Introduction to UML

What is UML?

- Unified Modeling Language
  - OMG Standard, Object Management Group
  - Based on work from Booch, Rumbaugh, Jacobson
- UML is a modeling language to express and design documents, software
  - Particularly useful for OO design
  - Not a process, but some have been proposed using UML
  - Independent of implementation language

Why use UML

- Open Standard, Graphical notation for
  - Specifying, visualizing, constructing, and documenting software systems
- Language can be used from general initial design to very specific detailed design across the entire software development lifecycle
- Increase understanding/communication of product to customers and developers
- Support for diverse application areas
- Support for UML in many software packages today (e.g. Rational, plugins for popular IDE's like NetBeans, Eclipse)
- Based upon experience and needs of the user community

Static vs. Dynamic Design

- Static design describes code structure and object relations
  - Class relations
  - Objects at design time
  - Doesn't change
- Dynamic design shows communication between objects
  - Similarity to class relations
  - Can follow sequences of events
  - May change depending upon execution scenario
  - Called Object Diagrams

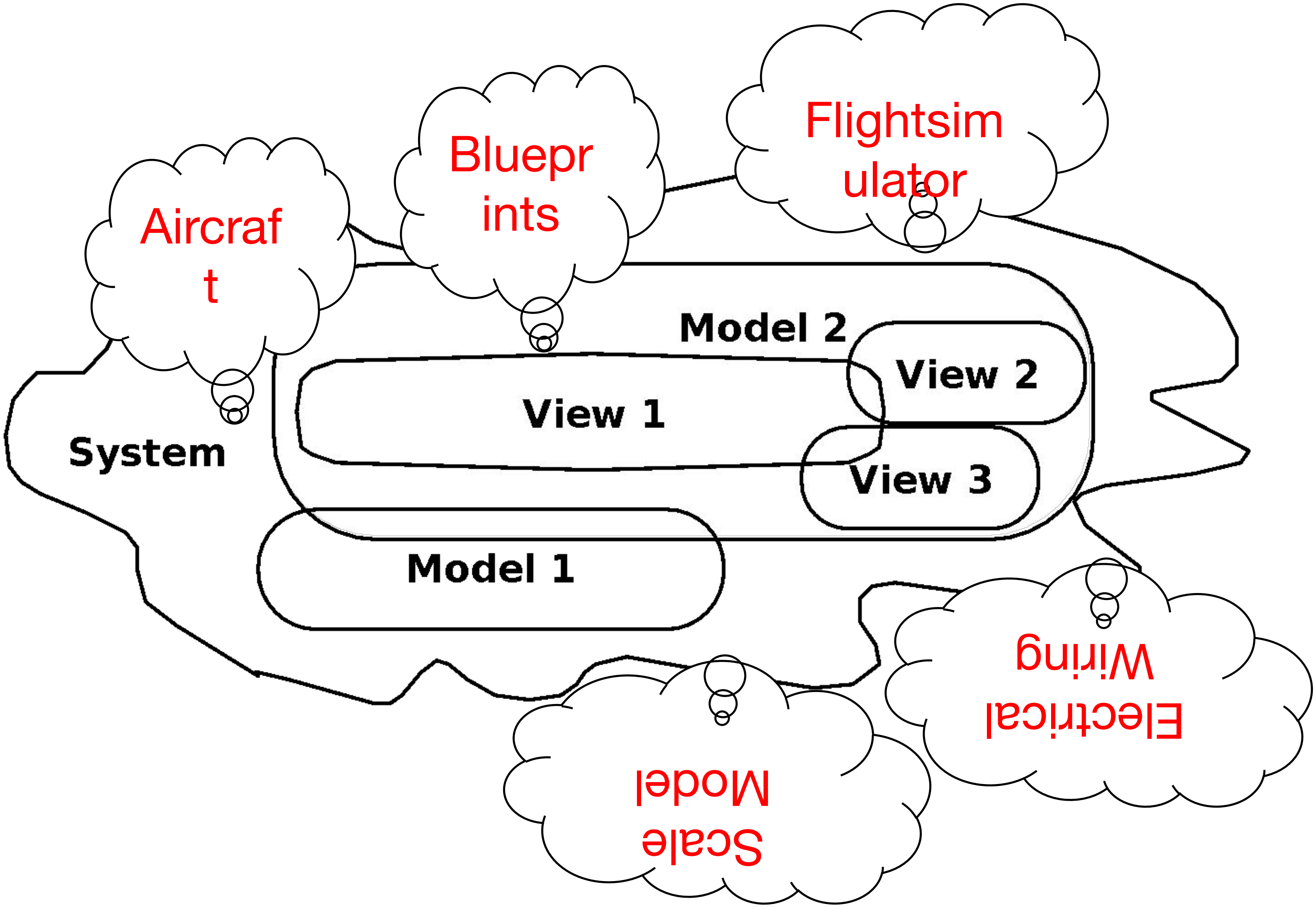
Systems, Models and Views

- A ***model*** is an abstraction describing a subset of a system
- A ***view*** depicts selected aspects of a model
- A ***notation*** is a set of graphical or textual rules for depicting views
- Views and models of a single system may overlap each other

Examples:

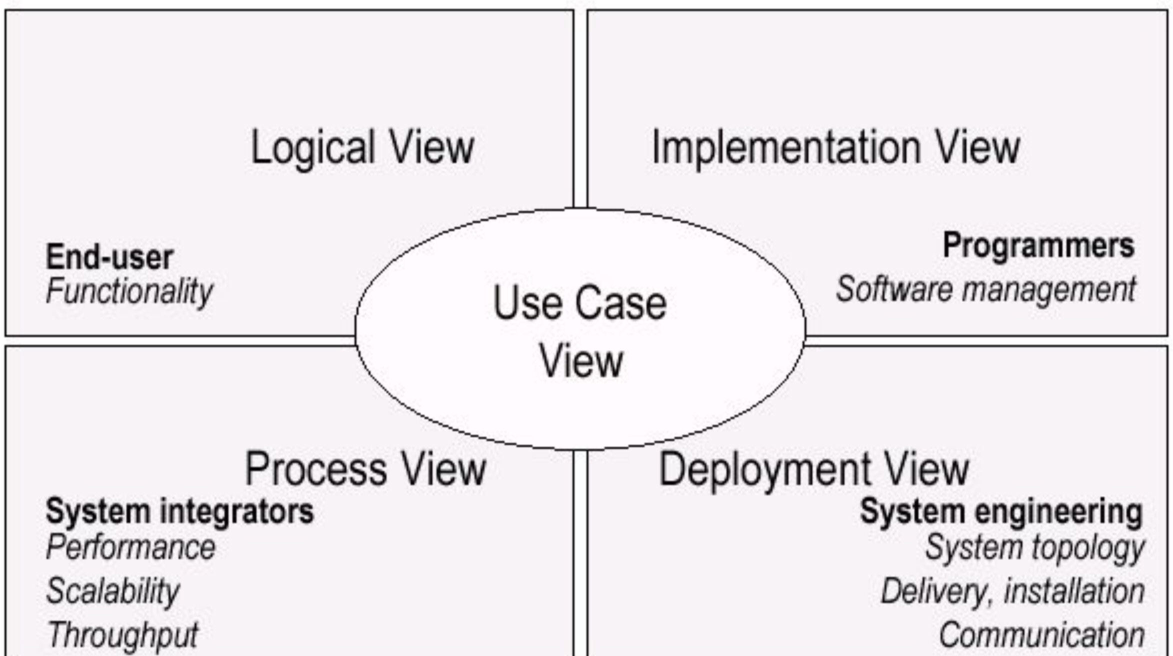
- System: Aircraft
- Models: Flight simulator, scale model
- Views: All blueprints, electrical wiring, fuel system

