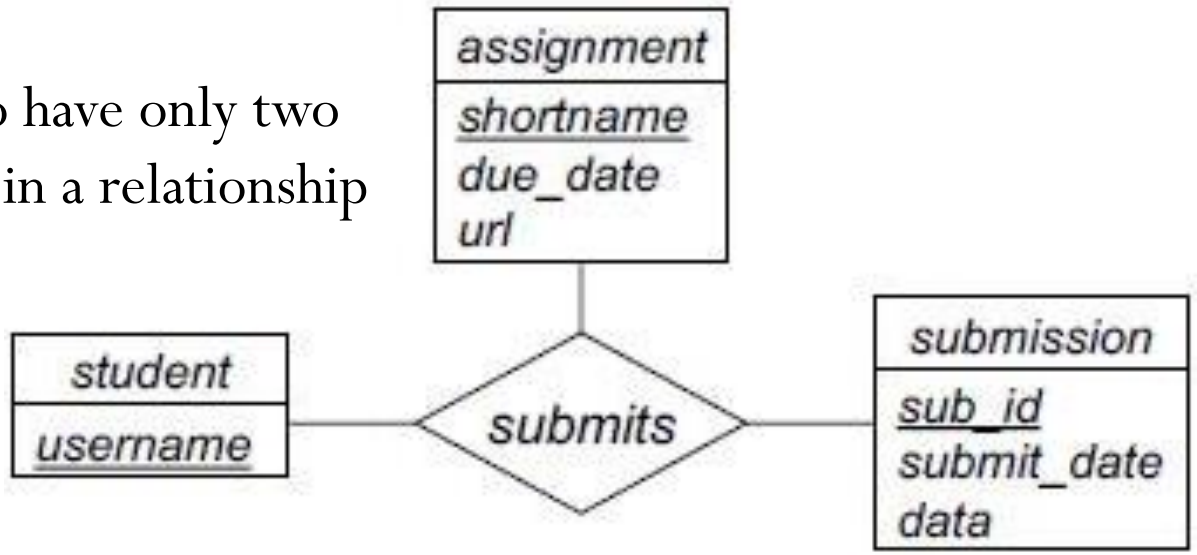
Binary vs. N-ary Relationships

- Using binary relationships is sometimes more intuitive for particular designs
- **Example:** office-equipment inventory database
  - Ternary relationship-set *inventory*, associating *department*, *machine*, and *vendor* entity-sets
- What if vendor info is unknown for some machines?
  - For ternary relationship, must use *null* values to represent missing vendor details
  - With binary relationships, can simply have no relationship between *machine* and *vendor*
- For cases like these, use binary relationships
  - If it makes sense to model as separate binary relationships, do it that way!

Course Database Example -1

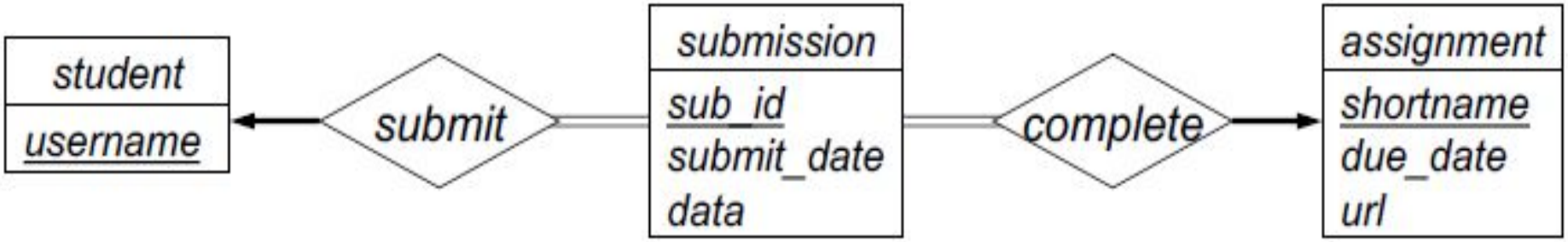
- **What about this case:**
  - Ternary relationship between *student*, *assignment*, and *submission*
  - Need to allow multiple submissions for a particular assignment, from a particular student

- **In this case, it could make sense to represent as a ternary relationship**
  - Doesn't make sense to have only two of these three entities in a relationship



