ADVANCED E-R FEATURES

CS121: Introduction to Relational Database Systems

Fall 2014 – Lecture 17

Extensions to E-R Model

- Basic E-R model is good for many uses
- Several extensions to the E-R model for more advanced modeling
  - Generalization and specialization
  - Aggregation
- These extensions can also be converted to the relational model
  - Introduces a few more design choices
- Will only discuss specialization today
  - See book §7.8.5 for details on aggregation
    (material will be included with Assignment 5 too)

Specialization

- An entity-set might contain distinct subgroups of entities
  - Subgroups have some different attributes, not shared by the entire entity-set
- E-R model provides <u>specialization</u> to represent such entity-sets
- Example: bank account categories
  - Checking accounts
  - Savings accounts
  - Have common features, but also unique attributes

Generalization and Specialization

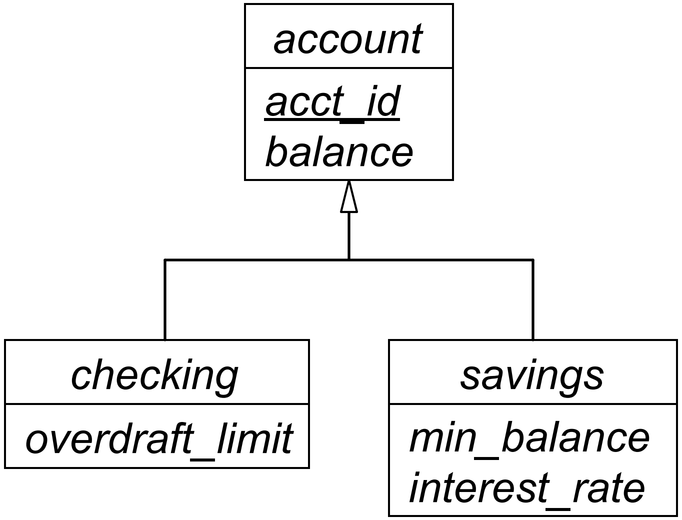
- Generalization: a “bottom up” approach
  - Taking similar entity-sets and unifying their common features
  - Start with specific entities, then create generalizations from them
- Specialization: a “top down” approach
  - Creating general purpose entity-sets, then providing specializations of the general idea
  - Start with the general notion, then refine it
- Terms are basically equivalent
  - Book refers to generalization as the overarching concept

Bank Account Example

- Checking and savings accounts both have:
  - account number
  - balance
  - owner(s)
- Checking accounts also have:
  - overdraft limit and associated overdraft account
  - check transactions
- Savings accounts also have:
  - minimum balance
  - interest rate

Bank Account Example (2)

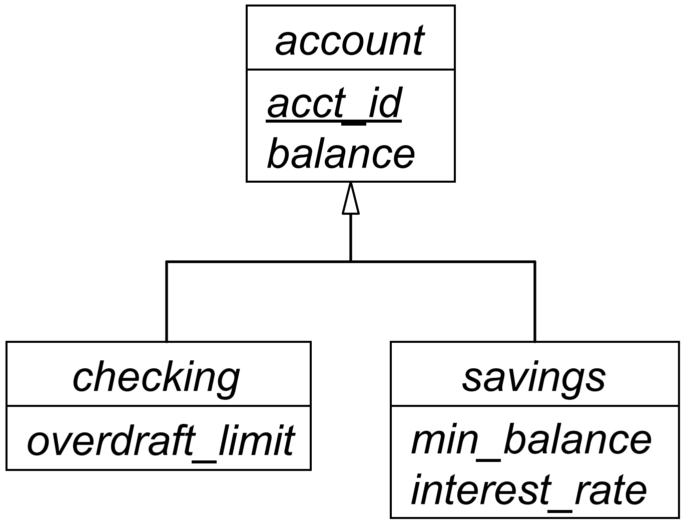
- Create entity-set to represent common attributes
  - Called the <u>superclass</u>, or higher-level entity-set
- Create entity-sets to represent specializations
  - Called <u>subclasses</u>, or lower-level entity-sets
- Join superclass to subclasses with hollow-head arrow(s)



Inheritance

- Attributes of higher-level entity-sets are inherited by lower-level entity-sets
- Relationships involving higher-level entity-sets are also inherited by lower-level entity-sets!
  - Lower-level entity-sets can also participate in *their own* relationship-sets, separate from higher-level entity-set
- Usually, entity-sets inherit from one superclass
  - Entity-sets form a <u>hierarchy</u>
- Can also inherit from multiple superclasses
  - Entity-sets form a <u>lattice</u>
  - Introduces many subtle issues, of course