Systems, Models and Views

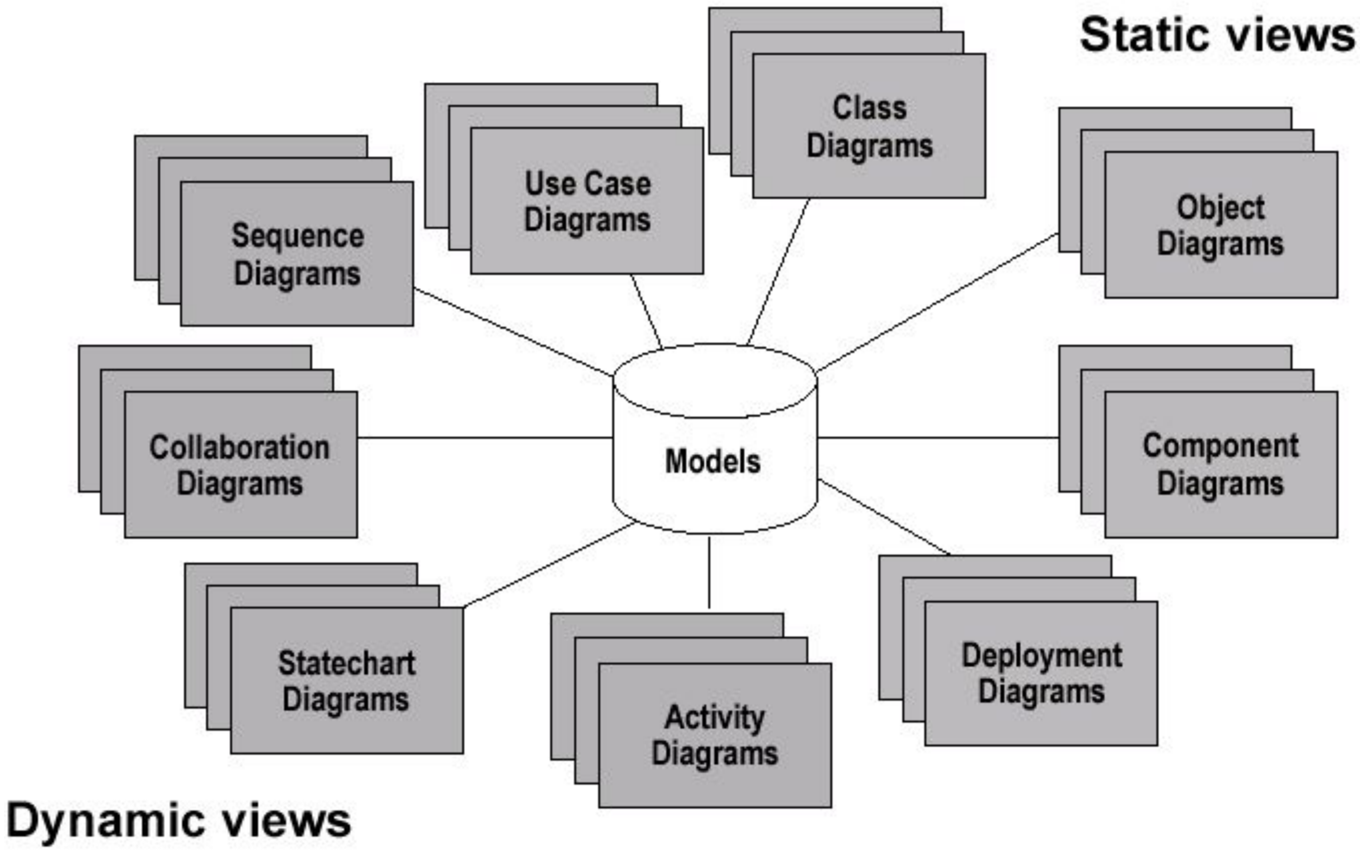


UML Models, Views, Diagrams

- UML is a multi-diagrammatic language
  - Each diagram is a view into a model
    - Diagram presented from the aspect of a particular stakeholder
    - Provides a partial representation of the system
    - Is semantically consistent with other views
  - Example views