Course Database Example - 2

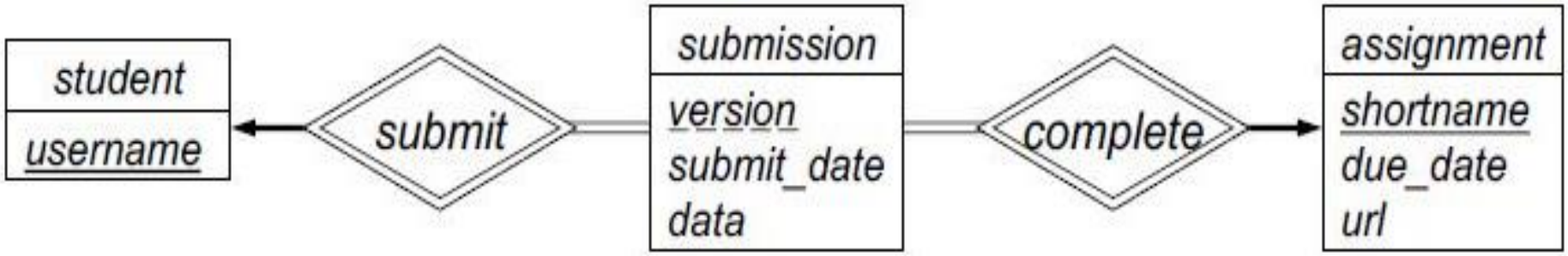
- Other ways to represent students, assignments and submissions?
- Can also represent as two binary relationships



- Note the total participation constraints!
  - Required to ensure that every *submission* has an associated *student*, and an associated *assignment*
  - Also, two one-to-many constraints

Course Database Example - 3

- Could even make *submission* a weak entity-set
  - Both *student* and *assignment* are identifying entities!

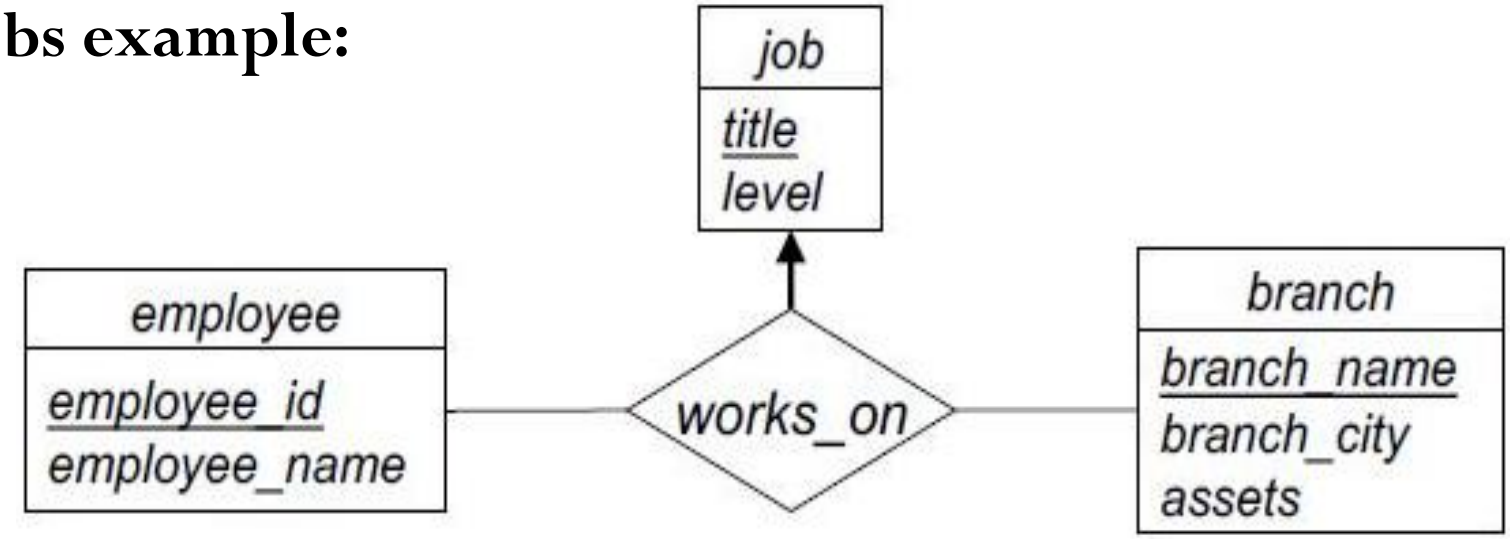


- **Discriminator for *submission* is version number**
- Primary key for *submission* ?
  - Union of primary keys from all owner entity-sets, plus discriminator