Specialization Constraints



- Can an account be both a savings account and a checking account?
- Can an account be neither a savings account nor a checking account?
- Can specify constraints on specialization
  - Enforce what "makes sense" for the enterprise

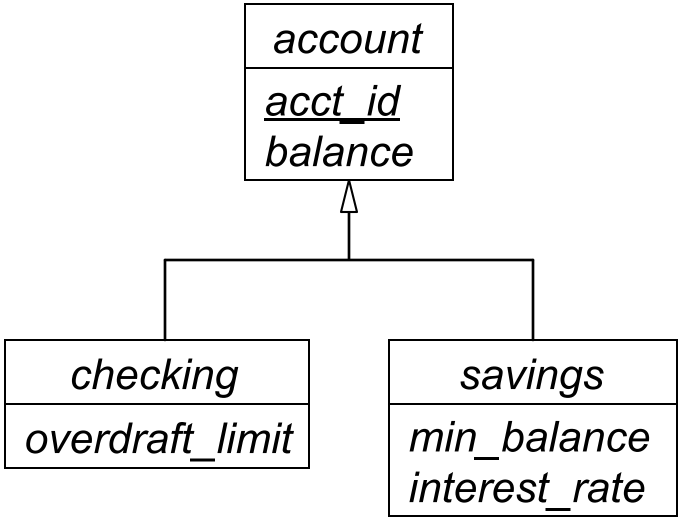
Disjointness Constraints

- "An account cannot be *both* a checking account and a savings account."
- An entity may belong to at most <u>one</u> of the lower-level entity-sets
  - Must be a member of *checking*, or a member of *savings*, but not both!
  - Called a "disjointness constraint"
  - A better way to state it: a <u>disjoint specialization</u>
- If an entity can be a member of multiple lower-level entity-sets:
  - Called an <u>overlapping specialization</u>

Disjointness Constraints (2)

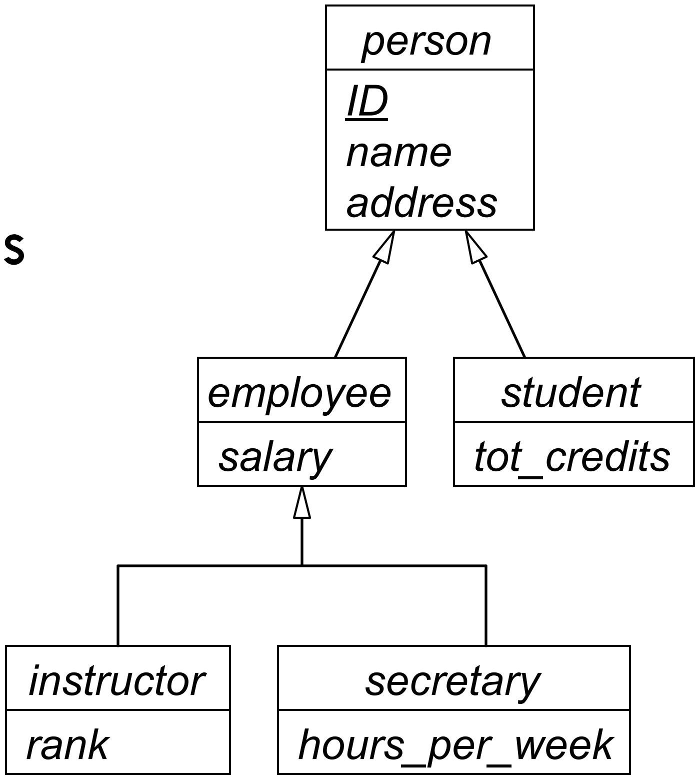
- How the arrows are drawn indicates whether the specialization is disjoint or overlapping

- Bank account example:
  - One arrow split into multiple parts indicates a disjoint specialization
  - An account may only be a checking account, or a savings account, not both



Disjointness Constraints (3)

- Another example from the book:
  - Specialization hierarchy for people at a university
- Multiple separate arrows indicates an overlapping specialization
  - A person can be an employee of the university and a student
- One arrow split into multiple parts is a disjoint specialization
  - An employee can be an instructor or a secretary, but not both

