E-R Diagrams

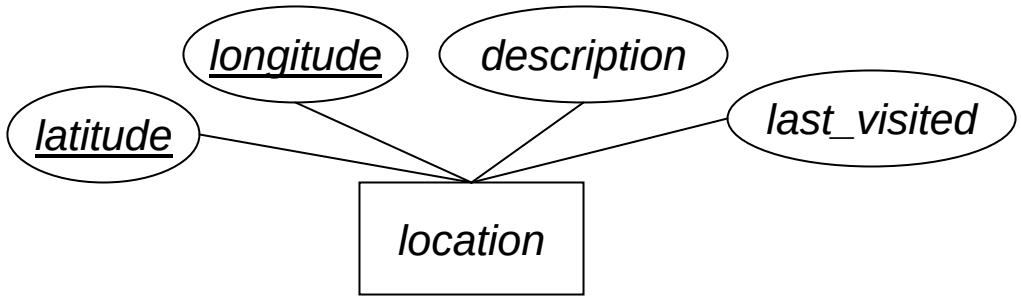
- Need to convert E-R model diagrams to an implementation schema
- Easy to map E-R diagrams to relational model, and then to SQL
  - Significant overlap between E-R model and relational model
  - Biggest difference is E-R composite/multivalued attributes, vs. relational model atomic attributes
- Three components of conversion process:
  - Specify schema of 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, …, a_n
  - Assume simple, single-valued attributes for now
- Create a relational schema with same name *E*, and same attributes a_1, a_2, …, a_n
- Primary key of relational schema is same as primary key of entity-set
  - No foreign key references for strong entity-sets
- Every entity in *E* represented by a tuple in corresponding relation

Entity-Set Examples

- Geocache location E-R diagram:

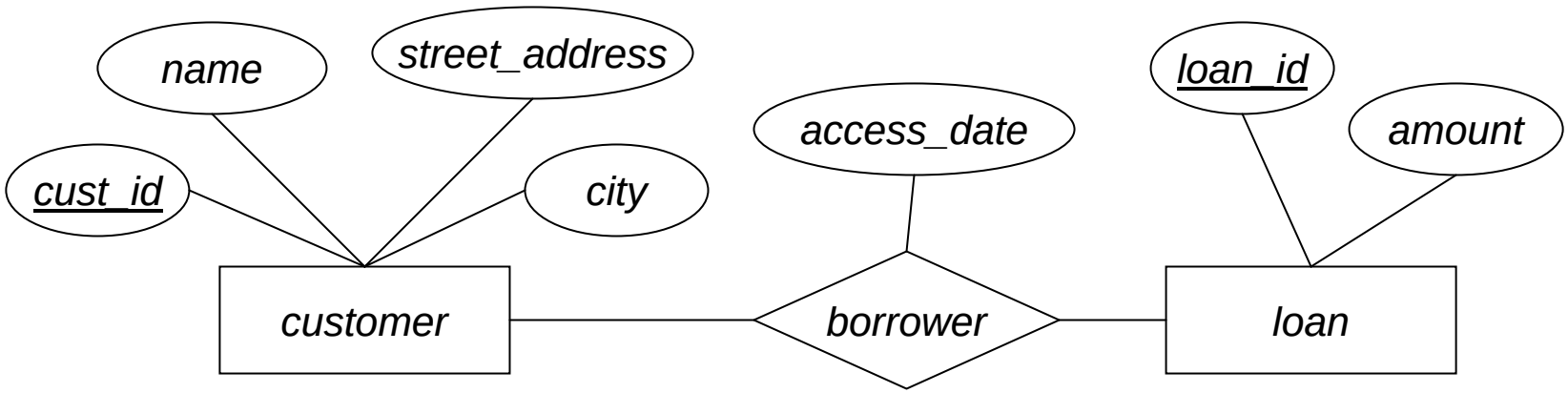


  - Entity-set named *location*
- Convert to relation schema:

  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*
  - Assume all participating entity-sets are strong entity-sets, for now
  - $a_1, a_2, \ldots, a_m$ 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 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 superkey, but not necessarily a candidate key
  - Primary key of *R* depends on *R*'s mapping cardinality

Relationship-Set Primary Keys

- For binary relationship-sets:
  - e.g. between strong entity-sets *A* and *B*
  - If many-to-many mapping, union of all entity-set primary keys becomes primary key of relationship-set
    - *primary_key*(*A*) ∪ *primary_key*(*B*)
  - If one-to-one mapping, either entity-set's primary key is acceptable
    - *primary_key*(*A*), or *primary_key*(*B*)
    - Should enforce candidate key constraint for each!

