Database Design

Core Database Design Steps

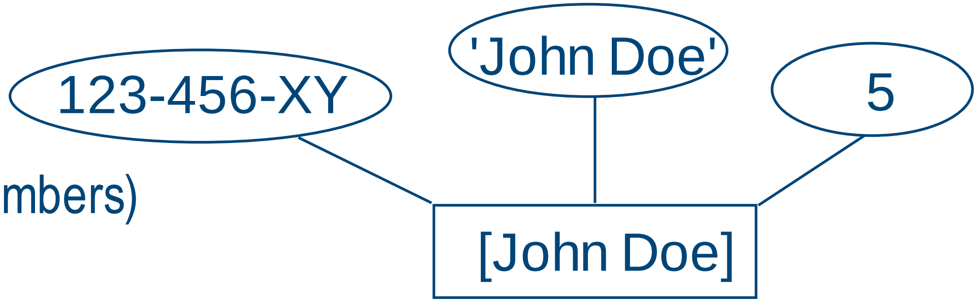
- Conceptual design ← Our focus in this Chapter
  - Construct a description of the information used in an enterprise
  - *Focus on documenting customer intention, disregard technology*
- Logical design
  - Construct a description based on a specific data model (e.g., relational)
  - *Focus on abstract tech, disregard implementation*
- Physical design
  - Describe implementation using a particular DBMS, file structures, indexes, security, …

Issues in Conceptual Design

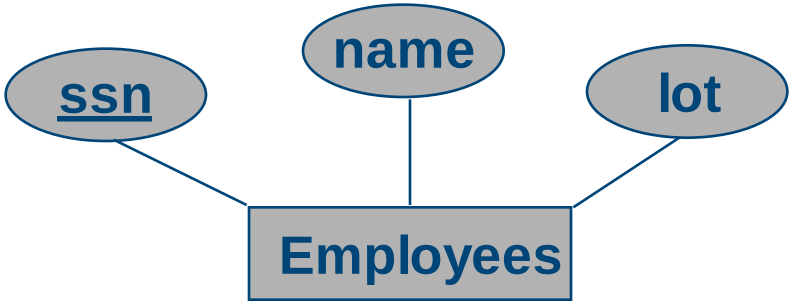
- Conceptual design: (we use ER Model at this stage)
  - What are the entities and relationships in the enterprise?
  - What information about these entities and relationships should we store in the database?
  - What are the integrity constraints or business rules that hold?
- database `schema' in the ER Model represented pictorially = ER diagrams
  - Can map an ER diagram into a relational schema
  - Actually lack of textual equivalent is shortcoming
  - … also: no formal semantics (originally)

Entity-Relationship Model: Basics

- Entity: Real-world object distinguishable from other objects
  - entity described (in DB) using a set of attributes
  - Simple attribute values (strings, numbers)

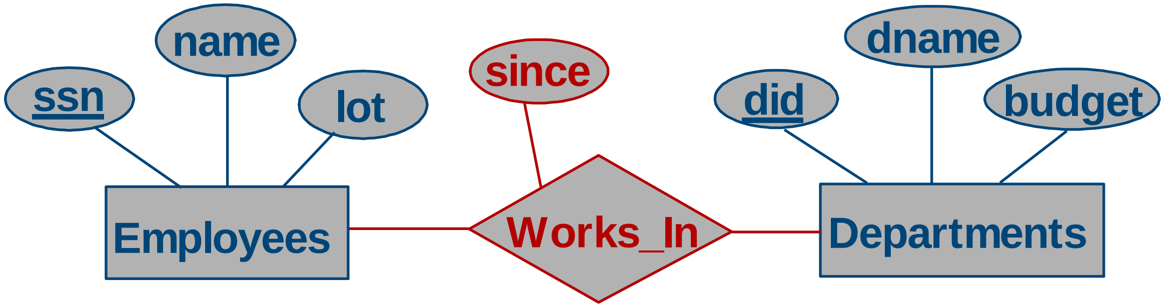


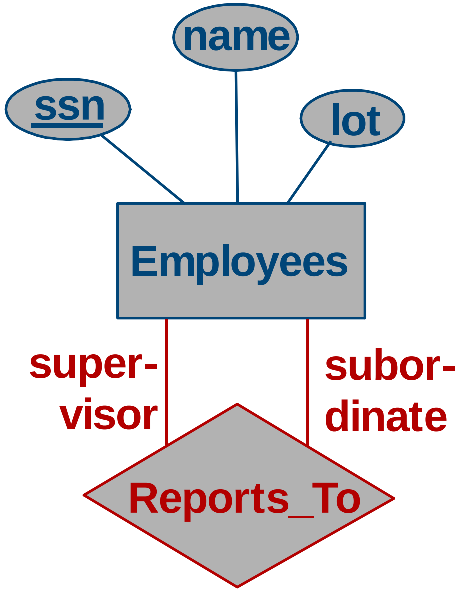
- Entity set: collection of similar entities
  - E.g., all employees
  - All entities in an entity set have the same set of attributes
    - *Until we consider ISA hierarchies, anyway!*
  - Each entity set has a key
  - Each attribute has a domain = data type



ER Model Basics (Contd.)