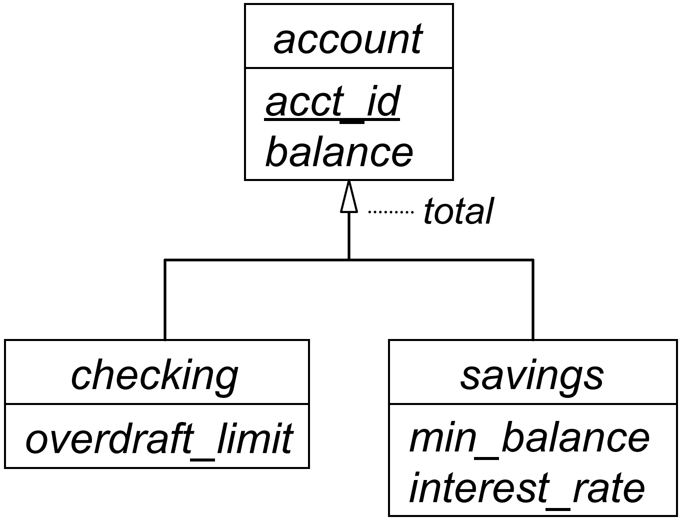


Completeness Constraints

- "An account must be a checking account, or it must be a savings account."
- Every entity in higher-level entity-set must also be a member of at least one lower-level entity-set
  - Called <u>total</u> specialization
- If entities in higher-level entity-set aren't required to be members of lower-level entity-sets:
  - Called <u>partial</u> specialization
- *account* specialization is a <u>total</u> specialization

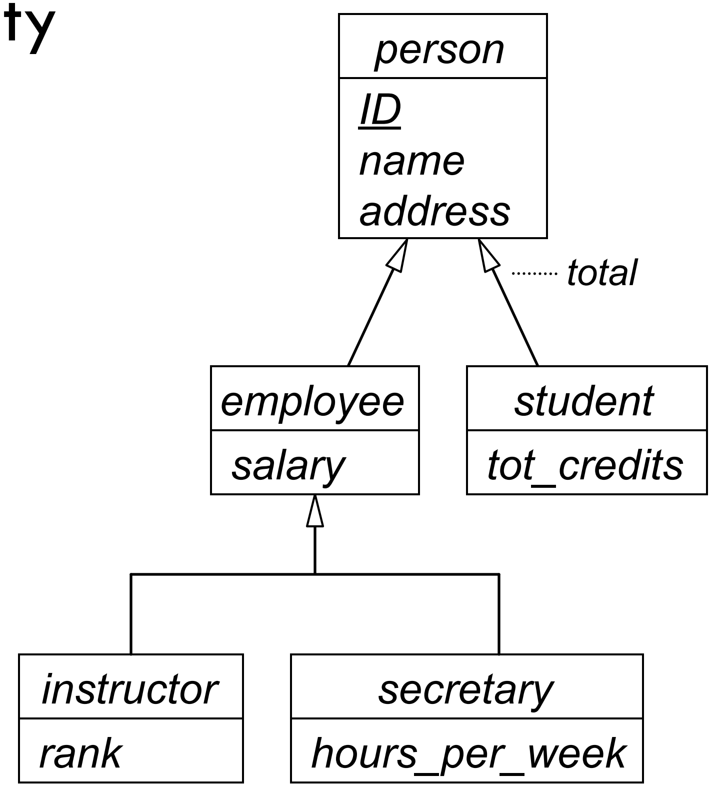
Completeness Constraints (2)

- Default constraint is <u>partial</u> specialization
- Specify total specialization constraint by annotating the specialization arrow(s)
- Updated bank account diagram:



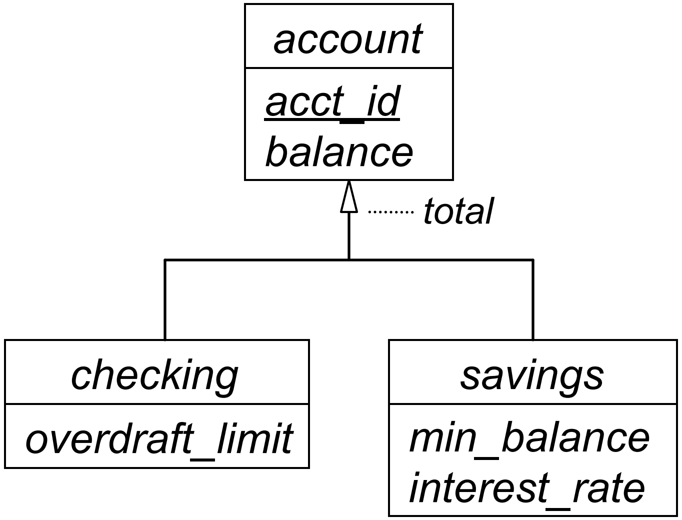
Completeness Constraints (3)

- Same approach with overlapping specialization
- Example: people at a university
  - Every person is an employee or a student
  - Not every employee is an instructor or a secretary
- Annotate arrows pointing to person with "total" to indicate total specialization
  - Every person must be an employee, a student, or both



Account Types?

