Extended E-R Features

Winter 2006-2007

Lecture 18

Extensions to E-R Model

- Basic E-R model is good for many uses
- Several extensions to E-R model for more advanced modeling
  - Generalization and specialization
  - Aggregation
- These extensions can also be converted to relational model
  - Introduce a few more design choices

Specialization

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

Generalization and Specialization

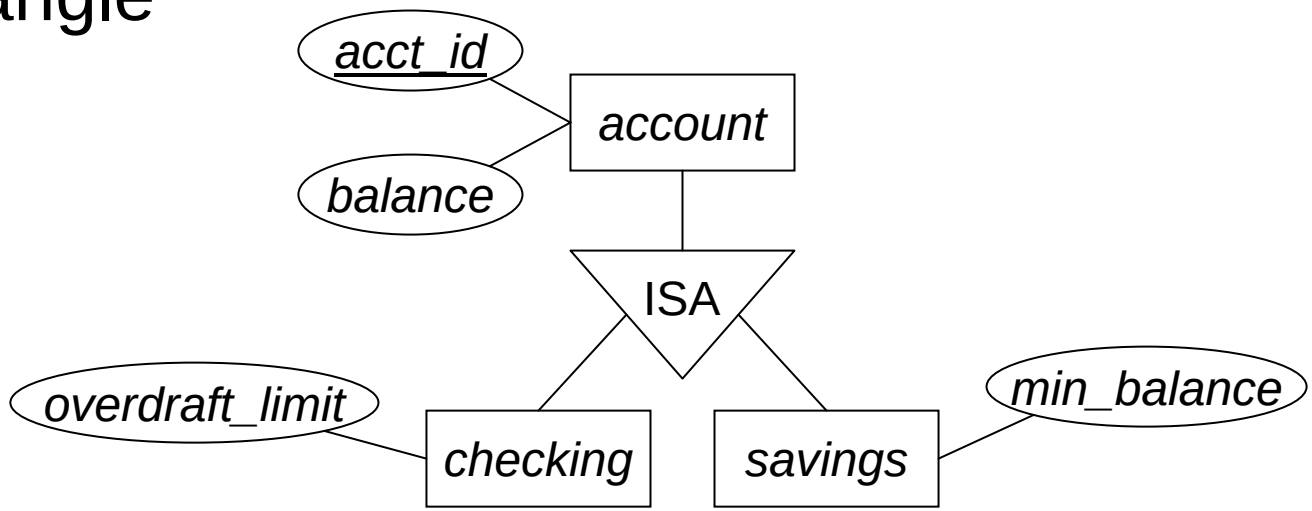
- Generalization: a “bottom up” approach
  - Taking similar entity-sets and unifying their common features
  - Start with specific entities, then create generalizations from them
- Specialization: a “top down” approach
  - Creating general purpose entity-sets, then providing specializations of the general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

Bank Account Example

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

Bank Account Example (2)