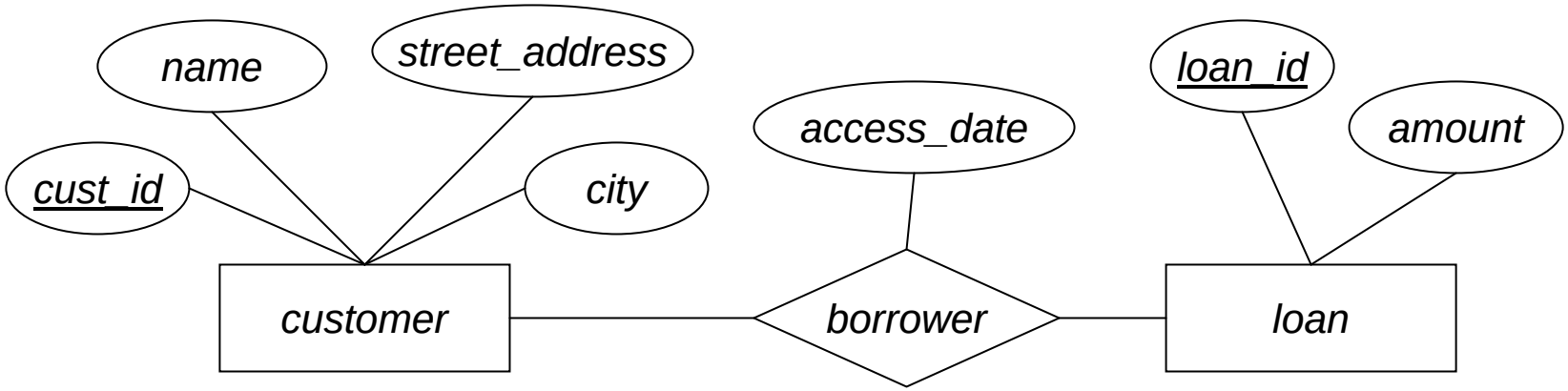
Relationship-Set Primary Keys (2)

- 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*

Relationship-Set Foreign Keys

- Relationship-sets associate entities in entity-sets
  - 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 a mechanism for indicating foreign key constraints
  - Don't forget about foreign keys and candidate keys!
  - Can specify both foreign key constraints, and candidate keys, in SQL DDL

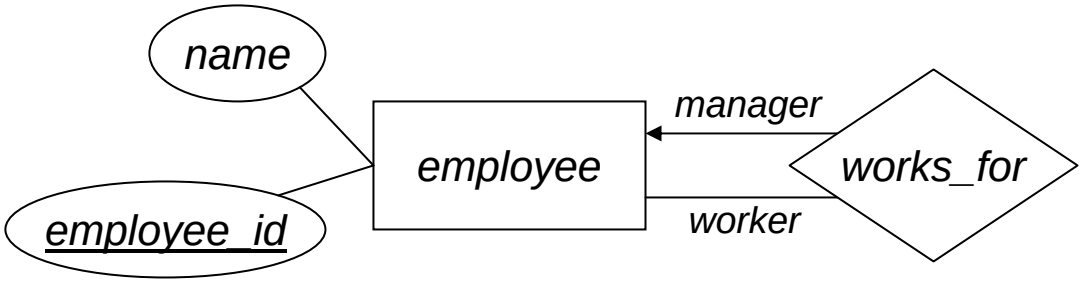
Relationship-Set Example



- 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

    borrower(*cust_id*, *loan_id*, *access_date*)

Relationship-Set Example (2)