- Our bank schema so far:



- How to tell whether an account is a checking account or a savings account?
  - No attribute indicates type of account

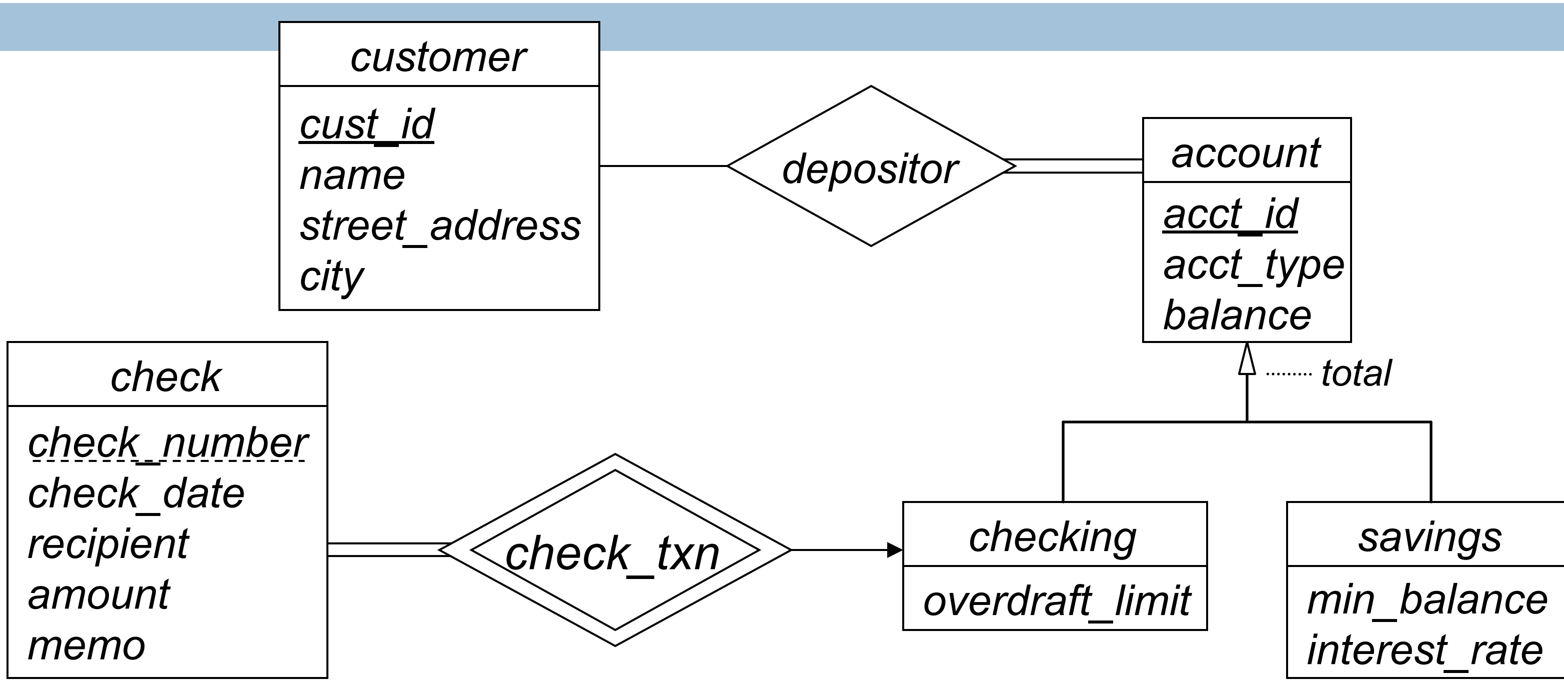
Membership Constraints

- <u>Membership constraints</u> specify which lower-level entity-sets each entity is a member of
  - e.g. which accounts are checking or savings accounts
- <u>Condition-defined</u> lower-level entity-sets
  - Membership is specified by a predicate
  - If an entity satisfies a lower-level entity-set's predicate then it is a member of that lower-level entity-set
  - If *all* lower-level entity-sets refer to the same attribute, this is called <u>attribute-defined</u> specialization
    - e.g. *account* could have an *account_type* attribute set to "c" for checking, or "s" for savings