- Relationship: (unique!) association among two or more entities
  - E.g., Attishoo works_in Pharmacy department
- Relationship Set: Collection of similar relationships
  - An n-ary (binary, ternary, ...) relationship set R relates n entity sets E1 ... En
  - each relationship in R involves entities e1 ∈ E1, ..., en ∈ En
  - Same entity set can participate in different relationship sets, or even in the same set (but then in different roles)





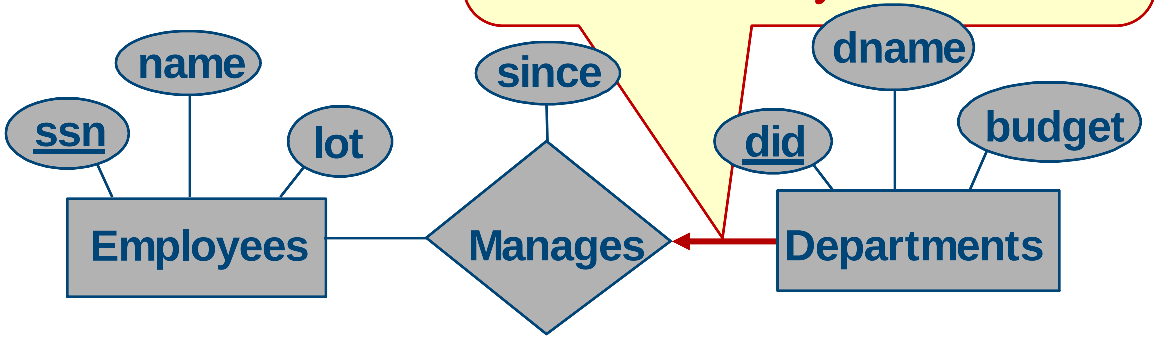
Constraints

- Used to capture more application semantics
- ...on relationship sets:
    - Key constraints (multiplicities)
- ...on entity sets:
    - Participation constraints

Key Constraints: Multiplicity

- Key constraints: how many entities [or other relships] can/must participate in given relship?
- Before, Works_In:
  - emp can work in many depts; dept can have many emps
- Now, **Manages**:
  - each dept has at most one manager
- Key constraint also called "multiplicity" of a relship
  - Why "key"?

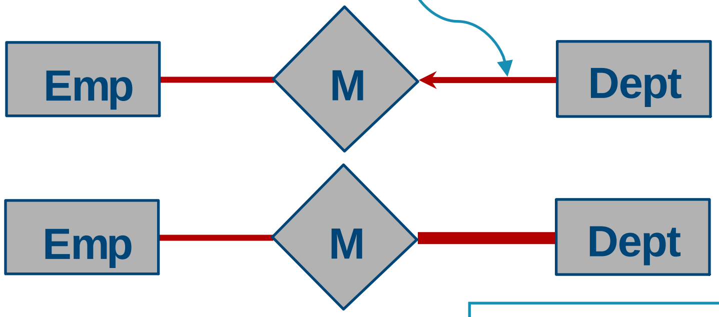
Forget about fat etc. - we will use UML + textual constraints where necessary



Arrow not fat!