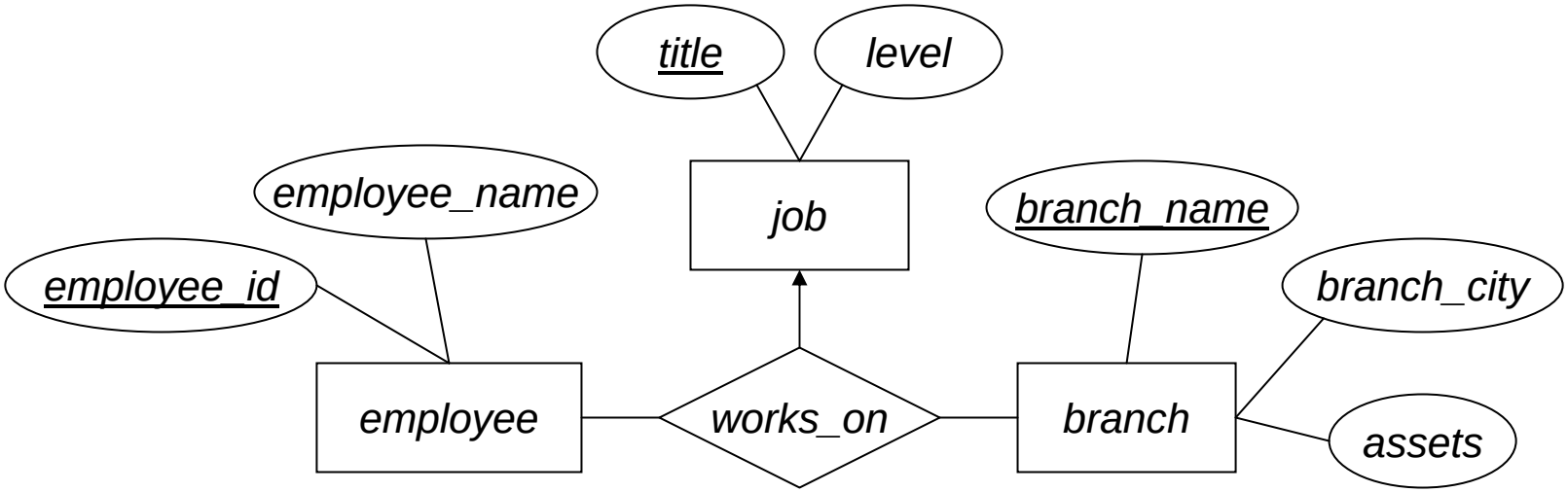


- Relation schema for *employee* entity-set:
  employee(*employee_id*, *name*)
- Relation schema for *works_for*:
  - One-to-many mapping from *manager* to *worker*
  - "Many" side is used for primary key
    works_for(*employee_id*, *manager_id*)

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*)