Membership Constraints (2)

- Entities may simply be assigned to lower-level entity-sets by a database user
  - No explicit predicate governs membership
  - Called <u>user-defined</u> membership
- Generally used when an entity's membership could change in the future

Final Bank Account Diagram

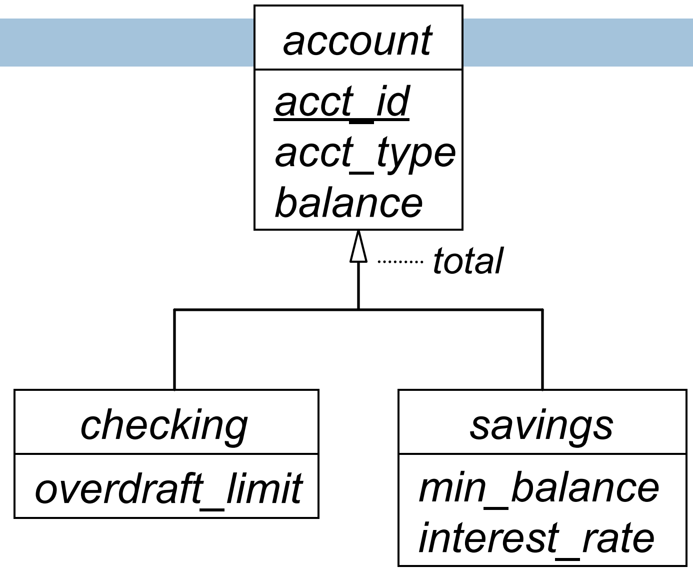


- Would also create relationship-sets against various entity-sets in hierarchy
  - associate *customer* with *account*
  - associate *check* weak entity-set with *checking*

Mapping to Relational Model

- Mapping generalization/specialization to relational model is straightforward
- Create relation schema for higher-level entity-set
  - Including primary keys, etc.
- Create schemas for lower-level entity-sets
  - Subclass schemas include superclass' primary key attributes!
  - Primary key is same as superclass' primary key
    - Subclasses can also contain their own candidate keys!
    - Enforce these candidate keys in implementation schema
  - Foreign key reference from subclass schemas to superclass schema, on primary-key attributes

Mapping Bank Account Schema



- Schemas:

  account(<u>*acct_id*</u>, *acct_type*, *balance*)

  checking(<u>*acct_id*</u>, *overdraft_limit*)

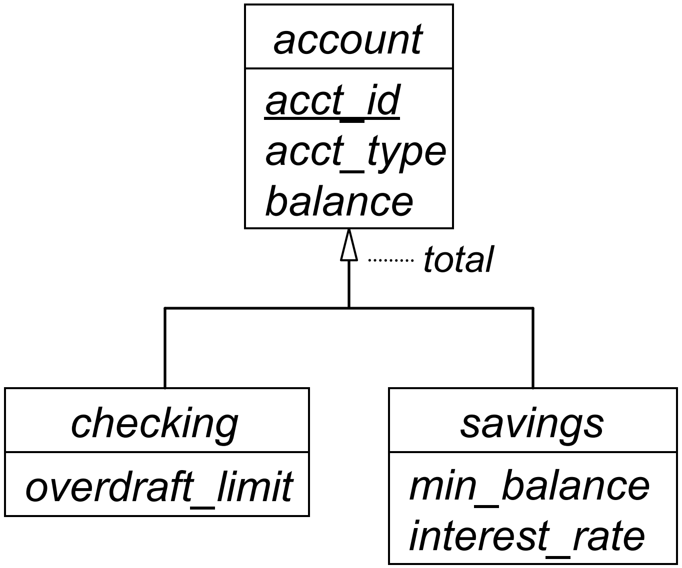
  savings(<u>*acct_id*</u>, *min_balance*, *interest_rate*)

  - Could use **`CHECK`** constraints on SQL tables for membership constraints, other constraints (although it may be expensive)

Alternative Schema Mapping

- If specialization is disjoint and complete, could convert only lower-level entity-sets to relational schemas
  - Every entity in higher-level entity-set also appears in lower-level entity-sets
  - Every entity is a member of *exactly one* lower-level entity-set
- Each lower-level entity-set has its own relation schema
  - All attributes of superclass entity-set are included on each subclass entity-set
  - No relation schema for superclass entity-set

