# Software Engineering

## Modeling Software Systems using UML

# LEARNING OBJECTIVES

1. Understand what is the UML and how the UML can be used to model software systems.

2. Appreciate that the UML is a modeling language and *not* a software development methodology.

3. Understand the basic modeling components of UML class diagrams: class, association and generalization.

# MODELING SOFTWARE SYSTEMS USING UML: OUTLINE

UML and Object-oriented Modeling
- Overview of the UML
- Object-oriented Modeling

Class
- Attribute
- Operation

Association
- Multiplicity
- Aggregation and Composition

Association Class

Generalization
- Inheritance
- Coverage

Constraints

# WHAT IS THE UML*?

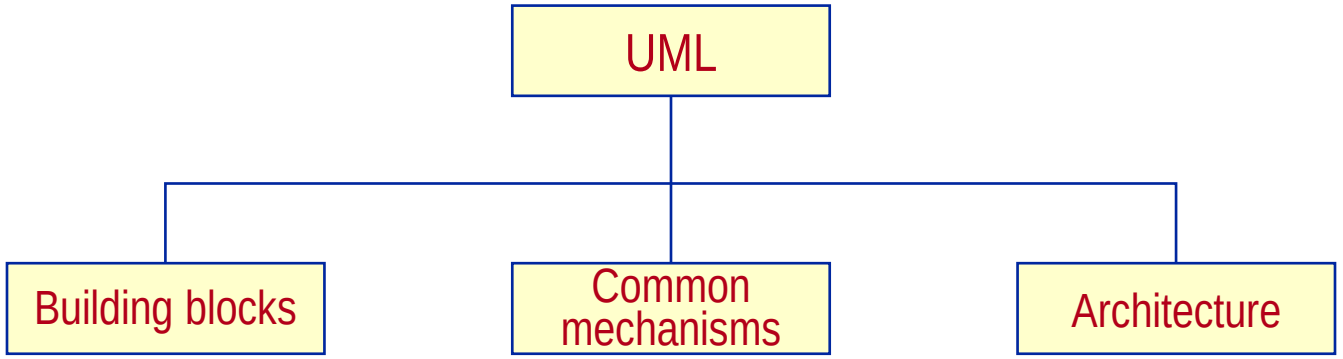
- General purpose *visual modeling language* for systems.
- *Incorporates current best practices* in OO modeling techniques.
- *Software development methodology/process neutral*.
- *Industry standard OO modeling language for modeling systems* (but can also be used for non-OO systems).

## Basic Premise of the UML

A software system can be modeled as a collection of collaborating objects.

* *U*nified *M*odeling *L*anguage

# UML STRUCTURE




- **Building blocks**
  - things
  - relationships
  - diagrams
- **Common mechanisms**
  - specifications
  - adornments
  - common divisions
  - extensibility mechanisms

- **Architecture**
  - use-case view
  - logical view
  - implementation view
  - process view
  - deployment view

# WHY BUILD MODELS?

How the customer explained it.

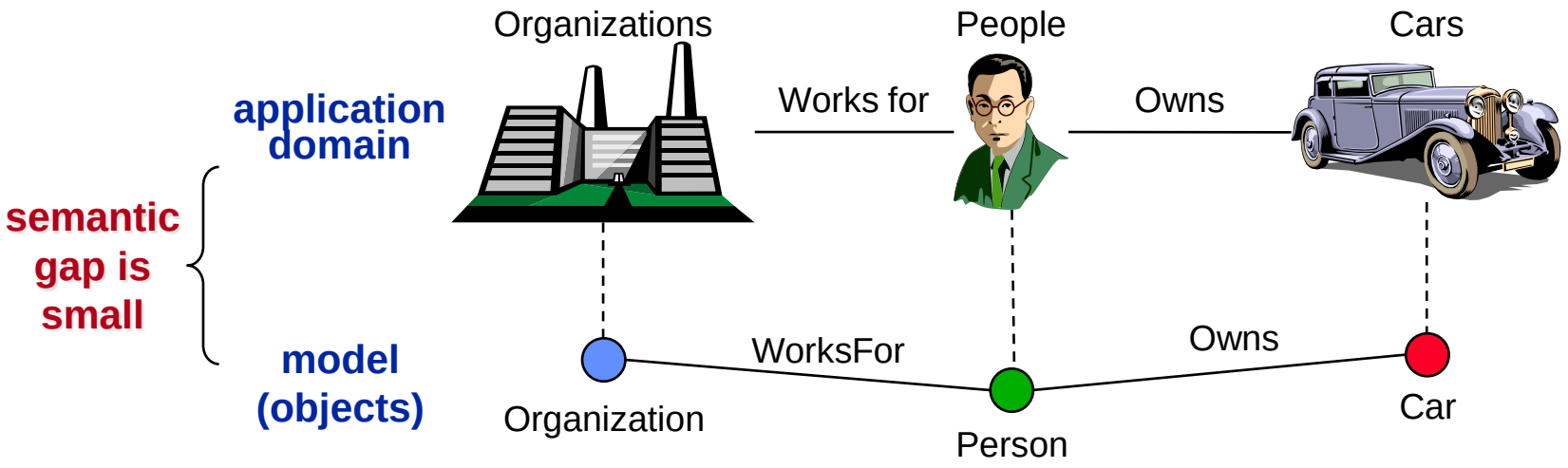
**What do you think is the problem here?**