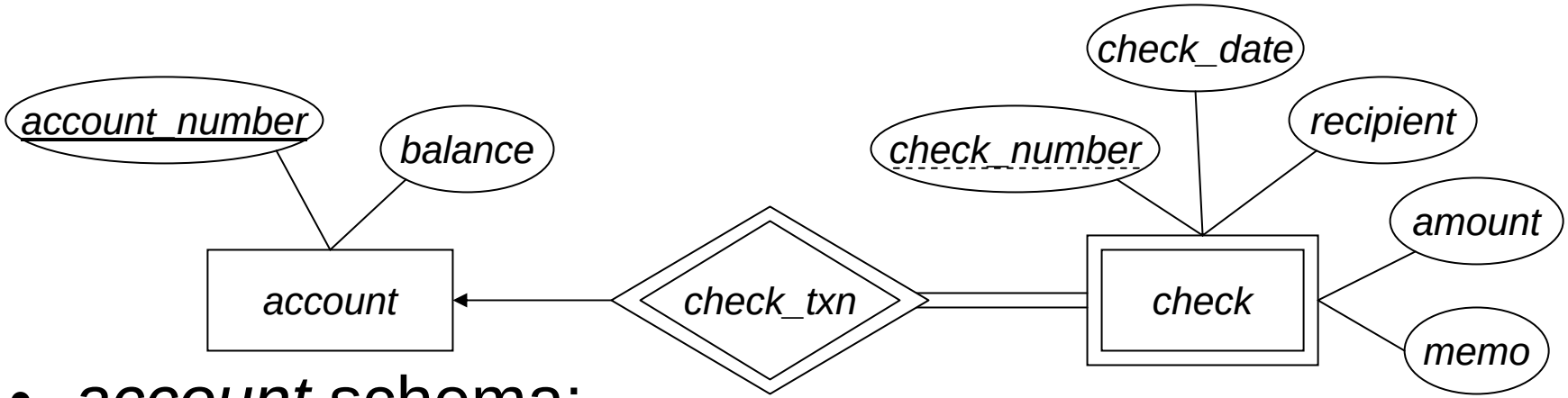
Weak Entity-Sets

- Weak entity-sets depend on at least one strong entity-set
  - Identifying entity-set, or owner entity-set
  - Relationship between the two called the identifying relationship
- Weak entity-set *A* owned by strong entity-set *B*
  - Attributes of *A* are $\{a_1, a_2, \ldots, a_m\}$
  - *primary_key*(*B*) = $\{b_1, b_2, \ldots, b_n\}$
  - Relational 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*) ∪ *primary_key*(*B*)
  - *A* has foreign key constraint on *primary_key*(*B*), to *B*

Identifying Relationship?

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

Weak Entity-Set Example



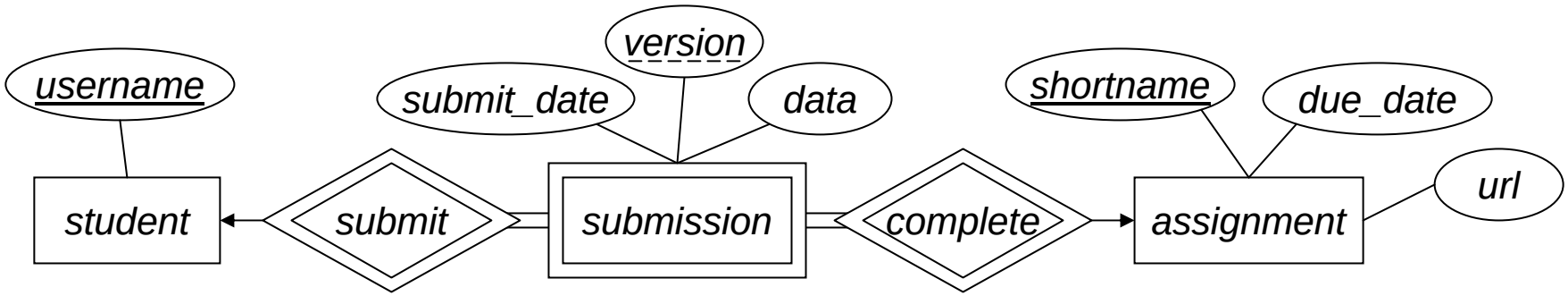
- *account* schema:

  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*)

Schema Combination

- Relationship between weak entity-set and strong entity-set doesn't need represented separately
  - Many-to-one relationship
  - Weak entity-set has total participation
  - Weak entity-set's schema includes representation of identifying relationship
- Can apply technique to other relationship-sets with many-to-one mapping
  - Entity-sets *A* and *B*, with relationship-set *AB*
  - Many-to-one mapping
  - *A*'s participation in *AB* is total

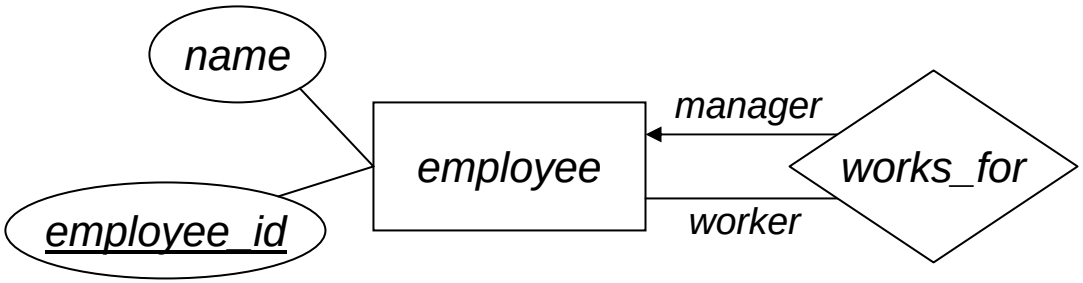
Schema Combination (2)