Models, Views, Diagrams



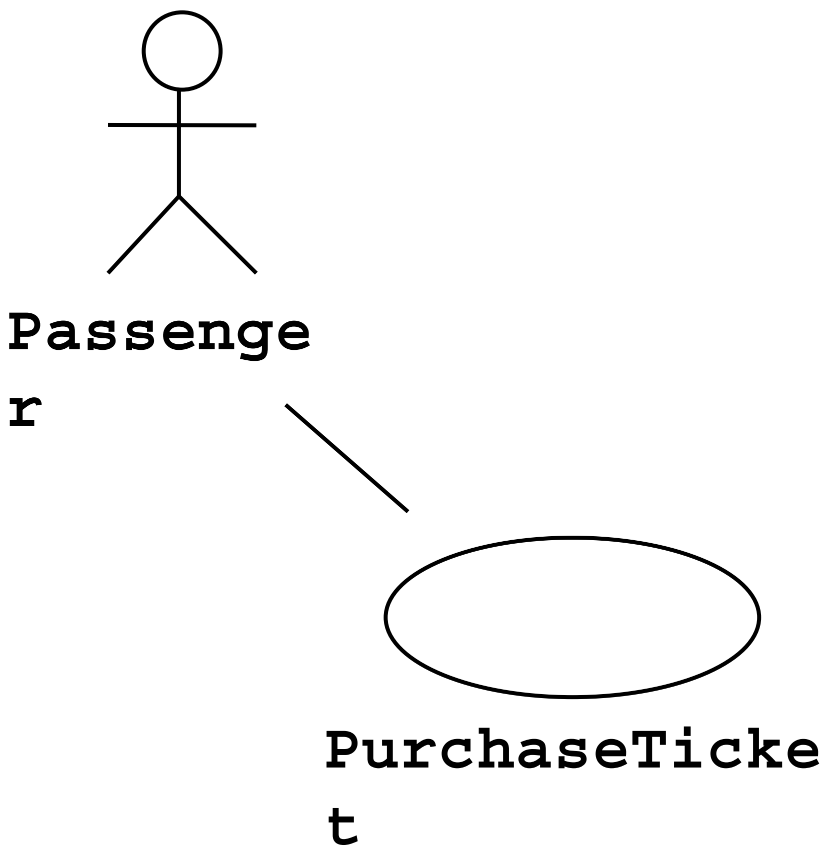
Basic Modeling Steps

- Use Cases
  - Capture requirements
- Domain Model
  - Capture process, key classes
- Design Model
  - Capture details and behaviors of use cases and domain objects
  - Add classes that do the work and define the architecture

UML Baseline

- Use Case Diagrams
- Class Diagrams
- Package Diagrams
- Interaction Diagrams
  - Sequence
  - Collaboration
- Activity Diagrams
- State Transition Diagrams
- Deployment Diagrams

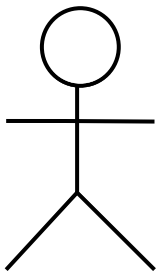
Use Case Diagrams



- Used during requirements elicitation to represent external behavior

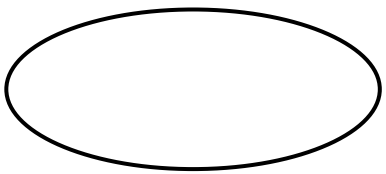
- ***Actors*** represent roles, that is, a type of user of the system
- ***Use cases*** represent a sequence of interaction for a type of functionality; summary of scenarios
- The use case model is the set of all use cases. It is a complete description of the functionality of the system and its environment

Actors



- An actor models an external entity which communicates with the system:
  - User
  - External system
  - Physical environment
- An actor has a unique name and an optional description.
- Examples:
  - Passenger: A person in the train
  - GPS satellite: Provides the system with GPS coordinates

Use Case



PurchaseTicke
t

A use case represents a class of functionality provided by the system as an event flow.

A use case consists of:

- Unique name
- Participating actors
- Entry conditions
- Flow of events
- Exit conditions
- Special requirements

Use Case Diagram: Example

Name: `Purchase ticket`

Participating actor: `Passenger`

Entry condition:

- `Passenger` standing in front of ticket distributor.
- `Passenger` has sufficient money to purchase ticket.

Exit condition:

- `Passenger` has ticket.