Alternative Account Schema



- Schemas, take 2:

  checking(<u>*acct_id*</u>, *acct_type*, *balance*, *overdraft_limit*)

  savings(<u>*acct_id*</u>, *acct_type*, *balance*, *min_balance*, *interest_rate*)

Alternative Account Schema (2)

- Alternative schemas:

  checking(<u>*acct_id*</u>, *acct_type*, *balance*, *overdraft_limit*)

  savings(<u>*acct_id*</u>, *acct_type*, *balance*, *min_balance*, *interest_rate*)
- Problems?
  - Enforcing uniqueness of account IDs!
  - Representing relationships involving both kinds of accounts
- Can solve by creating a simple relation:

  account(<u>*acct_id*</u>)
  - Contains *all* valid account IDs
  - Relationships involving accounts can use *account*
  - Need foreign key constraints again…

Generating Primary Keys

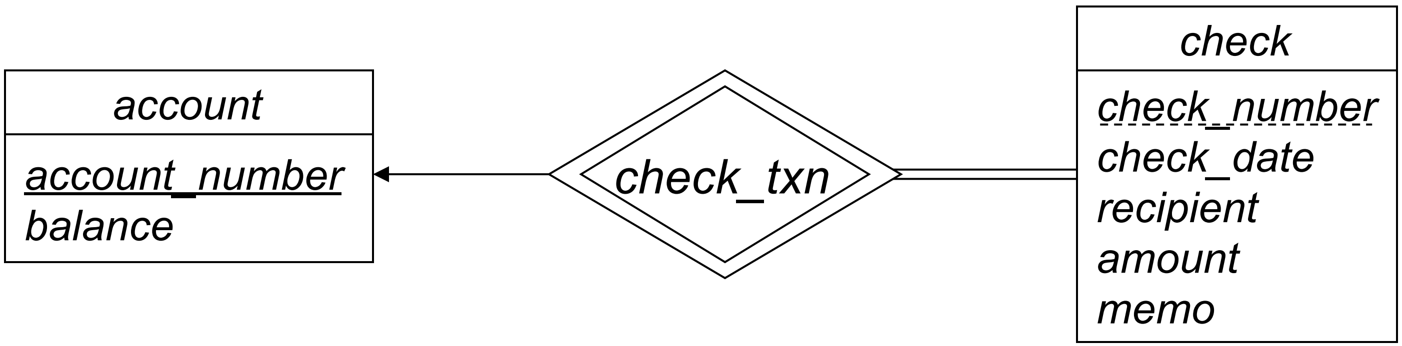
- *Generating* primary key values is actually the easy part
- Most databases provide <u>sequences</u>
  - A source of unique, increasing **INTEGER** or **BIGINT** values
  - Perfect for primary key values
  - Multiple tables can use the same sequence for their primary keys
- PostgreSQL example:

```
CREATE SEQUENCE acct_seq;

CREATE TABLE checking (
  acct_id INT PRIMARY KEY DEFAULT nextval('acct_seq');
  ...
);

CREATE TABLE savings (
  acct_id INT PRIMARY KEY DEFAULT nextval('acct_seq');
  ...
);
```

Alternative Schema Mapping

- Alternative mapping has serious drawbacks
  - Doesn't actually give many benefits in general case
- Fewer drawbacks if:
  - Total, disjoint specialization
  - No relationships against superclass entity-set
- If specialization is overlapping, some details will be stored multiple times
  - Unnecessary redundancy, and consistency issues
- Also limits future schema changes
  - Should always think about this when creating schemas

Recap: Weak Entity-Set Example



- *account* schema:

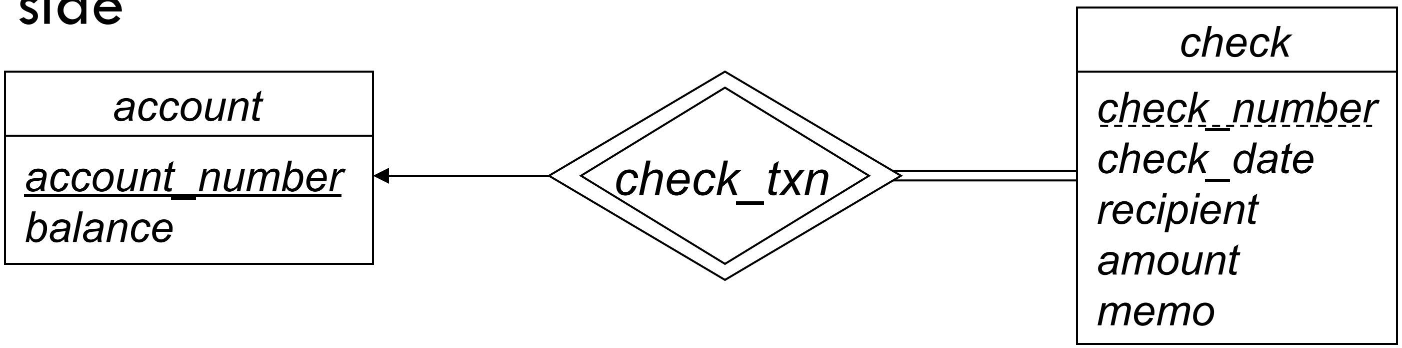
  account(<u>*account_number*</u>, *balance*)

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

  check(<u>*account_number*</u>, <u>*check_number*</u>, *check_date*, *recipient*, *amount*, *memo*)

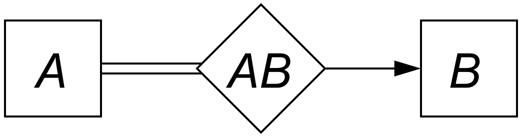
Schema Combination

- 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 already captures the identifying relationship
- Can apply this technique to other relationship-sets:
  - One-to-many mapping, with total participation on the "many" side



Schema Combination (2)

- Entity-sets *A* and *B*, relationship-set *AB*
  - Many-to-one mapping from *A* to *B*
  - *A*'s participation in *AB* is total

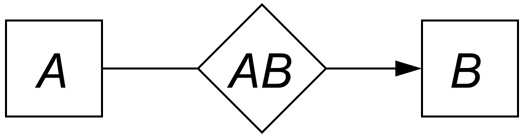


- Generates relation schemas *A*, *B*, *AB*
  - Primary key of *A* is *primary_key*(*A*)
  - Primary key of *AB* is also *primary_key*(*A*)
    - (*A* is on "many" side of mapping)
  - *AB* has foreign key constraints on both *A* and *B*
  - There is one relationship in *AB* for every entity in *A*
- Can combine *A* and *AB* relation schemas
  - Primary key of combined schema still *primary_key*(*A*)
  - Only requires one foreign-key constraint, to *B*

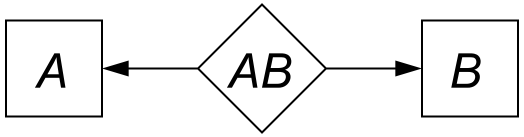
Schema Combination (3)

- In this case, when relationship-set is combined into the entity-set, the entity-set's primary key *doesn't change!*

- If *A*'s participation in *AB* is partial, can still combine schemas

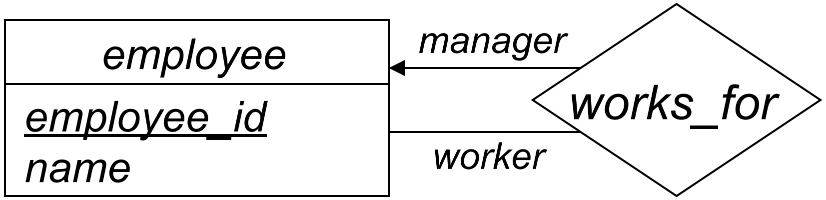


  - Must store *null* values for *primary_key*(*B*) attributes when an entity in *A* maps to no entity in *B*
- If *AB* is one-to-one mapping:



  - Can also combine schemas in this case
  - Could incorporate *AB* into schema for *A*, or schema for *B*
  - Don't forget that *AB* has <u>two</u> candidate keys…
    - The combined schema must still enforce both candidate keys