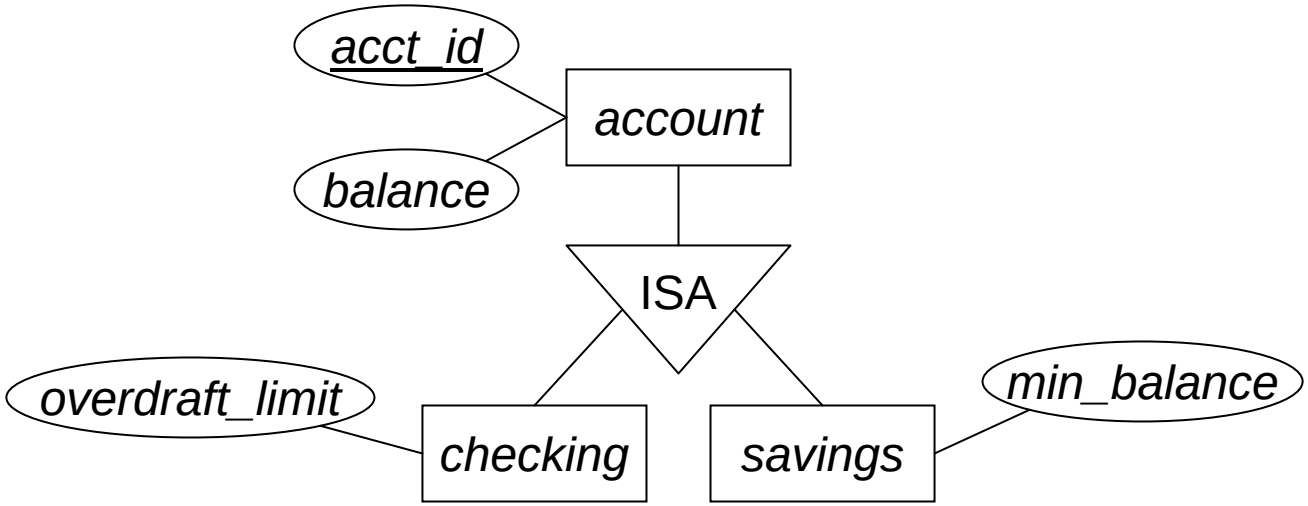
- Create entity-set to represent common attributes
  - Called the superclass, or higher-level entity-set
- Create entity-sets to represent specializations
  - Called subclasses, or lower-level entity-sets
- Join superclass to subclasses using “ISA” triangle



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!
  - A lower-level entity-set can participate in its own relationship-sets, too
- Usually, entity-sets inherit from one superclass
  - Entity-sets form a hierarchy
- Can also inherit from multiple superclasses
  - Entity-sets form a lattice
  - Introduces many subtle issues, of course

Specialization Constraints



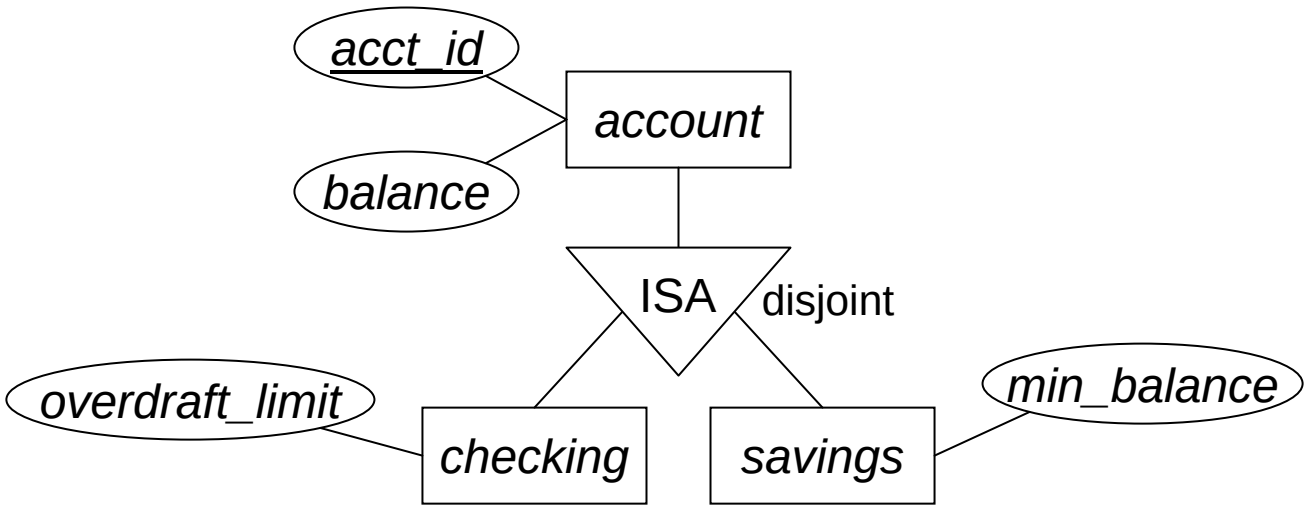
- Can an account be both a savings account and a checking account?
- Can an account be neither a savings account or a checking account?
- Can specify constraints on specialization
  - Enforce what “makes sense” for the enterprise