(*username*, *shortname*, *version*)

Binary vs. N-ary Relationships

- Sometimes ternary relationships are best
  - Clearly indicates all entities involved in relationship
  - Only way to represent certain constraints!
- **Bank jobs example:**



- **Each (*employee*, *branch*) pair can have only one job**
- **Simply cannot construct the same constraint using only binary relationships.**

Reason ?

E-R Model and Real Databases

- For E-R model to be useful, need to be able to convert diagrams into an implementation schema
- Turns out to be very easy to do this!
  - Big overlaps between E-R model and relational model
  - Biggest difference is E-R composite/multivalued attributes, vs. relational model atomic attributes
- Three components of conversion process:
  - Specify schema of the relation itself
  - Specify primary key on the relation
  - Specify any foreign key references to other relations

Strong Entity-Sets

- Strong entity-set E with attributes $a_1, a_2, \ldots, a_n$
  - Assume simple, single-valued attributes for now
- Create a relation schema with same name E, and same attributes $a_1, a_2, \ldots, a_n$
- Primary key of relation schema is same as primary key of entity-set
  - Strong entity-sets require no foreign keys to other things
- Every entity in E is represented by a tuple in the corresponding relation

Entity-Set Examples

- Geocache location E-R diagram:
  - Entity-set named *location*

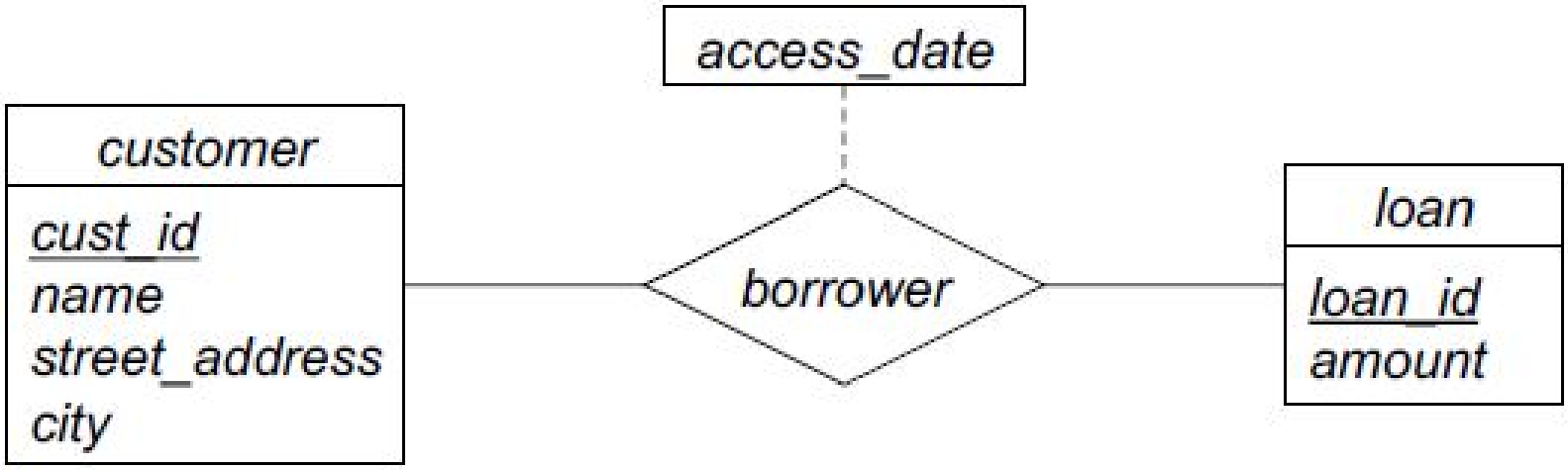
location
latitude
longitude
description
last_visited