Notation Variants: Multiplicity

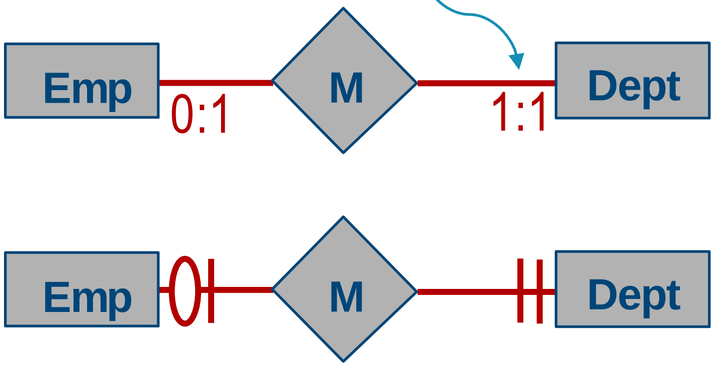
„ptr target is unique = 1“

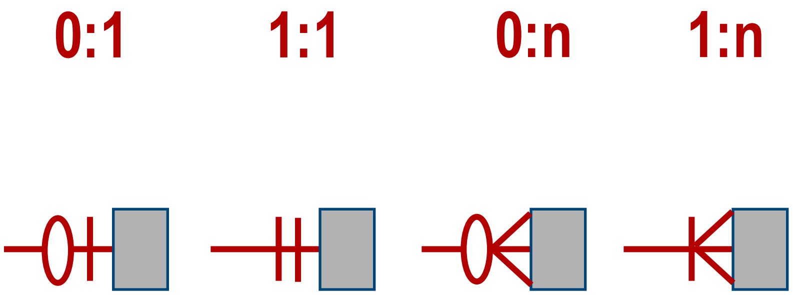


x:1 a la Ramakrishnan/Gehrke

1:x a la Ramakrishnan/Gehrke

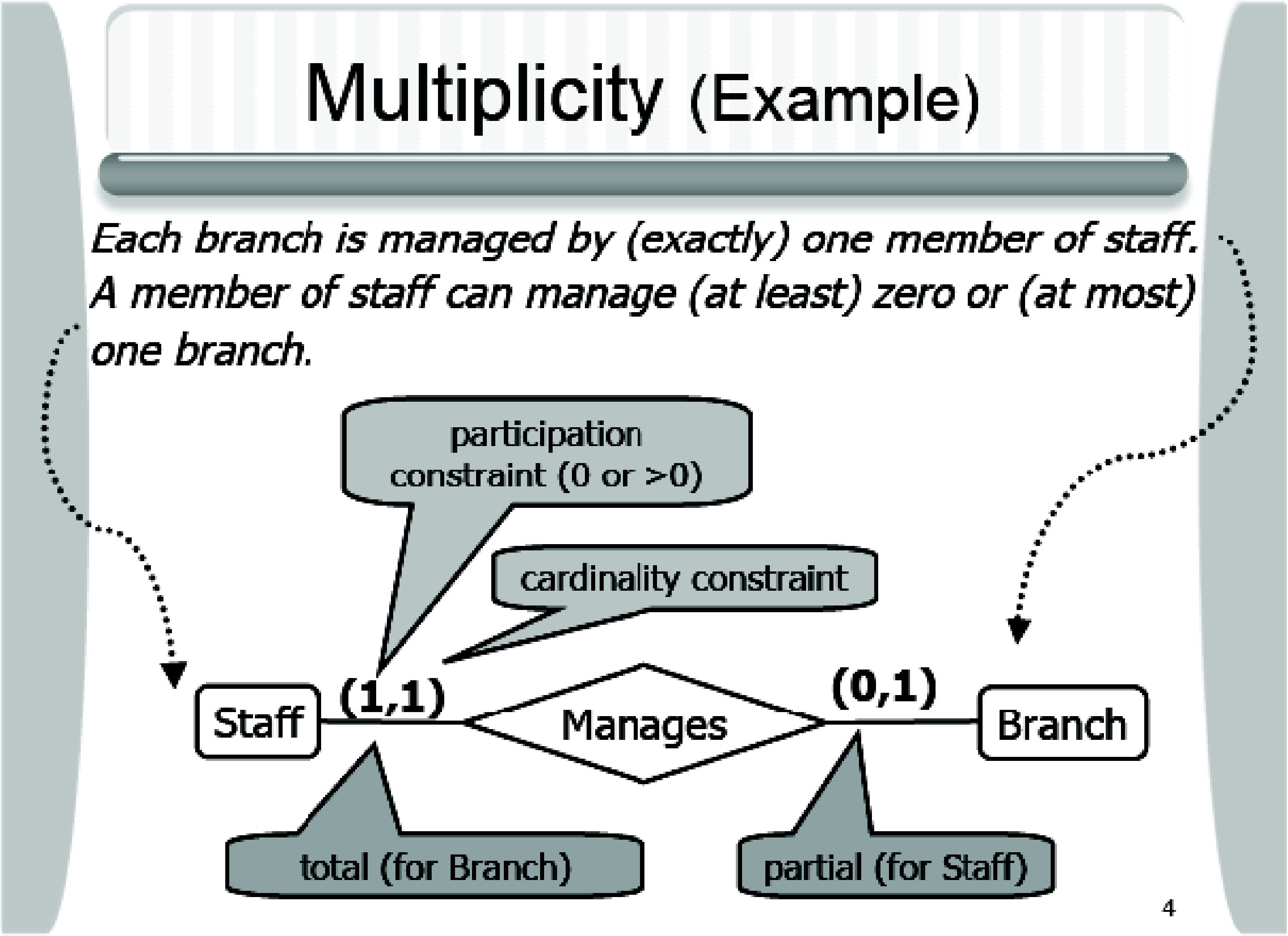
My personal preference – allows for more details





…plus many more

Citing a Similar Discussion by Bernhard Reus (U of Sussex)



Multiplicity (Example)

Each branch is managed by (exactly) one member of staff. A member of staff can manage (at least) zero or (at most) one branch.

participation constraint (0 or >0)

cardinality constraint

Staff (1,1) Manages (0,1) Branch

total (for Branch)

partial (for Staff)