**Why?**

# WHY BUILD MODELS?

- Models succinctly describe reality (i.e., they abstract reality).
  - They show essential details and filter out non-essential details.
- For software development, this allows us to focus on the "big picture",
  - i.e., programming-in-the-large.
- Such a focus allows us to better deal with the *complexity* of software development,
  - i.e., with human limitations in understanding complex things.
- The result is better understanding of requirements, cleaner designs, and more maintainable systems.

# WHY OBJECT-ORIENTED MODELING?




☞ Allows direct representation of "things" in an application domain.

☞ Reduces the "semantic gap" between the application domain and the model.

☞ Better represents how people think about reality.

**An application domain is modeled as a collection of objects.**

# OO MODELING & LEVELS OF ABSTRACTION

**Requirements level** → We construct a *requirements model*.

- We do not consider any aspects of the implementation of objects.

☞ **Focus: identifying objects (concepts) in the application domain.**

**Analysis & Design level** → We construct a *solution model*.

- We consider interfaces of objects (but no internal aspects).

☞ **Focus: how objects interact in the solution.**

**Implementation level** → We implement the *solution model*.

- We consider all details of objects (external and internal).

☞ **Focus: how to code objects.**

**The same OO concepts can be used at all levels.**

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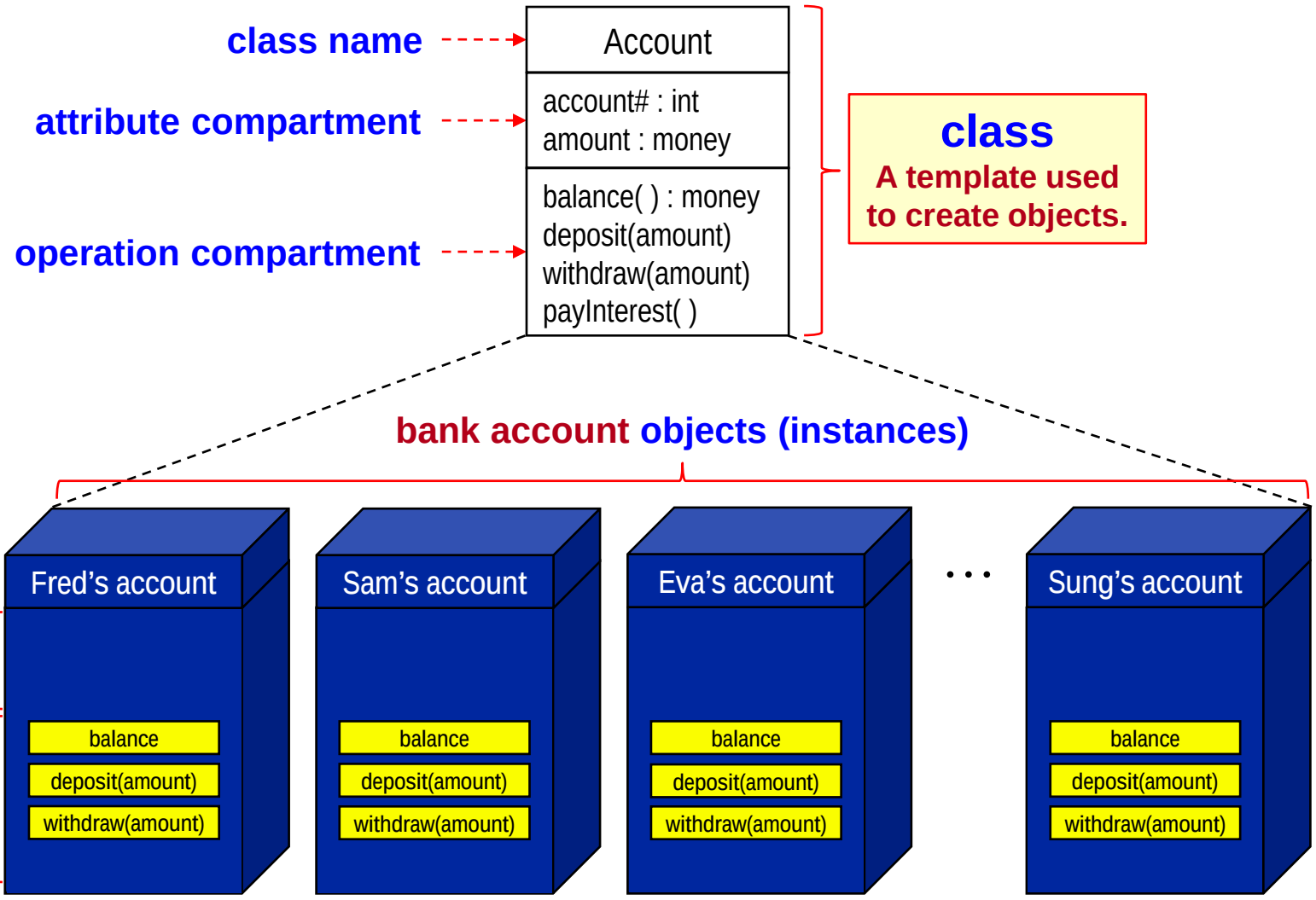
# CLASS


class name
attribute compartment
operation compartment
Account
account# : int
amount : money
balance( ) : money
deposit(amount)
withdraw(amount)
payInterest( )
class
A template used to create objects.
bank account objects (instances)
Fred's account
Sam's account