- Convert to relation schema:

location(*latitude*, *longitude*, *description*, *last_visited*)

Entity-Set Examples - 2

- **E-R diagram for customers and loans:**



- Convert *customer* and *loan* entity-sets:

  customer(*cust_id*, *name*, *street_address*, *city*)

  loan(*loan_id*, *amount*)

Relationship-Sets

- Relationship-set R
  - For now, assume that all participating entity-sets are strong entity-sets
  - $a_1, a_2, \ldots, a_m$ is the union of all participating entity-sets' primary key attributes
  - $b_1, b_2, \ldots, b_n$ are descriptive attributes on R (if any)
- Relational model schema for R is:
  - $\{a_1, a_2, \ldots, a_m\} \cup \{b_1, b_2, \ldots, b_n\}$
- $\{a_1, a_2, \ldots, a_m\}$ is a super-key, but not necessarily a candidate key
  - Primary key of R depends on R's mapping cardinality

Relationship-Sets: Primary Keys

- For binary relationship-sets:
  - e.g. between strong entity-sets *A* and *B*
  - If many-to-many mapping:
    - Primary key of relationship-set is union of all entity-set primary keys

$$primary\_key(A) \cup primary\_key(B)$$

- If one-to-one mapping:
  - Either entity-set's primary key is acceptable

$$primary\_key(A), \text{ or } primary\_key(B)$$

  - **Enforce both candidate keys in DB schema!**

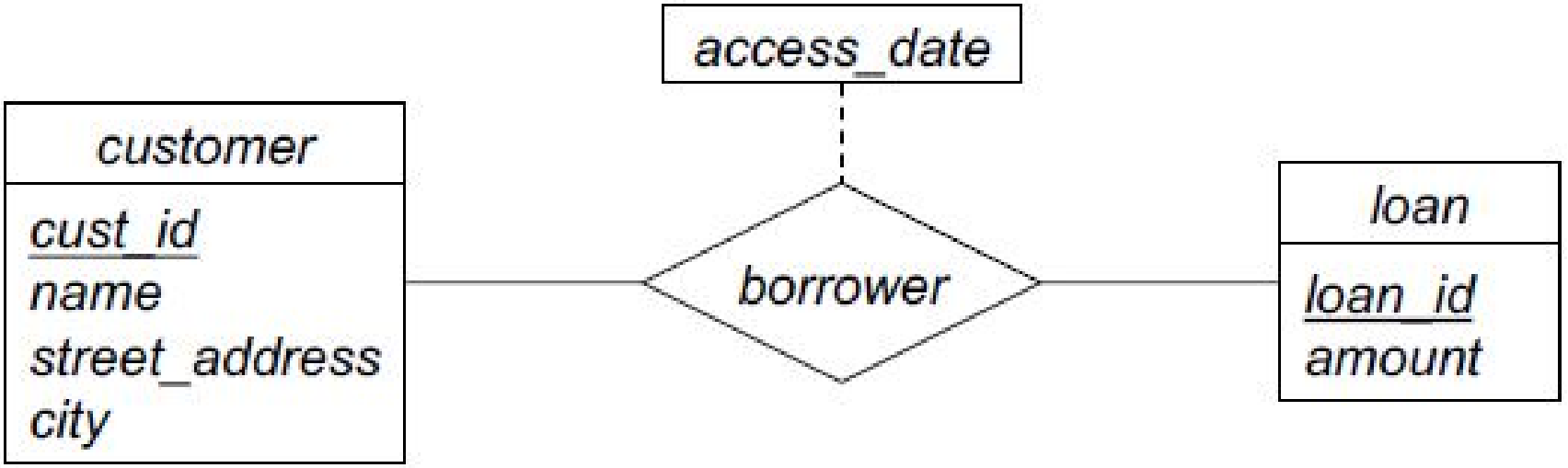
Relationship-Sets: Primary Keys

- For many-to-one or one-to-many mappings:
  - e.g. between strong entity-sets *A* and B
  - Primary key of entity-set on "many" side is primary key of relationship
- **Example:** relationship *R* between *A* and *B*
  - One-to-many mapping, with *B* on "many" side
  - Schema contains *primary_key*(*A*) ∪ *primary_key*(*B*), plus any descriptive attributes on *R*
  - *primary_key*(*B*) is primary key of *R*
    - Each $a \in A$ can map to many $b \in B$
    - Each value for *primary_key*(*B*) can appear only once in *R*