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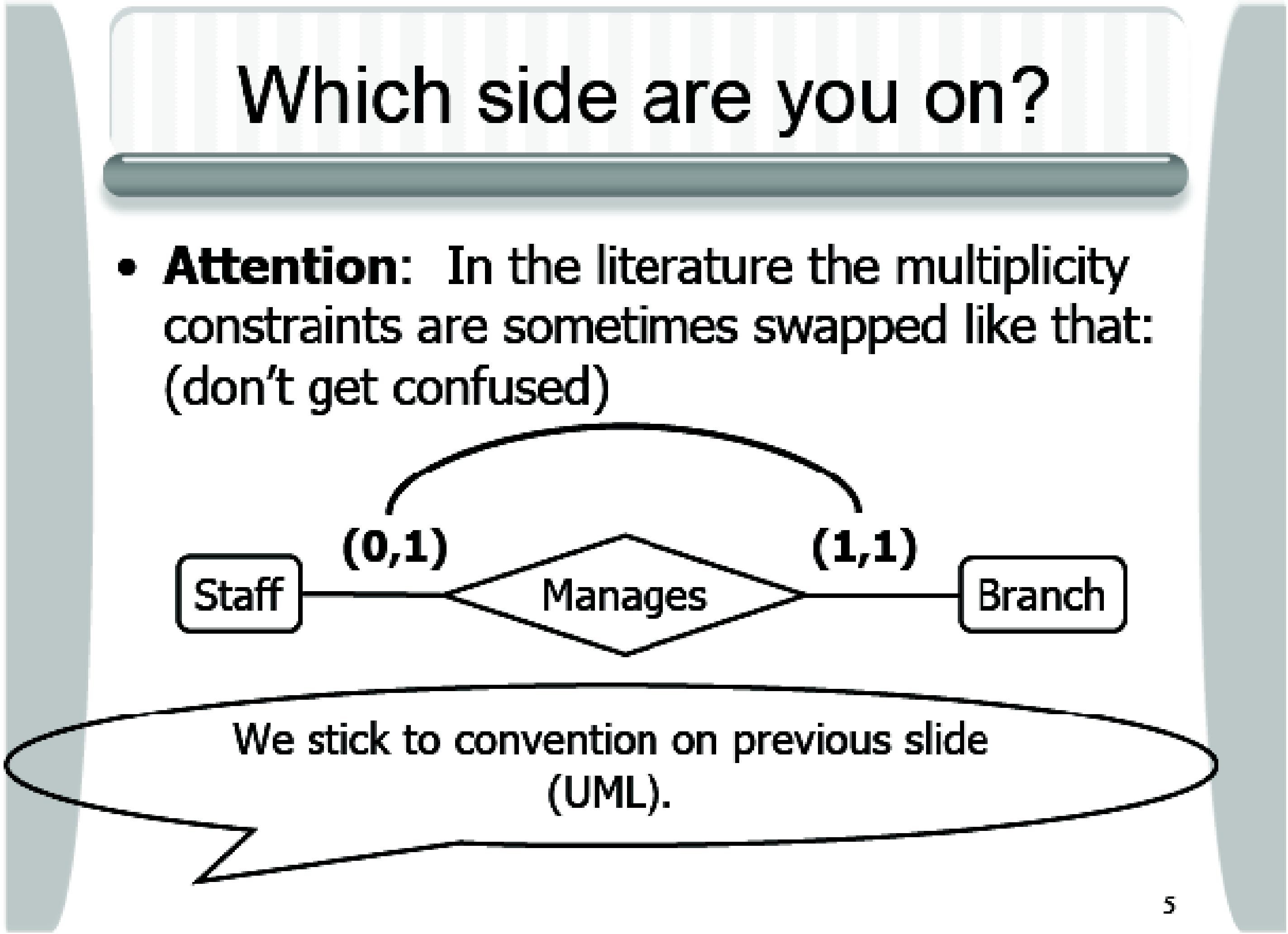
Citing a Similar Discussion by Bernhard Reus (U of Sussex)



Which side are you on?

- **Attention:** In the literature the multiplicity constraints are sometimes swapped like that: (don't get confused)

We stick to convention on previous slide (UML).

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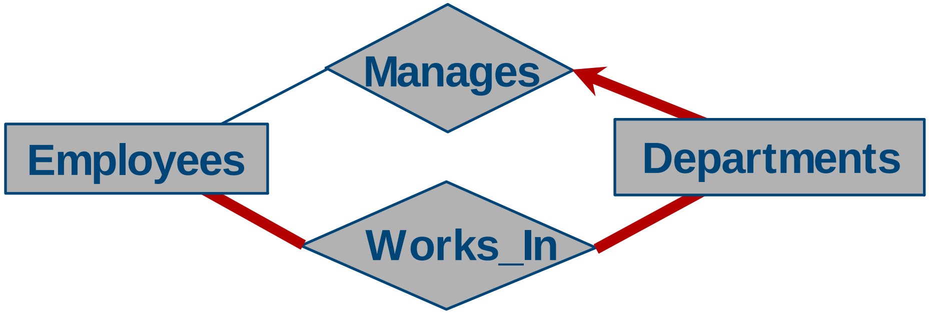
Key Constraints: Participation

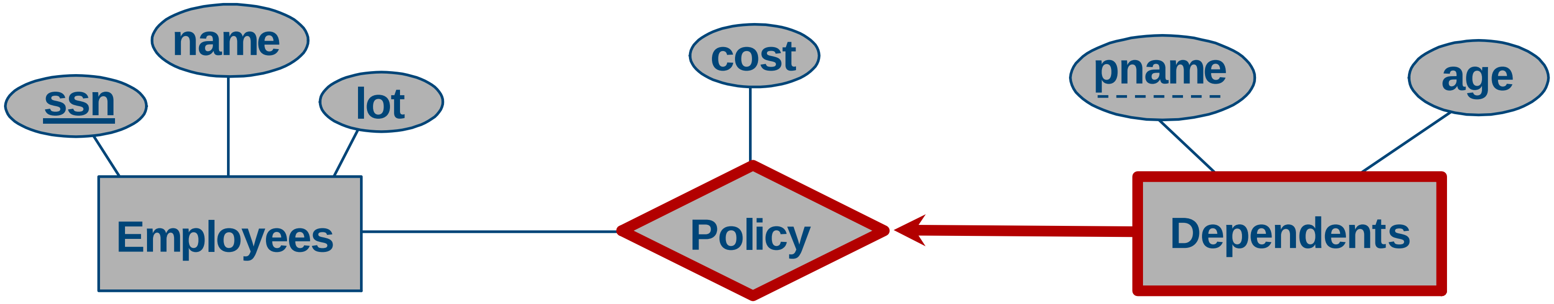
- Does every department have a manager?
- Entity set E is total wrt. relationship set R
  :⇔ all E entities participate in R
- Entity set E is partial wrt. relationship set R
  :⇔ some E entities do not participate in R