Eva's account
Sung's account
attributes
operations
balance
deposit(amount)
withdraw(amount)

# CLASS

**A *class* describes a collection of objects having common:**

**– semantics – attributes – operations – relationships**

☞ A class is a classifier; an object is an instance.

- A class is a "factory" for creating objects.
- A good class should capture one and only one abstraction.

  ☞ It should have one major theme.

- A class should be named using the vocabulary of the application domain (class names must be unique).

  ☞ So that it is meaningful and traceable from the application domain to the model.

# CLASS: ATTRIBUTE

**An *attribute* describes the data values held by objects in a class.**

- Attribute properties:
  - name: unique within a class, but not across classes.
  - type: the domain of values – string, integer, money, etc.

**For modeling, name and type should always be specified.**

| Account |
| --- |
| account# : int<br>amount : money |
| balance( ) : money<br>deposit(amount)<br>withdraw(amount)<br>payInterest( ) |

  - visibility: who can access the attribute's values.
    public (+), private (–), protected (#), package (~)
  - initial value [optional]: the attribute's initial value.
  - multiplicity [optional]: the number of simultaneous values.
  - changeability: whether the value can be changed.
    unspecified *(default)* readOnly

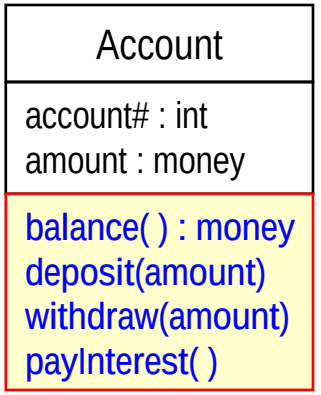
# CLASS: OPERATION

**An *operation* describes a function or transformation that may be applied to or by objects in a class.**

- Operation properties:
  - operation signature
    - operation name
    - parameter names
    - result type

    **For modeling, all should always be specified.**
  - visibility

    public (+), private (–), protected (#), package (~)




- An operation instance (its implementation) is called a method.