Schema-Combination Example



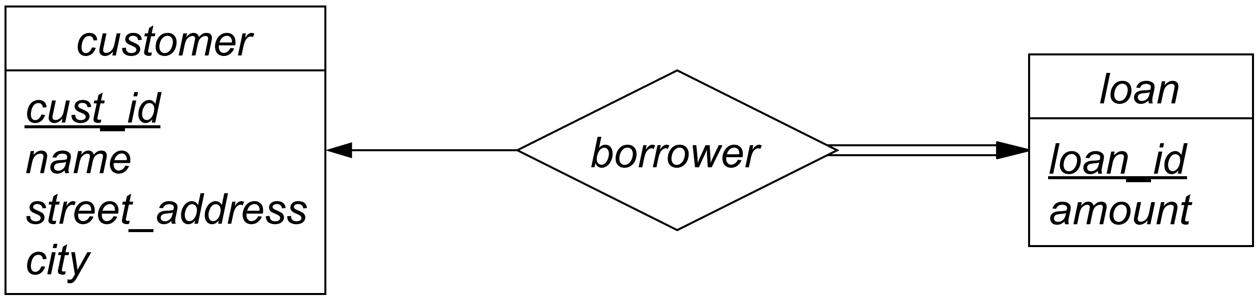
- Manager to worker mapping is one-to-many
- Relation schemas were:

  employee(*employee_id*, *name*)

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

  employee(*employee_id*, *name*, *manager_id*)
  - (A very common schema combination)
  - Need to store *null* for employees with no manager

Schema Combination Example (2)



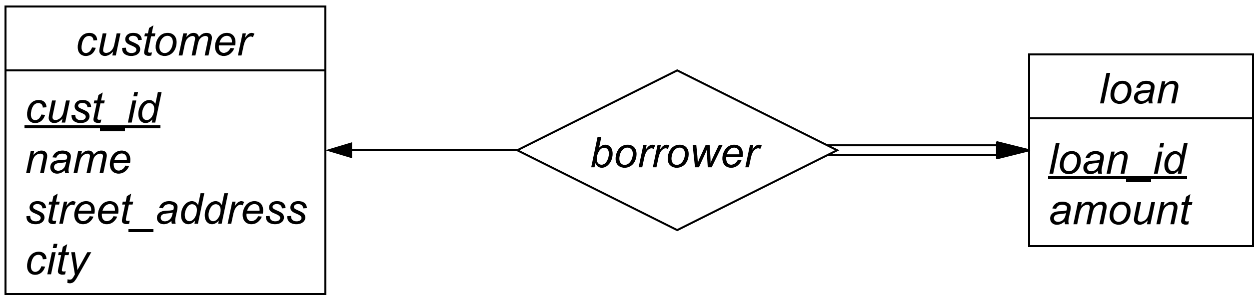
- One-to-one mapping between customers and loans

  customer(<u>*cust_id*</u>, *name*, *street_address*, *city*)

  loan(<u>*loan_id*</u>, *amount*)

  borrower(<u>*cust_id*</u>, *loan_id*) – *loan_id* also a candidate key
- Could combine *borrower* schema into *customer* schema or *loan* schema
  - Does it matter which one you choose?

Schema Combination Example (3)

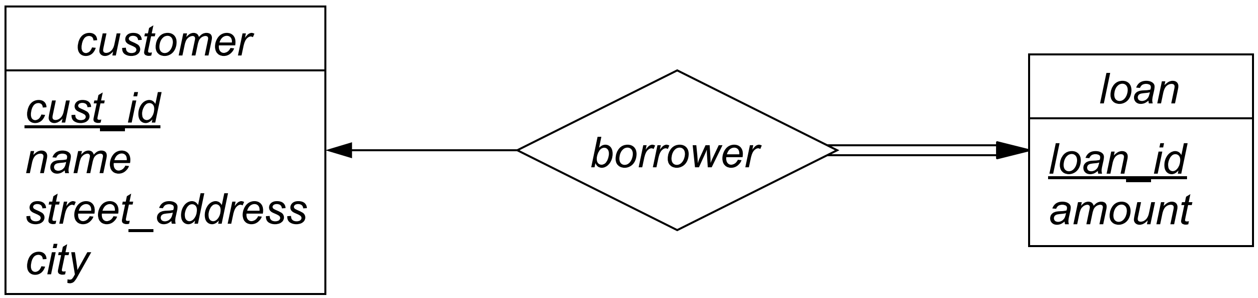


- Participation of *loan* in *borrower* will be total
  - Combining *borrower* into *customer* would require *null* values for customers without loans
- Better to combine *borrower* into *loan* schema

  customer(*<u>cust_id</u>*, *name*, *street_address*, *city*)

  loan(*<u>loan_id</u>*, *cust_id*, *amount*)
  - No *null* values!

Schema Combination Example (4)



- Schema:

  customer(<u>*cust_id*</u>, *name*, *street_address*, *city*)

  loan(<u>*loan_id*</u>, *cust_id*, *amount*)

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

Schema Combination Notes

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