- *What about* Works_In *branch?*
- *Manages arrow fat?*



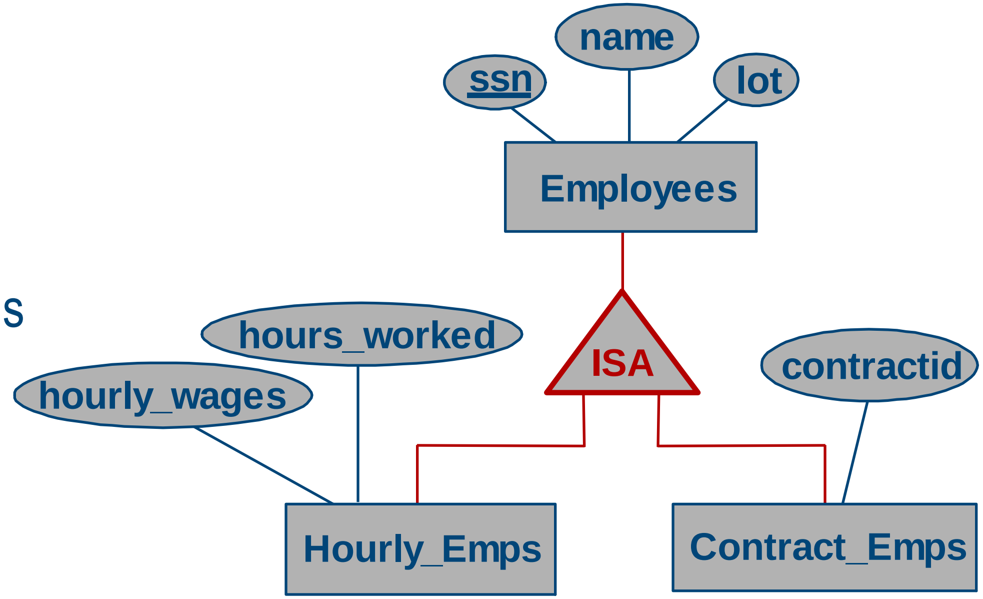
Weak Entities

- weak entity: identified uniquely only by considering the primary key of another (owner) entity
  - Owner entity set and weak entity set must participate in a one-to-many relationship set (one owner, many weak entities)
  - Weak entity set must have total participation in identifying relationship set (no identification of its own!)



ISA (`is a') Hierarchies

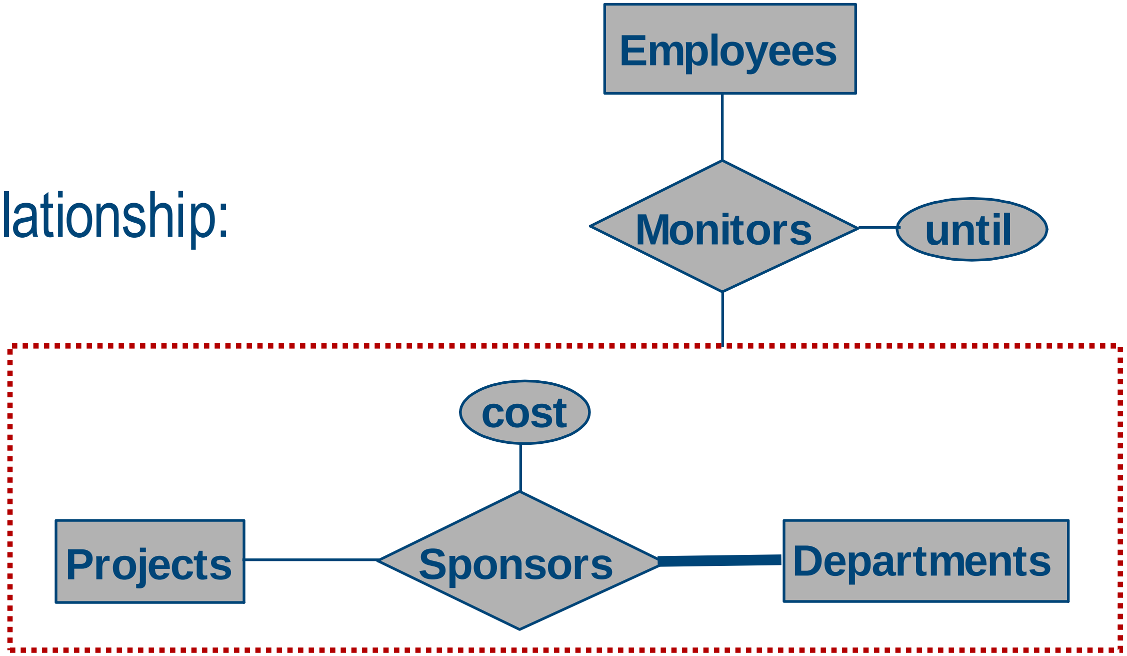
- A ISA B: every A entity is also a B entity ("A inherits from B")
  - A entities have attributes like B entities have, plus maybe more
  - A is called subclass, B superclass
- Purpose:
  - add attributes specific to a subclass
  - identify specific entitities that participate in a relationship