  ☞ An operation can have several methods that implement it (polymorphic operation).

# WHY CLASSES FOR MODELING SYSTEMS?

By abstracting a collection of objects and representing them as a class, ***the complexity of developing a system is reduced*** since it becomes easier to:

- **understand** the system → We need to understand only the classes, not the individual objects.
- **specify** the system → Classes provide a place to define and store common definitions only once.

**Choosing appropriate classes is an**

**IMPORTANT DESIGN DECISION**

**that *helps promote modular development*.**

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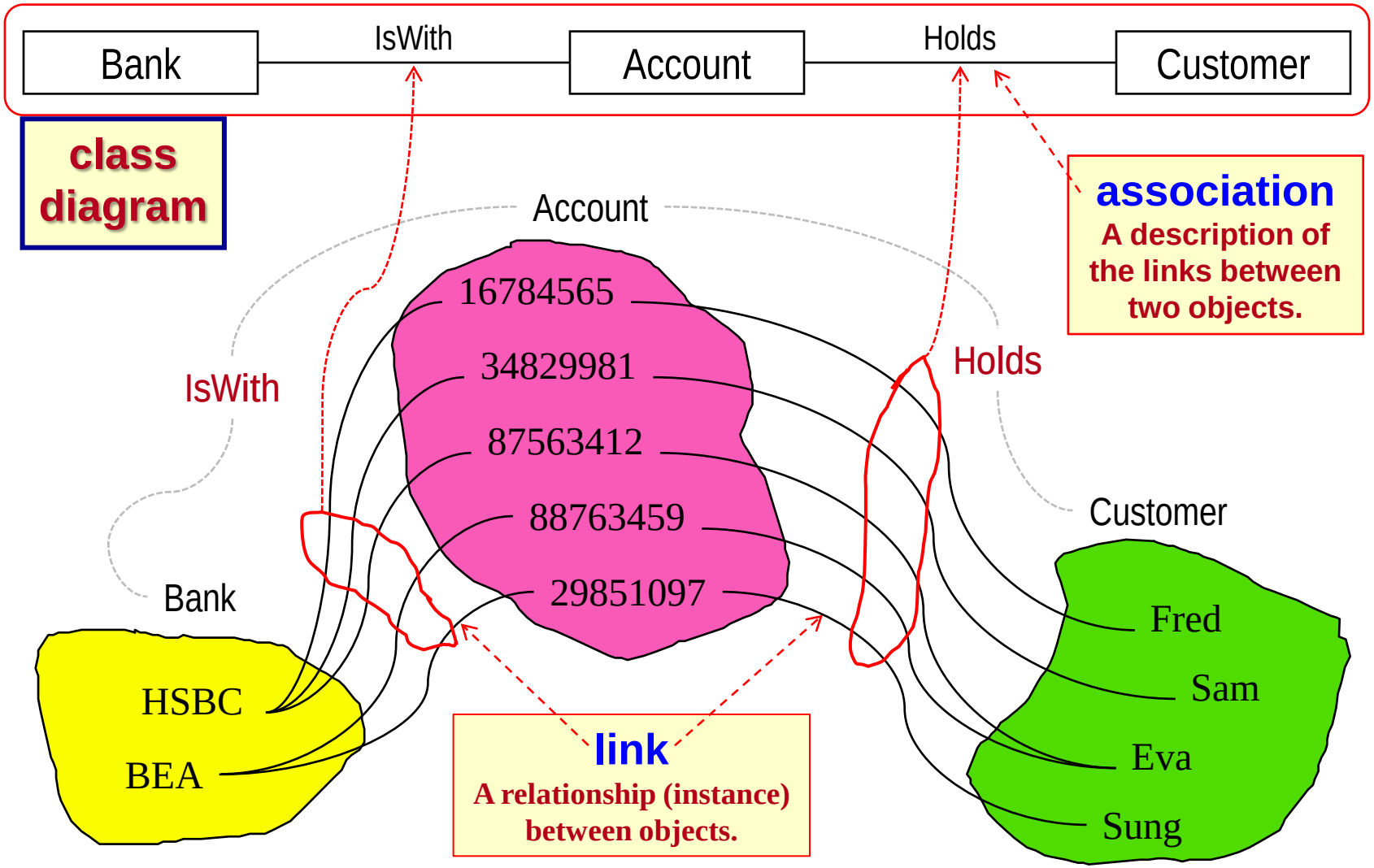
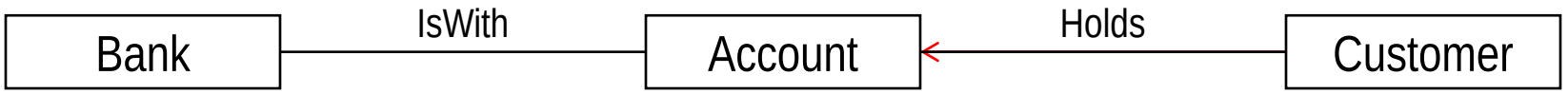
# ASSOCIATION