Relationship-Sets: Foreign Keys

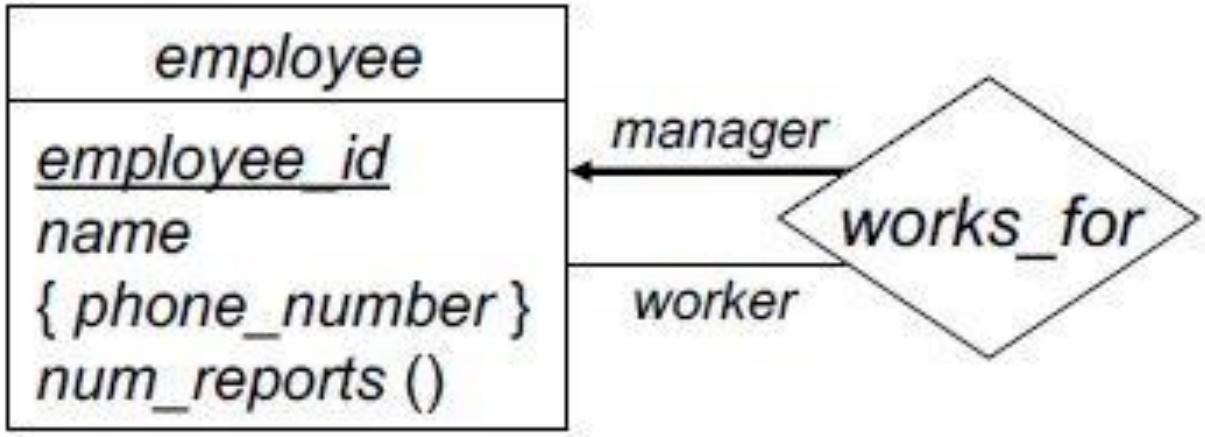
- Relationship-sets associate entities in entity-sets
  - We need foreign-key constraints on relation schema for R !
- For each entity-set E_i participating in R :
  - Relation schema for R has a foreign-key constraint on E_i relation, for $primary\_key(E_i)$ attributes
- Relation schema notation doesn't provide mechanism for indicating foreign key constraints
  - Don't forget about foreign keys and candidate keys!
    - Making notes on your relational model schema is a very good idea
  - Can specify both foreign key constraints and candidate keys in the SQL DDL

Relationship-Sets: Example - 1



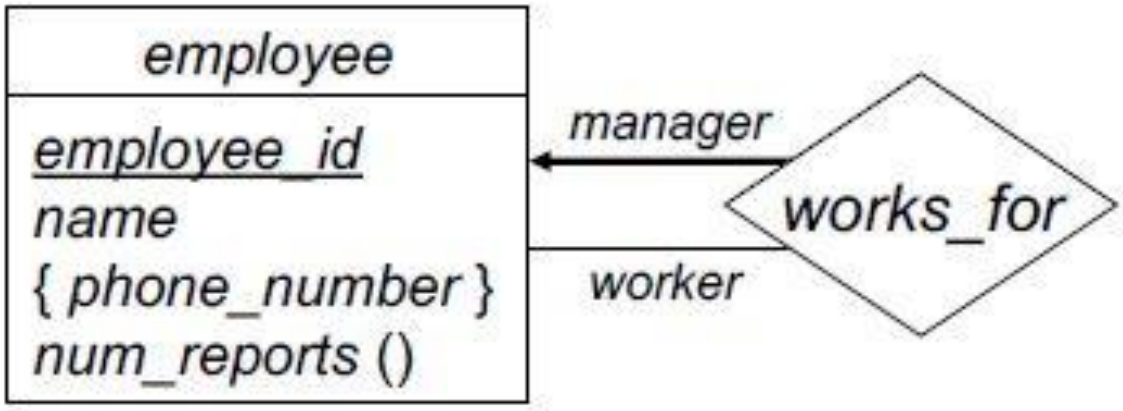
- **Relation schema for *borrower*:**
  - Primary key of *customer* is *cust_id*
  - Primary key of *loan* is *loan_id*
  - Descriptive attribute *access_date*
  - *borrower* mapping cardinality is many-to-many
  - **Result:** *borrower*(*cust_id*, *loan_id*, *access_date*)