- Constraints:
  - Overlap constraints: Can Joe be an Hourly_Emps as well as a Contract_Emps entity? (Allowed/disallowed)
  - Covering constraints: Does every Employees entity also have to be an Hourly_Emps or a Contract_Emps entity? (Yes/no)

Aggregation

- Aggregation = relationship involving (entitity sets and) a relationship set
- Aggregation allows us to treat a relationship set as an entity set for purposes of participation in (other) relationships
- Aggregation vs. ternary relationship:
  - Monitors is a distinct relationship, with a descriptive attribute
  - each sponsorship is monitored by at most one employee



Conceptual Design Using the ER Model

- Design choices:
  - concept modeled as entity or attribute?
  - concept modeled as entity or relationship?
  - Identifying relationships: Binary or ternary? Aggregation?
- Constraints in the ER Model:
  - A lot of data semantics can (and should) be captured
  - But some constraints cannot be captured in ER diagrams – *comment your design!*
- *Let's see…*

Summary of ER

- ER model popular for conceptual design
  - simple & expressive
  - close to the way people think about their applications
- Basic constructs:
  entities and relationships, both with attributes
- Some additional constructs:
  weak entities, ISA hierarchies, and aggregation
- Note: There are many variations on ER model

Summary of ER (Contd.)

- Several kinds of integrity constraints can be expressed in the ER model
  - key constraints
  - participation constraints
  - overlap/covering constraints for ISA hierarchies
- Some foreign key constraints implicit in definition of a relationship set
  - Some (actually: many) constraints cannot be expressed in the ER model
    - *notably, functional dependencies*
  - But: constraints play an important role in determining the best database design

Summary of ER (Contd.)

- ER design is subjective
  - often many ways to model a given scenario
  - When in doubt (and not only then), ask customer how they will query their data – this usually gives valuable insights
  - Analyzing alternatives can be tricky, esp. large schemas (SAP R/3: 15,000 tables!)
- Common choices include:
  - Entity vs. attribute, entity vs. relationship, binary or n-ary relationship
  - whether or not to use ISA hierarchies, whether or not to use aggregation
- Ensuring good database design: resulting relational schema should be analyzed and refined further → logical design phase
  - Functional dependency information, normalization techniques

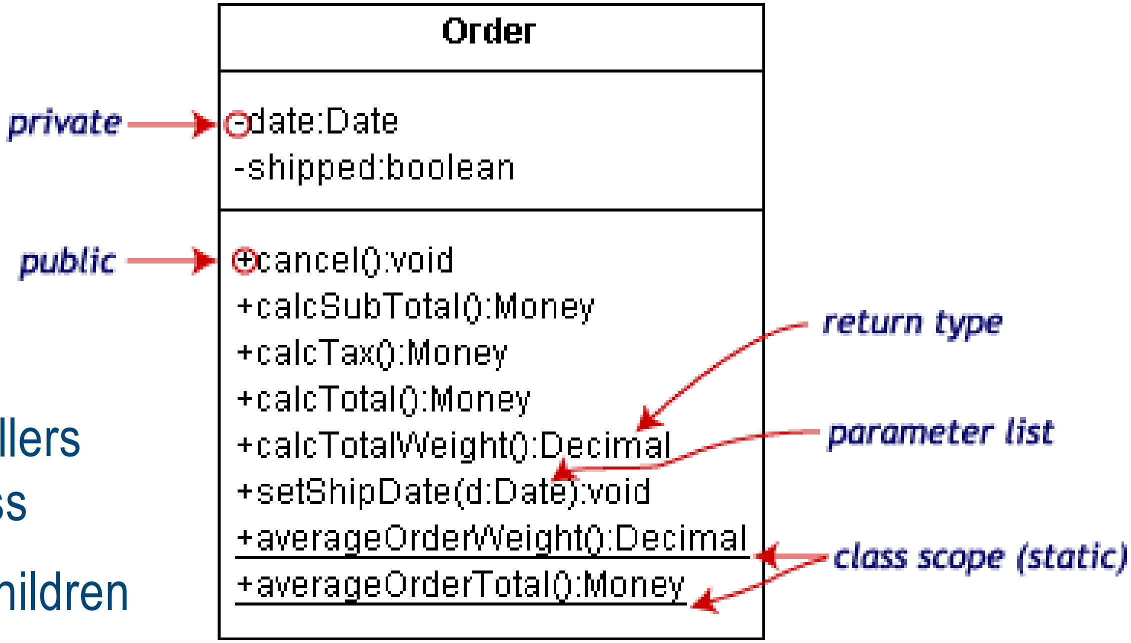
UML™

[not in DBMS book, see course website]

- UML = Unified Modeling Language [www.uml.org]
  - Issued by OMG [Object Management Group, www.omg.org]
- "UML is a graphical language for visualizing, specifying, constructing, and documenting the artifacts of a software-intensive system."
  - does not prescribe particular methodology or process
- Notation & semantics for domains:
  - Use Case Model; Communication Model; Dynamic Model; Class Model; Physical Component Model; Physical Deployment Model
- Much more comprehensive than ER!