# ASSOCIATION

**An *association* describes a collection of links with common semantics.**



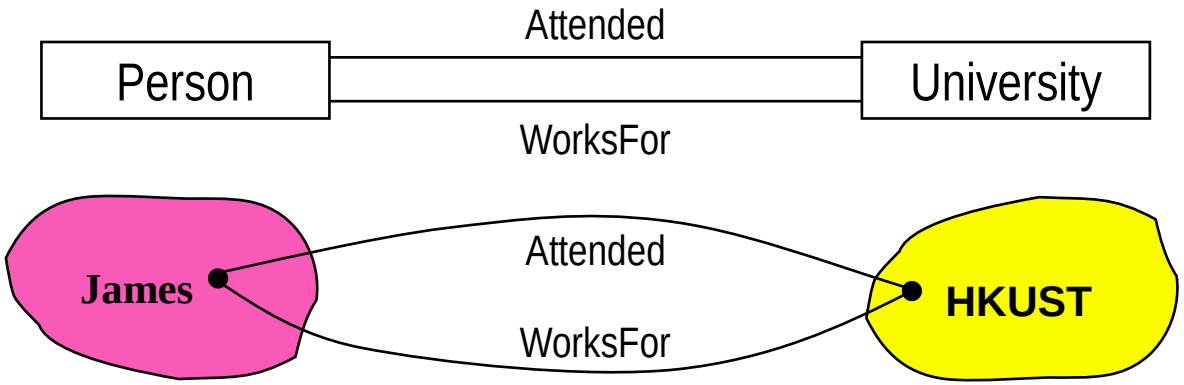

☞ An association is a classifier; a link is an instance.

☞ Conceptually, associations are inherently bi-directional.

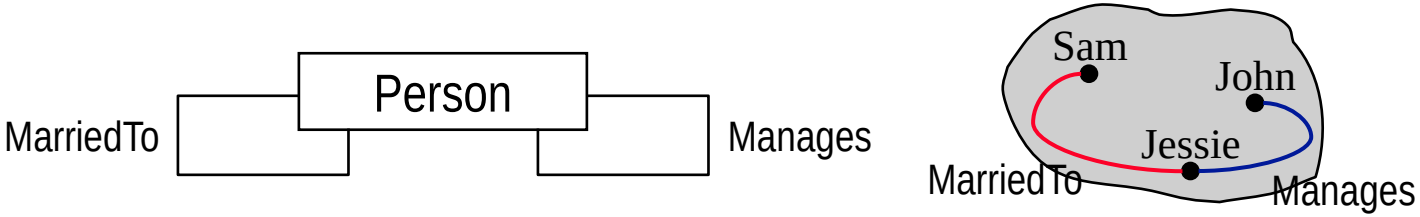
☞ Can show navigability of associations with an arrowhead.
(Implies that the source object has a reference to the target object.)

# ASSOCIATIONS AND CLASSES

- Two different classes can be related by several associations.



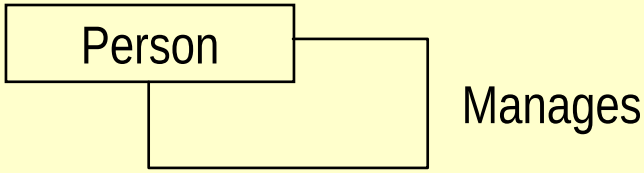

- The same class can be related by several associations.