Relationship-Sets: Example - 2



- In cases like this, must use roles to distinguish between the entities involved in the relationship-set
  - *employee* participates in *works_for* relationship-set twice
  - Can't create a schema (*employee_id*, *employee_id*) !
- Change names of key-attributes to distinguish **roles**
  - e.g. (*manager_employee_id*, *worker_employee_id*)
  - e.g. (*manager_id*, *employee_id*)

Relationship-Sets: Example - 2



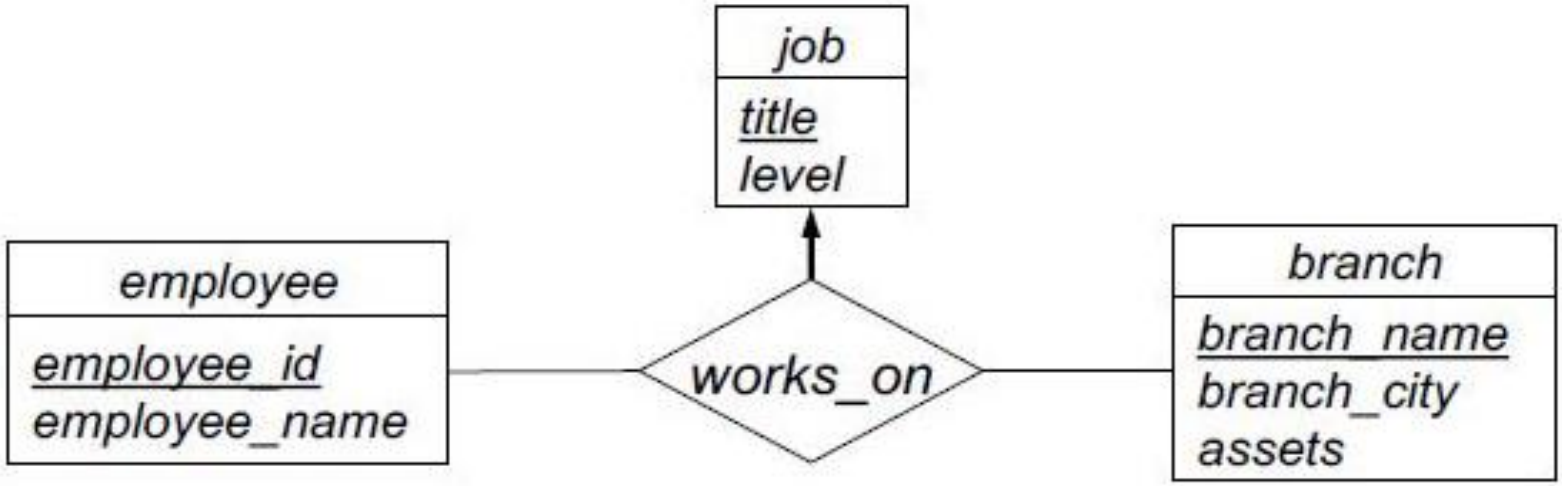
- Relation schema for *employee* entity-set:
  - (For now, ignore *phone_number* and *num_reports*…)

    employee(*employee_id*, *name*)
- Relation schema for *works_for*:
  - One-to-many mapping from *manager* to *worker*
  - "Many" side is used for primary key
  - **Result:** *works_for*(*employee_id*, *manager_id*)

N-ary Relationship Primary Keys

- **For degree > 2 relationship-sets:**
  - If no arrows ("many-to-many" mapping), relationship-set primary key is union of all participating entity-sets' primary keys
  - If one arrow ("one-to-many" mapping), relationship-set primary key is union of primary keys of entity-sets without an arrow
  - Don't allow more than one arrow for relationship-sets with degree > 2

N-ary Relationship-Set: Example



- Entity-set schemas:

  job(*title*, *level*)

  employee(*employee_id*, *employee_name*)

  branch(*branch_name*, *branch_city*, *assets*)

- Relationship-set schema:
  - Primary key includes entity-sets on non-arrow links

    works_on(*employee_id*, *branch_name*, *title*)