Classes

- Class Model at the core of object-oriented development and design
- Naming: instance (ER: entity) belongs to class (ER: entity set)
- Attributes and methods may be marked as:
  - Private -- not visible to callers outside the class
  - Protected -- only visible to children of the class
  - Public -- visible to all



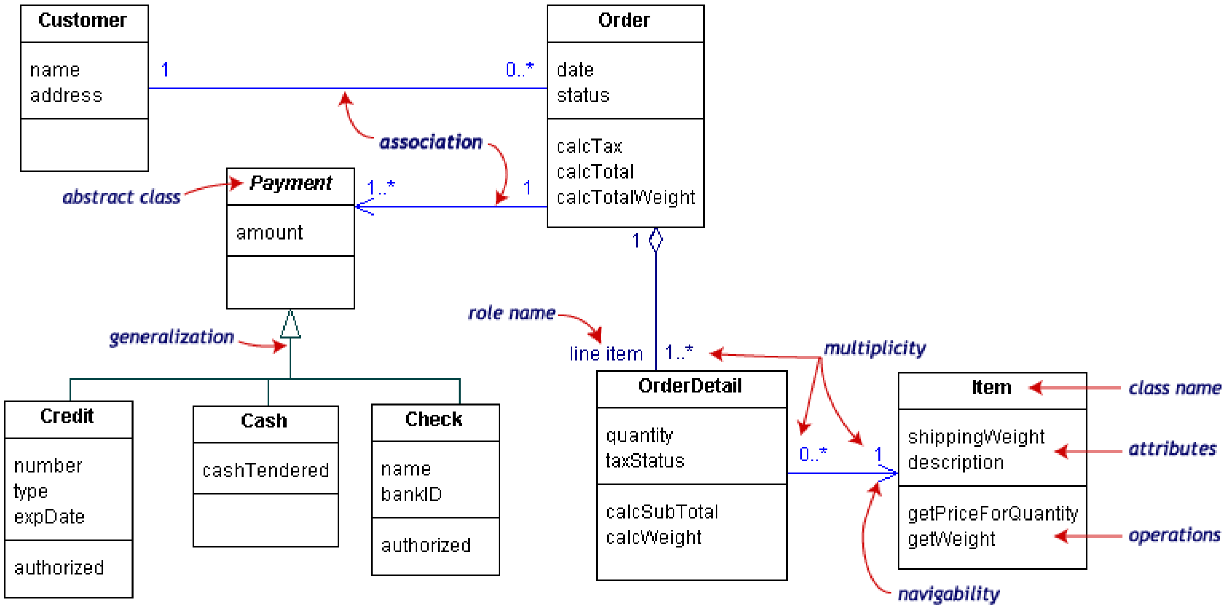
Order

-date:Date
-shipped:boolean

+cancel():void
+calcSubTotal():Money
+calcTax():Money
+calcTotal():Money
+calcTotalWeight():Decimal
+setShipDate(d:Date):void
+averageOrderWeight():Decimal
+averageOrderTotal():Money

Relationships & Class Diagrams

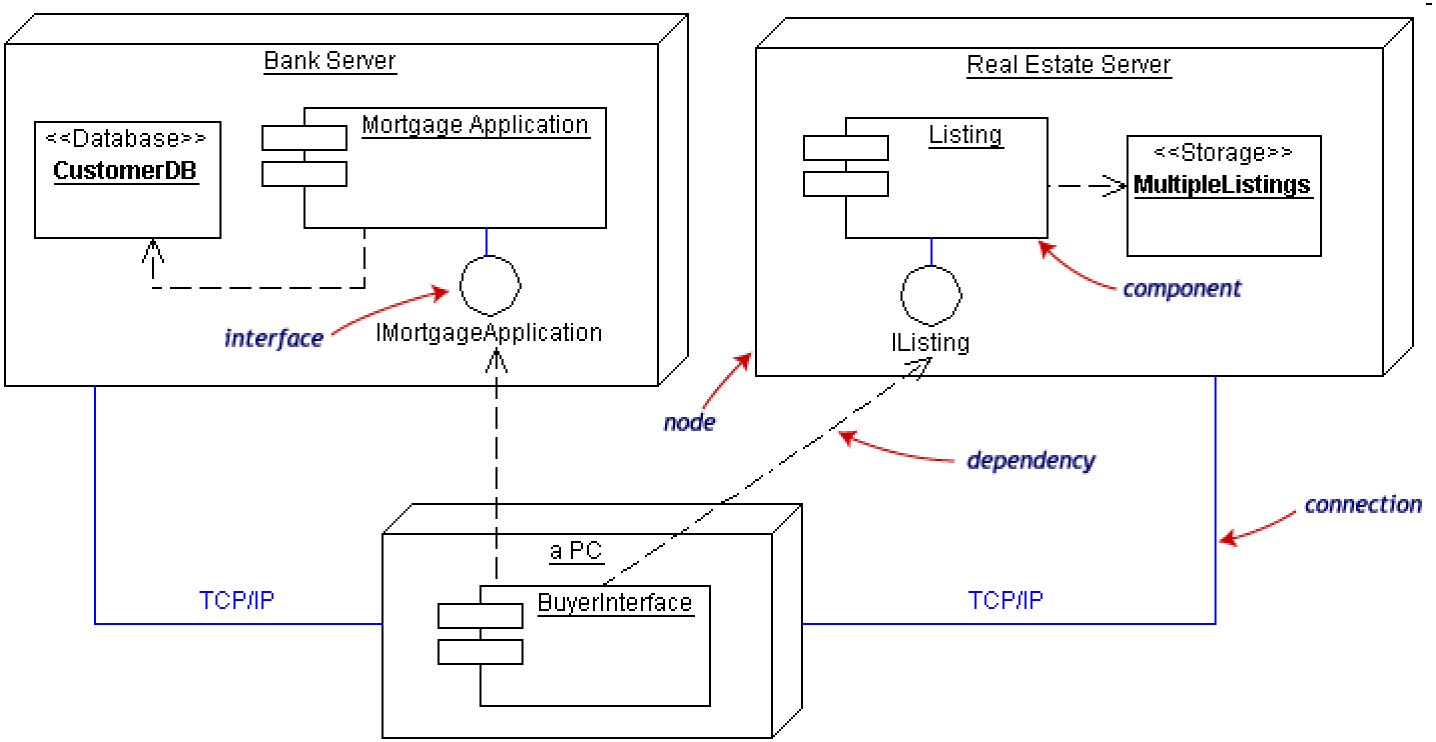
- Relationship types:
  - association ("must know about the other")
  - aggregation / composition (class belongs to a collection)
  - generalization (one class is a superclass of the other)
- Navigability arrows
- Multiplicity
- Role names (optional)