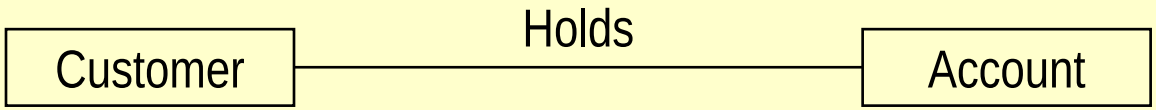

**The collection of class and association names must be unique.**

# ASSOCIATION: DEGREE

- **unary** (reflexive)
  relates *one* class to itself

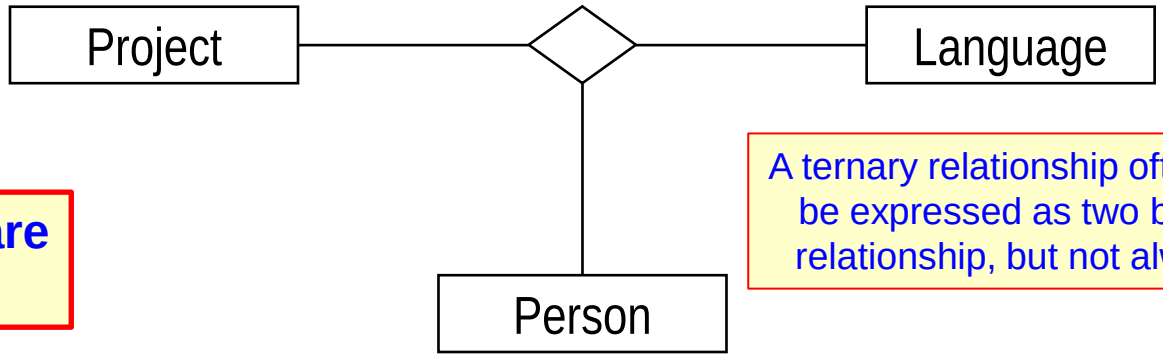



- **binary**
  relates *two* classes




**We will use only unary and binary associations in this course.**

- **ternary**
  relates *three* classes



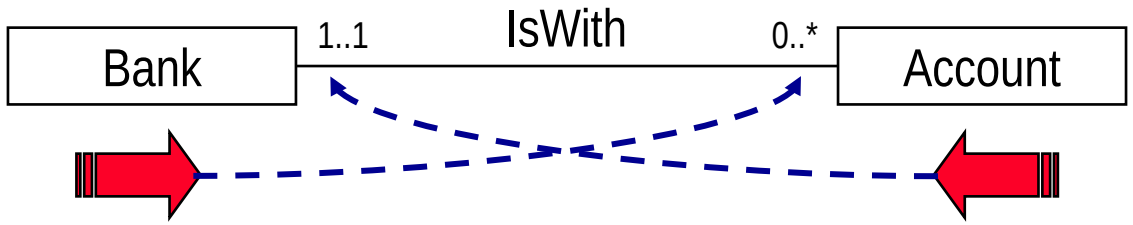

A ternary relationship often can be expressed as two binary relationship, but not always.

**Higher degrees are extremely rare!**

**In practice, the majority of associations are binary!**

# ASSOCIATION: MULTIPLICITY

***Multiplicity*** **specifies a restriction on the number of objects in a class that may be related to an object in another class.**




**For a given bank, how many accounts can it have?**

☞ A bank may have no accounts or it may have many accounts.

**For a given account, how many banks can it be with?**

☞ An account must be with exactly one bank.