Disjointness Constraints

- “An account must be either a checking account, or a savings account, but not both.”
- An entity may belong to only one 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 disjoint specialization
- If an entity can be a member of multiple lower-level entity-sets:
  - Called an overlapping specialization

Disjointness Constraints (2)

- Default constraint is overlapping!
- Indicate disjoint specialization with word “disjoint” next to triangle
- Updated bank account diagram:

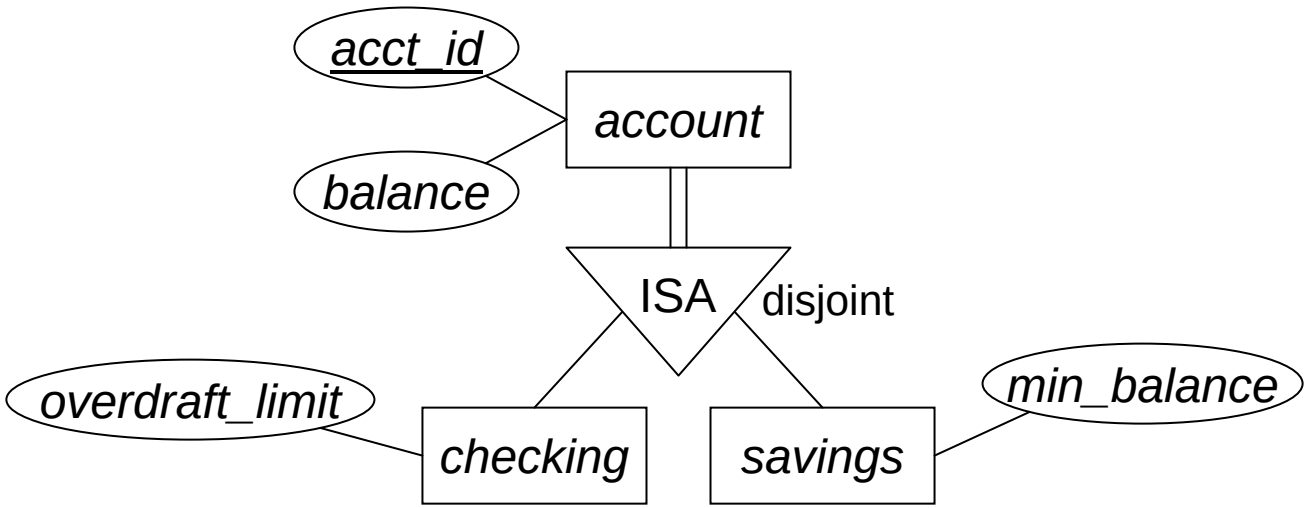


Completeness Constraints

- “An account must be a checking account or a savings account.”
- Every entity in higher-level entity-set must also be a member of at least one lower-level entity-set
  - Called total specialization
- If entities in higher-level entity-set aren’t required to be members of lower-level entity-sets:
  - Called partial specialization
- *account* specialization is a total specialization