- Entity-sets *A* and *B*, relationship-set *AB*
  - Many-to-one mapping
  - *A*'s participation in *AB* is total
- Generates relation schemas *A*, *B*, *AB*
  - Primary key of *AB* is *primary_key*(*A*)
    - (*A* is on "many" side of mapping)
  - *AB* has foreign key constraints on both *A* and *B*
- Combine *A* and *AB* relation schemas
  - Primary key of combined schema still *primary_key*(*A*)
  - Only need one foreign-key constraint, to *B*

Schema Combination (3)

- If *A*'s participation in *AB* is partial, can still combine schemas
  - Need to store *null* values for *primary_key*(*B*) attributes when an entity in *A* maps to no entity in *B*
- If *AB* is one-to-one mapping:
  - Can also combine schemas in this case
  - Could incorporate *AB* into schema for *A*, or schema for *B*
  - When relationship-set is combined into an entity-set, the entity-set's primary key *doesn't change!*

Schema-Combination Example



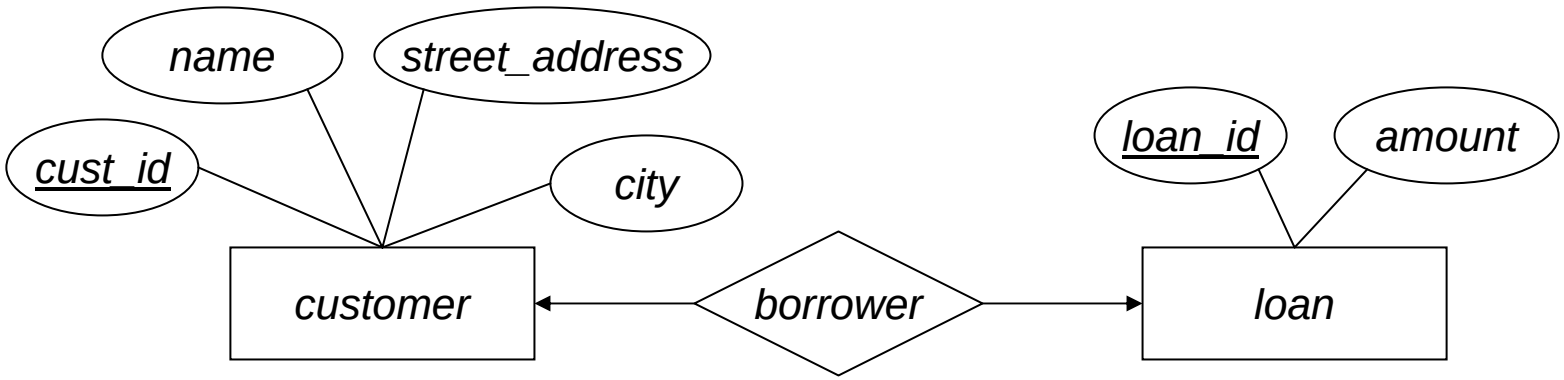
- Manager to worker mapping is one-to-many
- Relation schemas were:

  employee(*employee_id*, *name*)

  works_for(*employee_id*, *manager_id*)
- Could combine into:

  employee(*employee_id*, *name*, *manager_id*)
  - Need to store *null* for employees with no manager

Schema Combination Example (2)



- One-to-one mapping between customers, loans

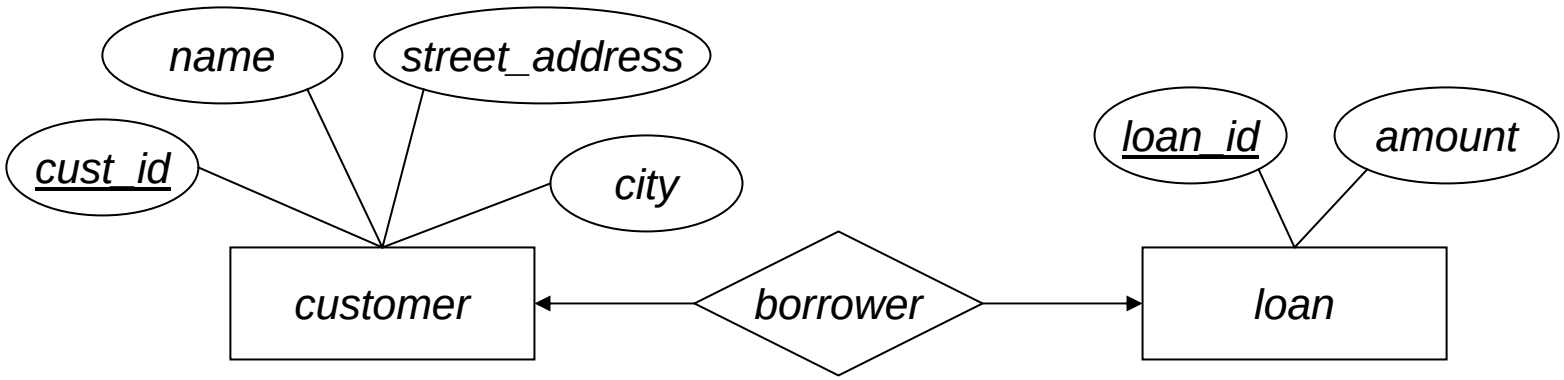
  customer(*cust_id*, *name*, *street_address*, *city*)