**Multiplicity is an *application domain constraint*!**

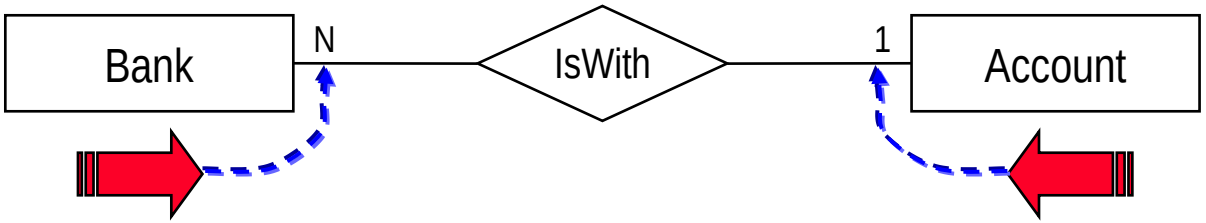
# ASSOCIATION: MULTIPLICITY (cont'd)

## A NOTE FOR COMP 3311 STUDENTS

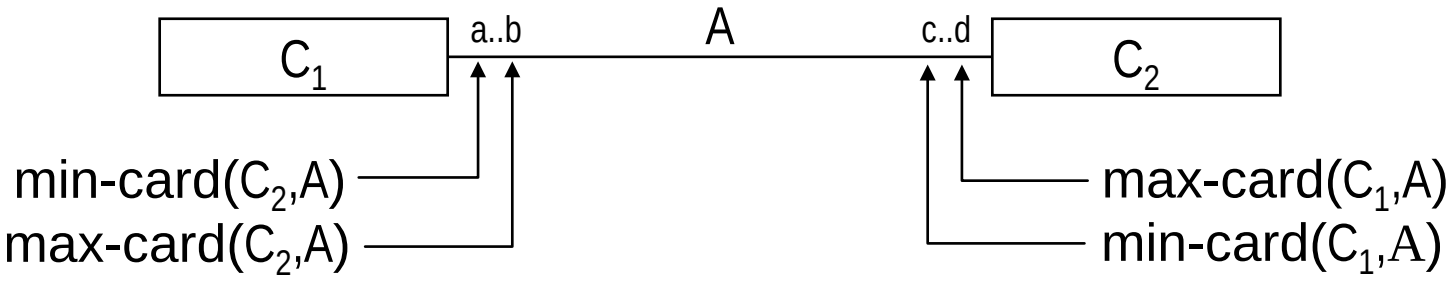
**Both the ER model and the UML can represent the data requirements of a system.**

**However, placement of the multiplicity in the ER model used in COMP 3311 *is different* than that of the UML.**

**CAUTION: BE CAREFUL NOT TO MIX UP NOTATIONS!**



# ASSOCIATION: MULTIPLICITY (cont'd)




## minimum cardinality (min-card)

min-card($C_1$,A): the *minimum number of links* in which each object of $C_1$ can participate in association A

min-card($C_1$,A) = 0 → optional participation *(may not be related)*

min-card($C_1$,A) > 0 → mandatory participation *(must be related)*

## maximum cardinality (max-card)

max-card($C_1$,A): the *maximum number of links* in which each object of $C_1$ can participate in association A

# ASSOCIATION: MULTIPLICITY (cont'd)


**special cardinalities:**

max-card = * → an unlimited upper bound (∞)

min-card = 1 and max-card = 1 → can use 1 by itself

min-card = 0 and max-card = * → can use * by itself

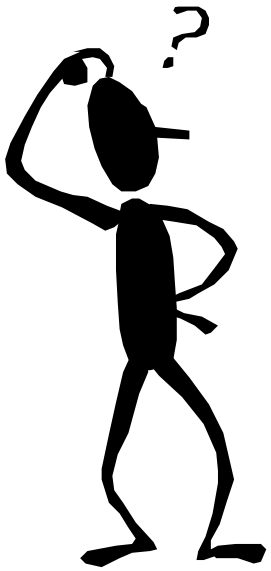
# MULTIPLICITY EXAMPLE


- A student must enroll in at least one course and can enroll in at most five courses

- A course must have at least ten students enrolled in it and cannot have more than forty-five students enrolled in it.