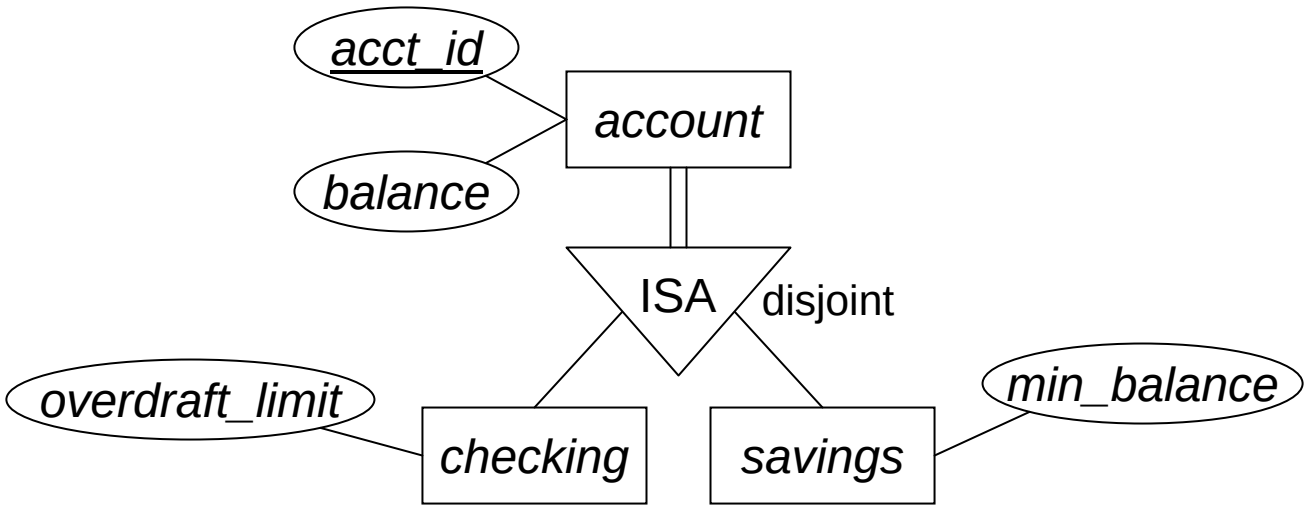
Completeness Constraints (2)

- Default constraint is partial specialization
- Specify total specialization constraint with a double line on superclass side
- Updated bank account diagram:



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

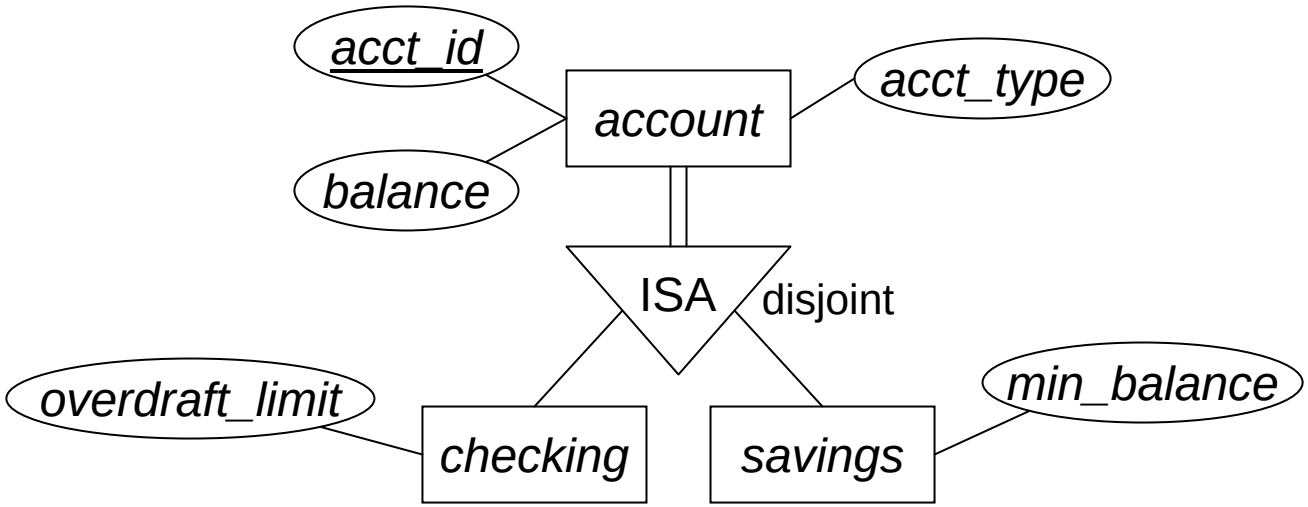
- Membership constraints specify which entities are members of lower-level entity-sets
  - e.g. which accounts are checking or savings accounts
- Condition-defined lower-level entity-sets
  - Membership is specified by a predicate
  - If an entity satisfies a lower-level entity-set's predicate then it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

Membership Constraints (2)

- Entities may simply be assigned to lower-level entity-sets by a database user
  - No explicit predicate governs membership
  - Called user-defined membership
- Generally used when an entity's membership could change in the future
- Bank account example:
  - Accounts *could* use user-defined membership, but wouldn't make so much sense
  - Makes it harder to write queries involving only one kind of account
  - Best choice is probably attribute-defined membership