Weak Entity-Sets

- Weak entity-sets depend on at least one strong entity-set
  - The identifying entity-set, or owner entity-set
  - Relationship between the two is called the identifying relationship
- Weak entity-set A owned by strong entity-set B
  - Attributes of A are $\{a_1, a_2, \ldots, a_m\}$
    - Some subset of these attributes comprises the discriminator of A
  - $primary\_key(B) = \{b_1, b_2, \ldots, b_n\}$
  - Relation schema for A:

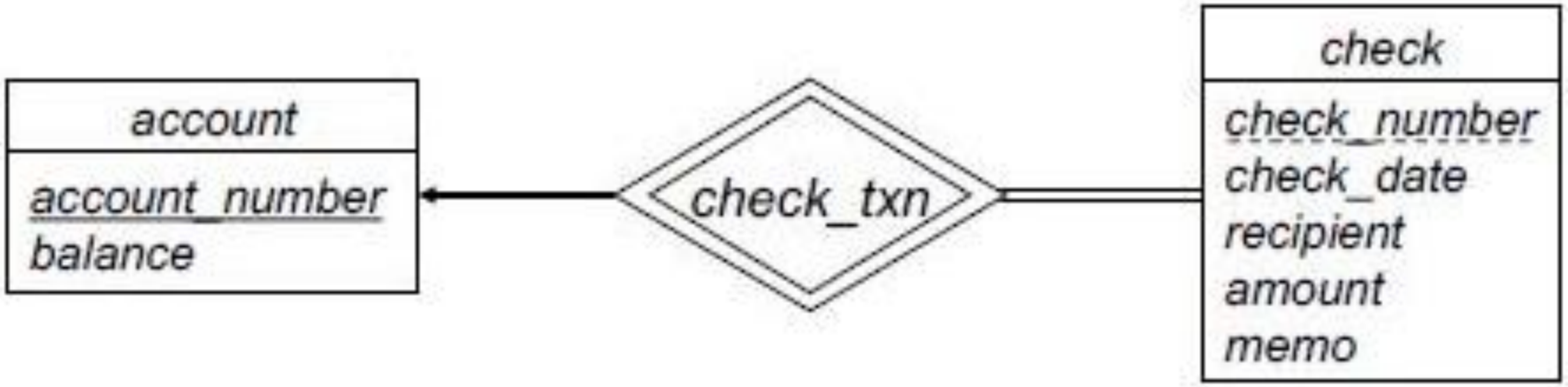
    $$\{a_1, a_2, \ldots, a_m\} \cup \{b_1, b_2, \ldots, b_n\}$$

  - Primary key of A is $discriminator(A) \cup primary\_key(B)$
  - A has a foreign key constraint on $primary\_key(B)$, to B

Identifying Relationship?

- The identifying relationship is many-to-one, with no descriptive attributes
- Relation schema for weak entity-set already includes primary key for strong entity-set
  - Foreign key constraint is imposed, too
- No need to create relational model schema for the identifying relationship
  - Would be redundant to the weak entity-set's relational model schema!

Weak Entity-Set Example - 1



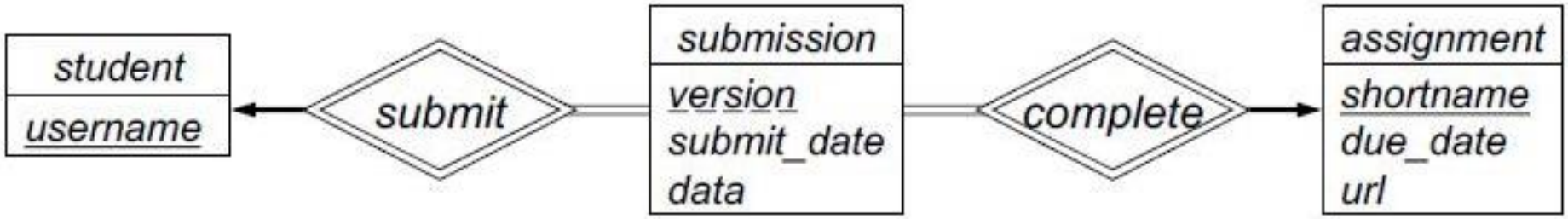
- *account* schema:

  account(*account_number*, *balance*)

- *check* schema:
  - Discriminator is *check_number*
  - Primary key for *check* is: (*account_number*, *check_number*)

  check(*account_number*, *check_number*, *check_date*, *recipient*, *amount*, *memo*)

Weak Entity-Set Example - 2



- Schemas for strong entity-sets:

  student(*username*)

  assignment(*shortname*, *due_date*, *url*)

- Schema for *submission* weak entity-set:
  - Discriminator is *version*
  - Both *student* and *assignment* are owners!