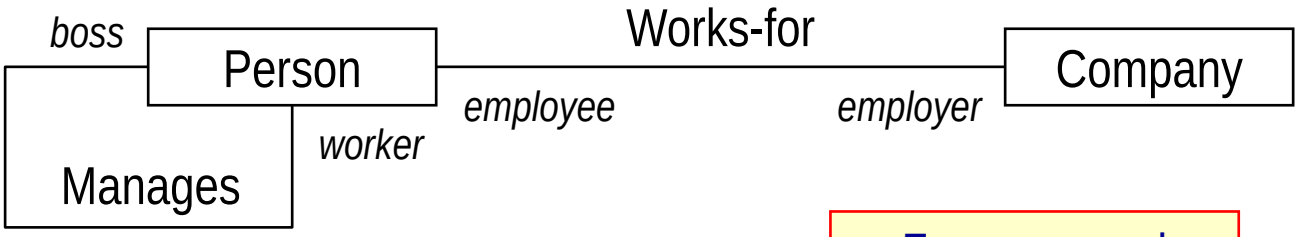
# SINEX — COURSE PROJECT QUESTION

What is the most likely multiplicity of the following associations?



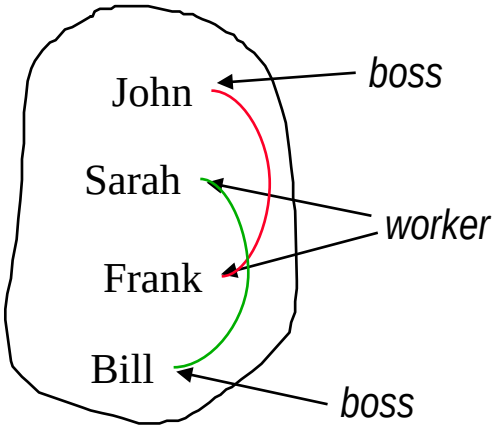
# ASSOCIATION: ROLE

**A *role* is one end of an association.**




For unary and binary associations there are two roles.

**Who manages who?**

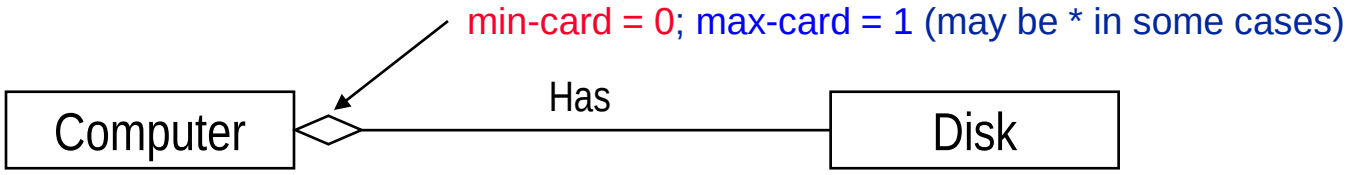



**It is necessary to use role names when an association relates objects from the same class.**

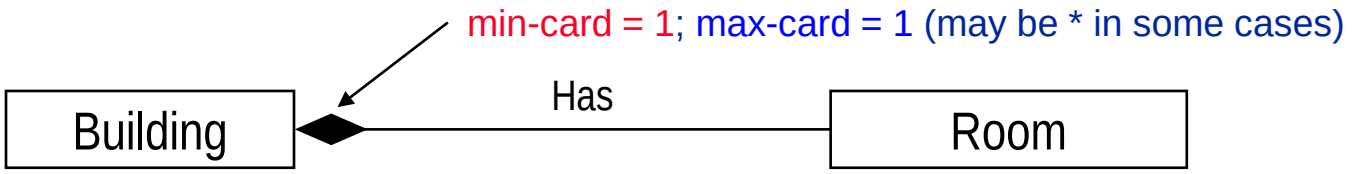
# AGGREGATION/COMPOSITION ASSOCIATION

- A special type of association in which there is a "part-of" relationship between one class and another class.

☞ A component may exist independent of the aggregate object of which it is a part → aggregation. [◇ adornment]




☞ A component may not exist independent of the aggregate object of which it is a part → composition. [◆ adornment]



# WHEN TO USE AGGREGATION/COMPOSITION?

- Would you use the phrase "part of" to describe the association or name it "Has"?

  ☞ **BUT BE CAREFUL!** Not all "Has" associations are aggregations.

- Is there an intrinsic asymmetry to the association where one object class is subordinate to the other(s)?

- Are operations on the whole automatically applied to the part(s)? → composition

**The decision to use aggregation is a matter of *judgment*.**
**It is a design decision.**

**It is not wrong to use association rather than aggregation!**
**(In a real project, when in doubt, use association!)**

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# EXERCISE