Bank Accounts

- Final bank account diagram:

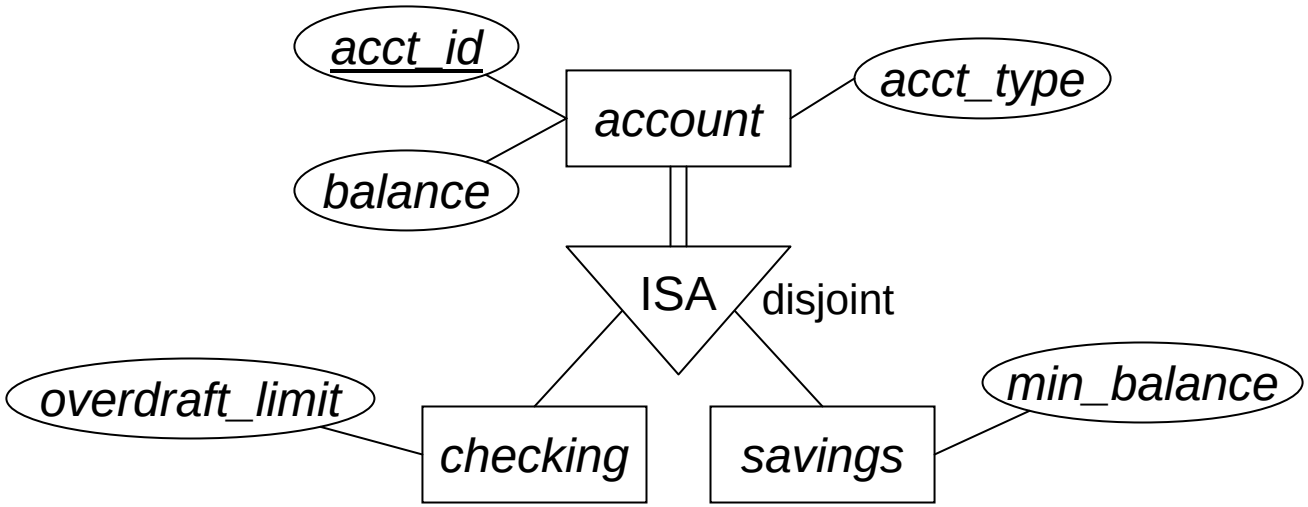


- Would also create relationship-sets against various entity-sets in hierarchy
  - associate *customer* with *account*
  - associate *check_txns* weak entity-set with *checking*

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
    - If subclass contains its own primary key, treat as a separate candidate key
  - 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*)

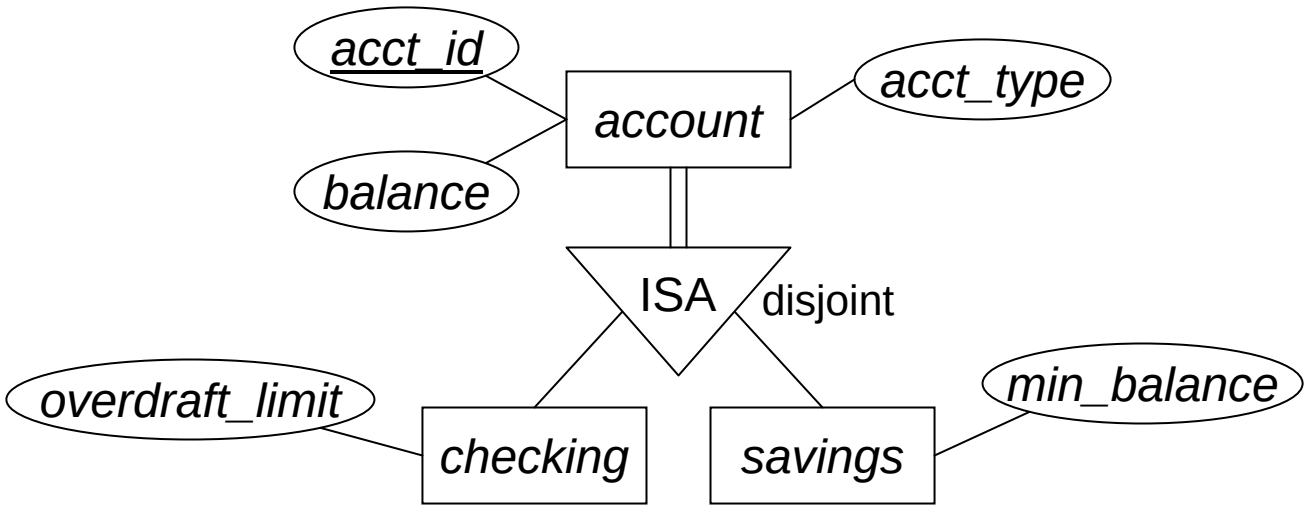
  savings(<u>*acct_id*</u>, *min_balance*)