  loan(*loan_id*, *amount*)

  borrower(*cust_id*, *loan_id*)

  - *borrower* could also use *loan_id* for primary key
- Could combine *borrower* schema into *customer* or *loan* schema
  - Does it matter which one you choose?

Schema Combination Example (3)

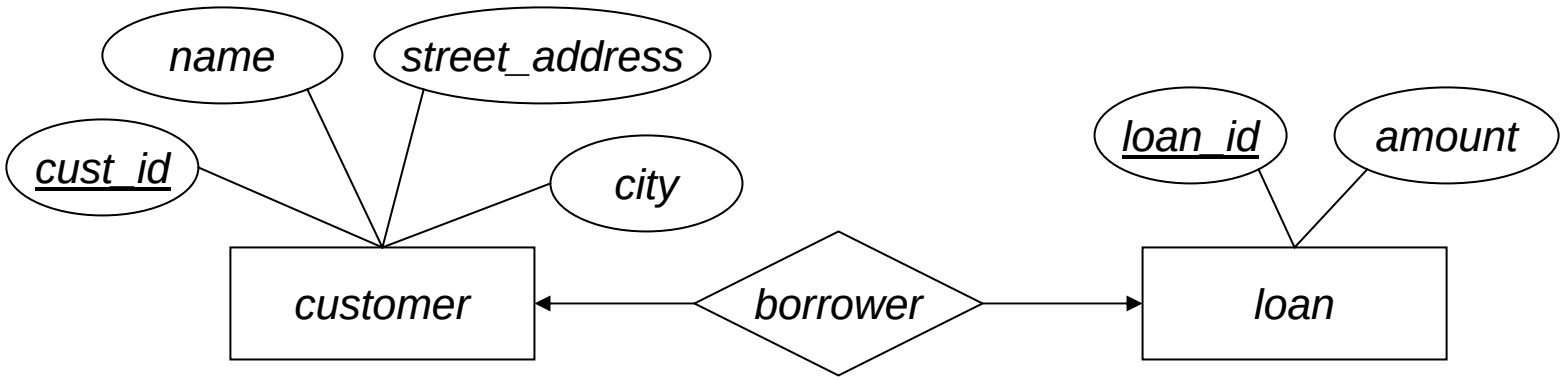


- Participation of *loan* in *borrower* will be total
  - Combining *borrower* into *customer* would require *null* values for customers without loans
- Better to combine *borrower* into *loan* schema

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

  loan(*loan_id*, *cust_id*, *amount*)
  - No *null* values!

Schema Combination Example (4)



- Schema:

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

  loan(*loan_id*, *cust_id*, *amount*)

- What if, after a while, we wanted to change the mapping cardinality?
  - Change to schema would be significant
  - Would need to migrate existing data to new schema