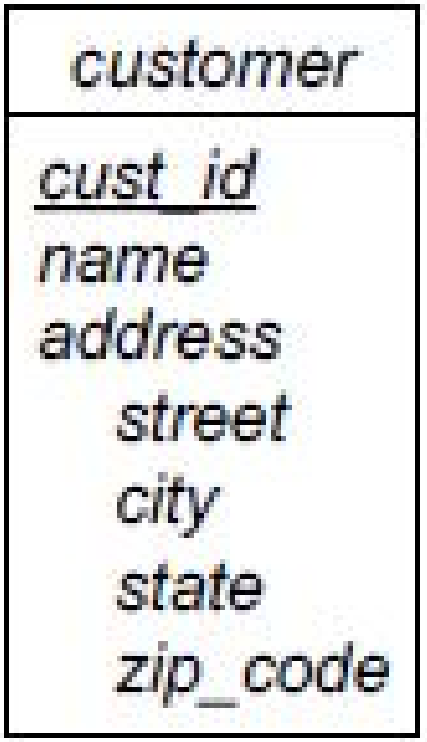
  submission(*username*, *shortname*, *version*, *submit_date*, *data*)
    - Two foreign keys in this relation as well

Composite Attributes

- Relational model simply doesn't handle composite attributes
  - All attribute domains are *atomic* in the relational model
- When mapping E-R composite attributes to relation schema: simply flatten the composite
  - Each component attribute maps to a separate attribute in relation schema
  - In relation schema, simply can't refer to the composite as a whole
  - (Can adjust this mapping for databases that support composite types)

Composite Attribute Example

Customers with addresses:



Each component of *address* becomes a separate attribute

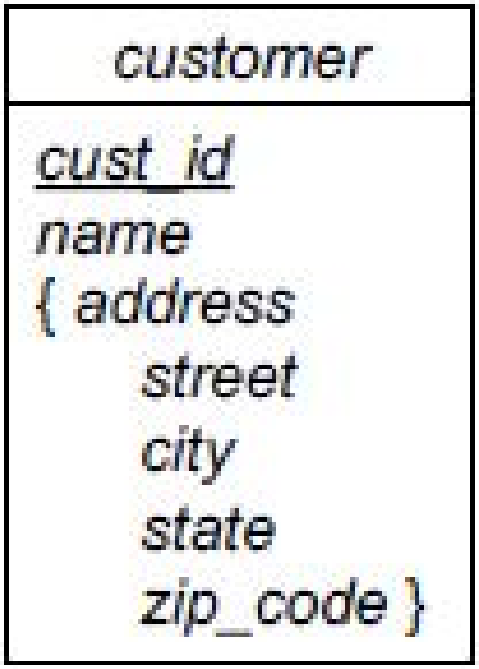
customer(*cust_id*, *name*, *street*, *city*, *state*, *zip_code*)

Multivalued Attributes

- Multivalued attributes require a separate relation
  - Again, no such thing as a multivalued attribute in the relational model
  - E-R constraint on multivalued attributes: in a specific entity's multivalued attribute, each value may only appear once
- For a multivalued attribute M in entity-set E
  - Create a relation schema R to store M, with attribute(s) A corresponding to the single-valued version of M
  - Attributes of R are: $primary\_key(E) \cup A$
  - Primary key of R includes all attributes of R
    - Each value in M for an entity e must be unique
  - Foreign key from R to E, on $primary\_key(E)$ attributes

Multivalued Attribute Example

Change our E-R diagram to allow customers to have multiple addresses:



- Now, must create a separate relation to store the addresses

  customer(*cust_id*, *name*)

  cust_addrs(*cust_id*, *street*, *city*, *state*, *zipcode*)

  - **Large primary keys aren't ideal – tend to be costly**

THANK YOU