  – Could use **`CHECK`** constraints SQL tables for membership constraints, other constraints

Alternative Schema Mapping

- If specialization is disjoint and complete, can 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:

  checking(*acct_id*, *acct_type*, *balance*, *overdraft_limit*)

  savings(*acct_id*, *acct_type*, *balance*, *min_balance*)

Alternative Account Schema (2)

- Alternative schemas:
  checking(*acct_id*, *acct_type*, *balance*, *overdraft_limit*)
  savings(*acct_id*, *acct_type*, *balance*, *min_balance*)
- Problems?
  - Enforcing uniqueness of account IDs!
  - Representing relationships involving general accounts
- Can solve by creating a simple relation:
  account(*acct_id*)
  - 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 sequences
  - A source of **`INTEGER`** or **`BIGINT`** values
  - Perfect for primary key values
  - Multiple tables can use a sequence for their primary keys
- PostgreSQL example:

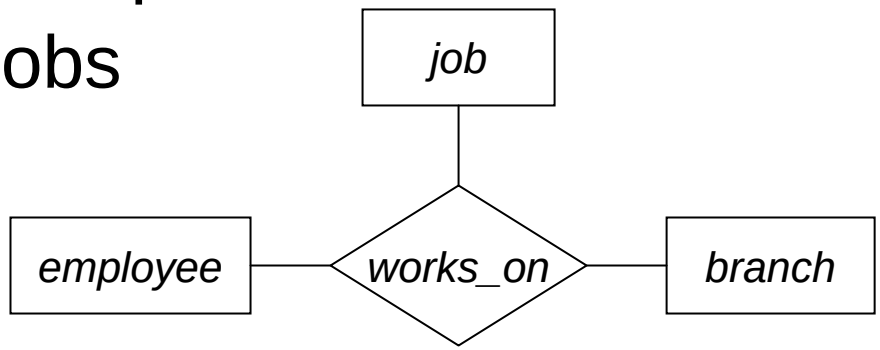
```
CREATE SEQUENCE acct_seq;

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 some drawbacks
  - Doesn’t actually give many benefits in general case
  - Biggest issue is managing primary keys!
- Fewer drawbacks if:
  - Total, disjoint specialization
  - No relationships against superclass entity-set
- If specialization is overlapping, some details are stored multiple times