Schema Combination Notes

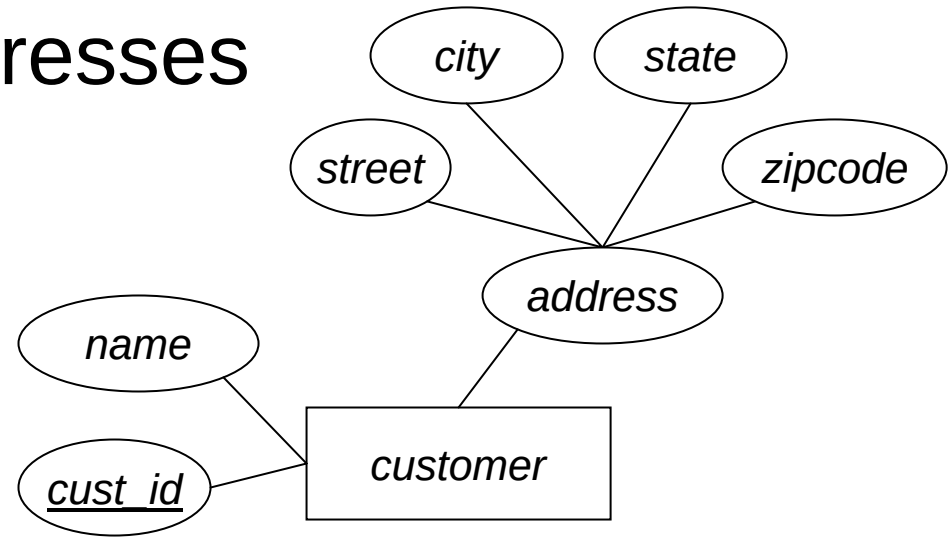
- Benefits of schema combination:
  - Eliminate a foreign-key constraint, and associated performance impact
    - Constraint enforcement
    - Extra join operations in queries
  - Reduce storage requirements
- Drawbacks of schema combination:
  - May necessitate use of *null* values
  - Makes it harder to change mapping cardinality constraints in the future

Composite Attributes

- Relational model doesn’t handle composite attributes
- When mapping E-R composite attributes to relation schema:
  - Each component attribute maps to a separate attribute in relation schema
  - In relation schema, simply can’t refer to 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

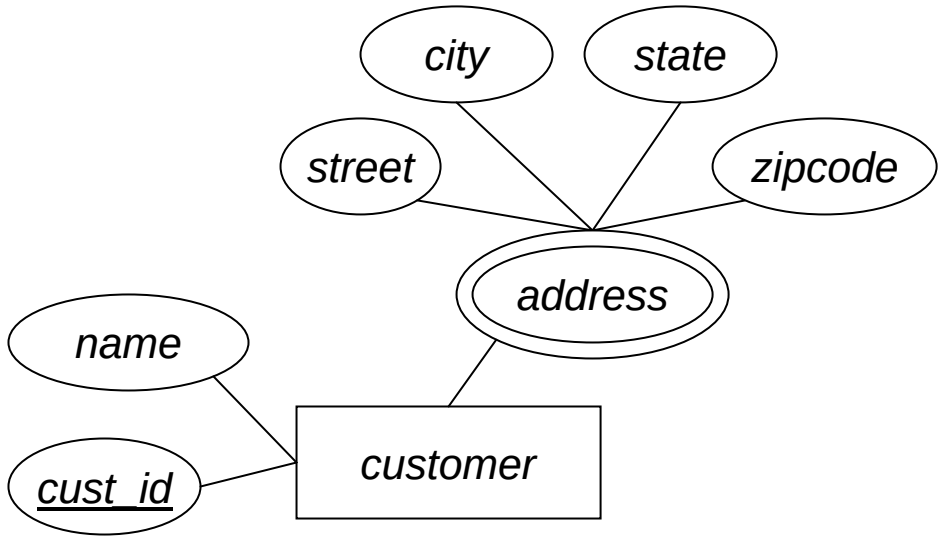
  customer(*cust_id*, *name*, *street*, *city*, *state*, *zipcode*)

Multivalued Attributes

- Multivalued attributes require a separate relation schema
  - No such thing as a multivalued attribute in relational model
- For multivalued attribute *M* in entity-set *E*
  - Create a relation schema *R* to store *M*, with attribute *A* corresponding to *M*
    - *A* is single-valued version of *M*
  - Attributes of *R* are: $A \cup primary\_key(E)$
  - Primary key of *R* includes <u>all</u> attributes of *R*
    - Each value in *M* for entity *e* must be unique
  - Foreign key constraint from *R* to *E*, on *primary_key*(*E*) attributes

Multivalued Attribute Example

- Customers with multiple addresses



- Create separate relation to store each address

  customer(*cust_id*, *name*)

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

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