Customer
name
address
1
0..*
Order
date
status
calcTax
calcTotal
calcTotalWeight
association
abstract class
Payment
1..*
1
amount
1
generalization
role name
line item
1..*
multiplicity
Credit
number
type
expDate
authorized
Cash
cashTendered
Check
name
bankID
authorized
OrderDetail
quantity
taxStatus
calcSubTotal
calcWeight
0..*
1
Item
class name
shippingWeight
description
attributes
getPriceForQuantity
getWeight
operations
navigability

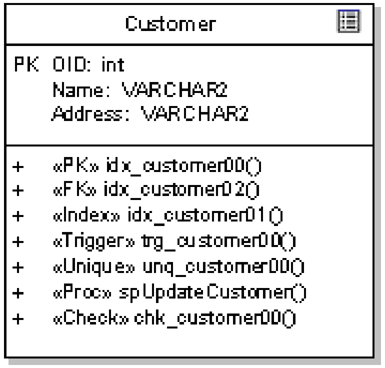
Components and Deployment Diagrams

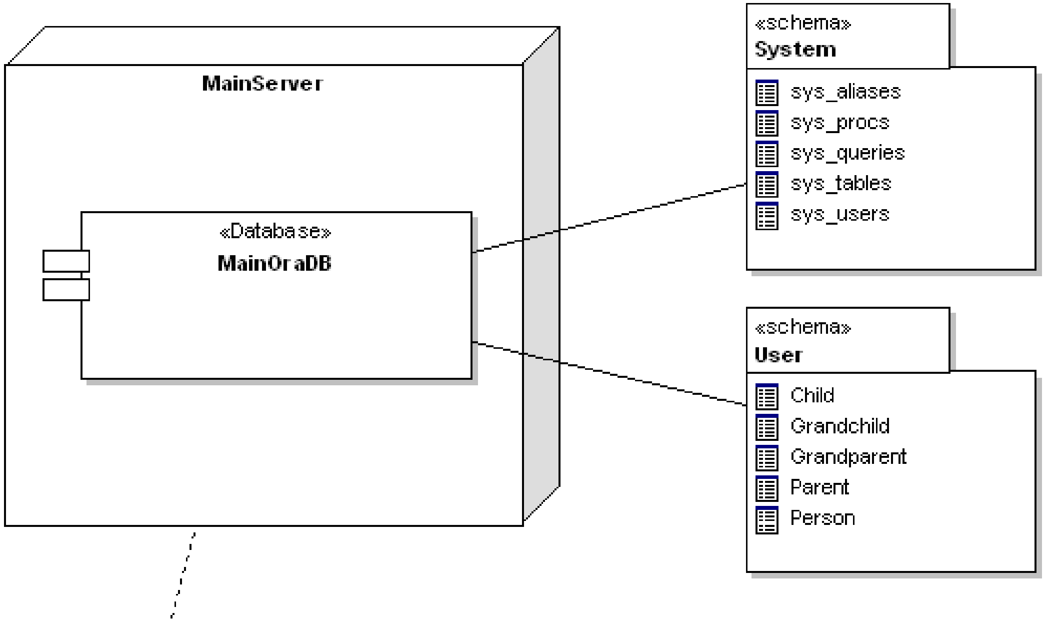
- Component = code module
- Deployment diagram = physical configuration of software and hardware



Excursion: UML Physical DB Modelling

- Some relational constructs that can be expressed:
  - primary key constraint (PK), foreign key constraint (FK), index constraint (Index), trigger (Trigger), uniqueness constraint (Unique), stored procedure (Proc), validity check (Check)


Customer
PK OID: int
Name: VARCHAR2
Address: VARCHAR2
+ «PK» idx_customer00()
+ «FK» idx_customer02()
+ «Index» idx_customer01()
+ «Trigger» trg_customer00()
+ «Unique» unq_customer00()
+ «Proc» spUpdateCustomer()
+ «Check» chk_customer00()



A Node is a physical piece of hardware (such as a Unix server) on which components are deployed. The database component in this example is also mapped to two logical «schema», each of which contains a number of tables.