  - Unnecessary redundancy, and consistency issues
- Also limits future schema changes

Relationships of Relationships

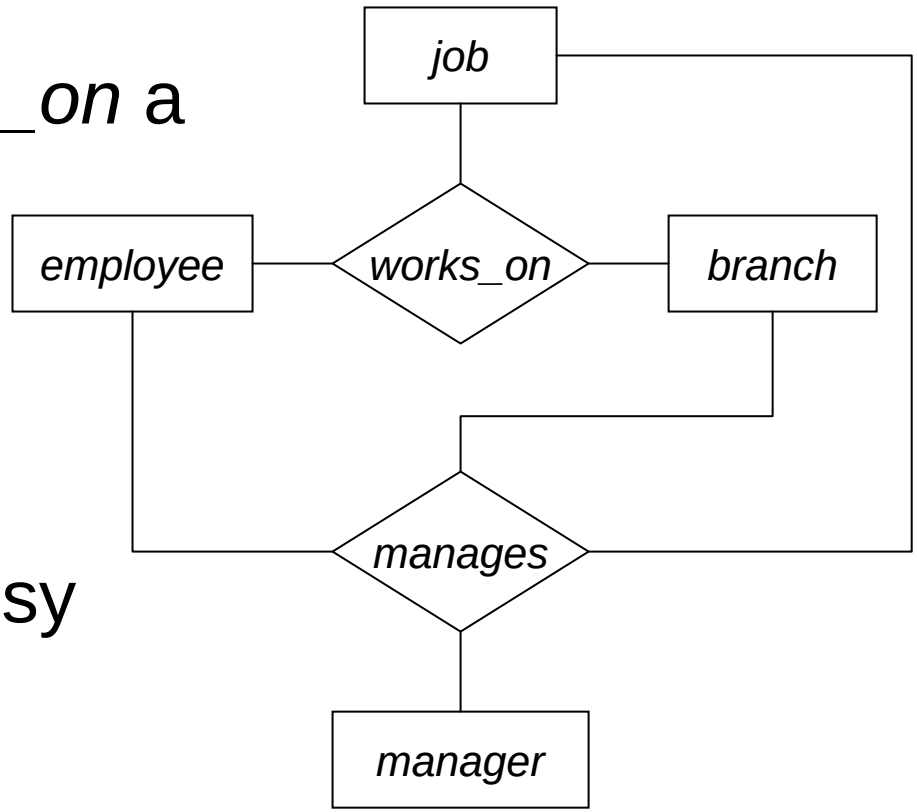
- Basic E-R model can't represent relationships involving other relationships
- Example: employee jobs



- Want to assign a manager to each (employee, branch, job) combination
  - Need a separate *manager* entity-set
  - Relationship between each manager, employee, branch, and job entity

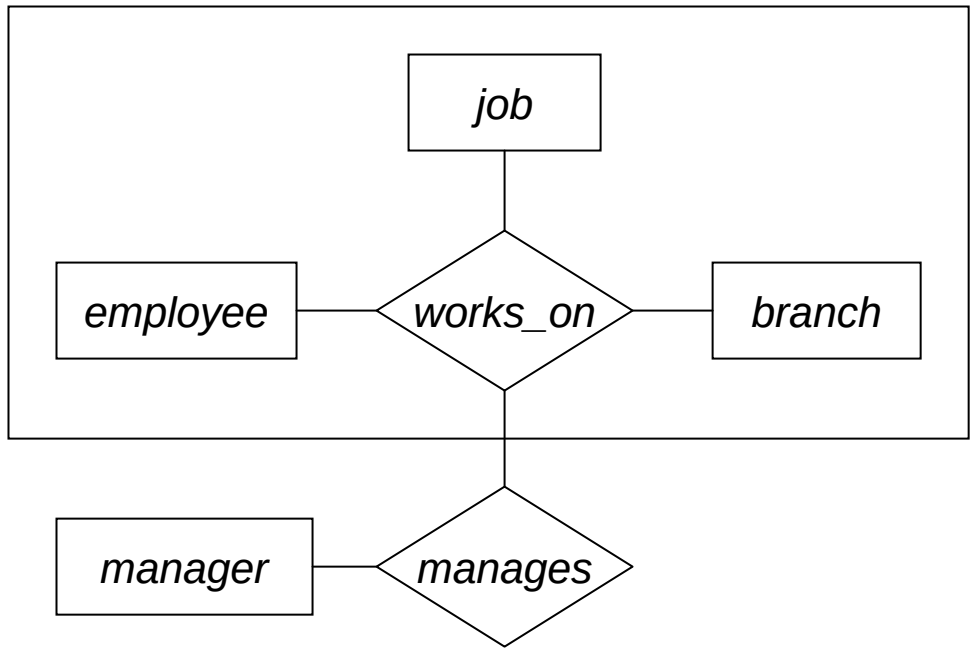
Redundant Relationships

- One option: a quaternary relationship
  - This option has lots of redundant information
  - Benefit is that some jobs might not require a manager
- Could also make *works_on* a quaternary relationship
  - Don't use a separate *manager* relation
  - Jobs with no manager would use *null* values instead
- These options are clumsy



Aggregation

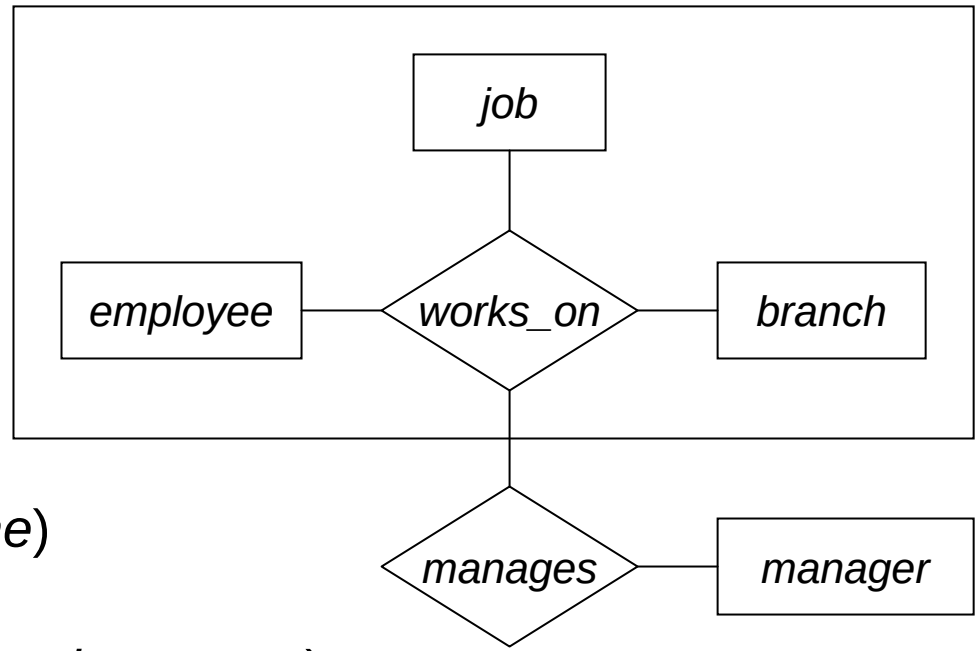
- Another option is to treat *works_on* relationship as an aggregate
  - Build a relationship against the aggregate
  - *manages* implicitly includes set of entities participating in a *works_on* relationship instance
  - Jobs can also have no manager



Mapping to Relational Model

- Mapping for aggregation is straightforward
- For entity-sets and relationship-set being used as an aggregate, mapping is unchanged
- Relationship-set against the aggregate:
  - Includes primary keys of participating entity-sets
  - Includes all primary key attributes of aggregated relationship-set
  - Also includes any descriptive attributes
  - Primary key of relationship-set includes all the above primary key attributes
  - Foreign key against aggregated relationship-set, as well as participating entity-sets

Manager Example



- Job schemas:

  employee(*emp_id*, *emp_name*)

  job(*title*, *level*)

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

  works_on(*emp_id*, *branch_name*, *title*)

- Manager schemas:

  manager(*mgr_id*, *mgr_name*)

  manages(*mgr_id*, *emp_id*, *branch_name*, *title*)

Differences

- Differences between version with aggregation, and version with quaternary relationship?
- Biggest difference:
  - Quaternary relationship's schema derives primary and foreign key constraints from participating entities
  - Relationship using aggregation derives primary and foreign key constraints from aggregate relationship
- A subtle difference
  - Doesn't have any significant practical impact

Review

- Covered two extensions to E-R model
  - Higher level abstractions
- Generalization and specialization
  - Can specify constraints:
    - Membership constraints
    - Completeness constraints
    - Disjointedness constraints
- Aggregation
  - Can build relationships that include other relationships
- Straightforward mappings to relational model
- Next time: normal forms!