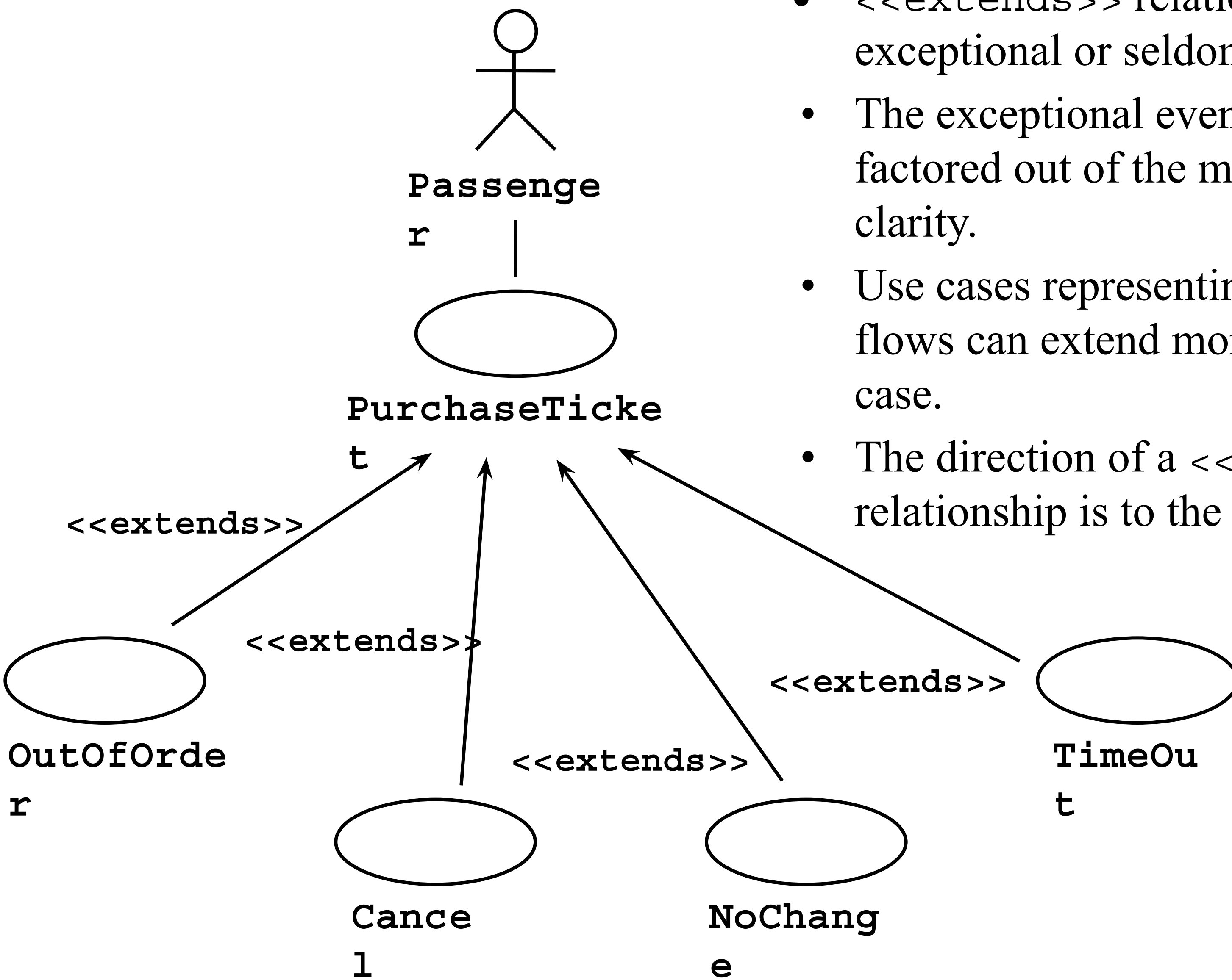
Event flow:

1. `Passenger` selects the number of zones to be traveled.
2. Distributor displays the amount due.
3. `Passenger` inserts money, of at least the amount due.
4. Distributor returns change.
5. Distributor issues ticket.

Anything missing?

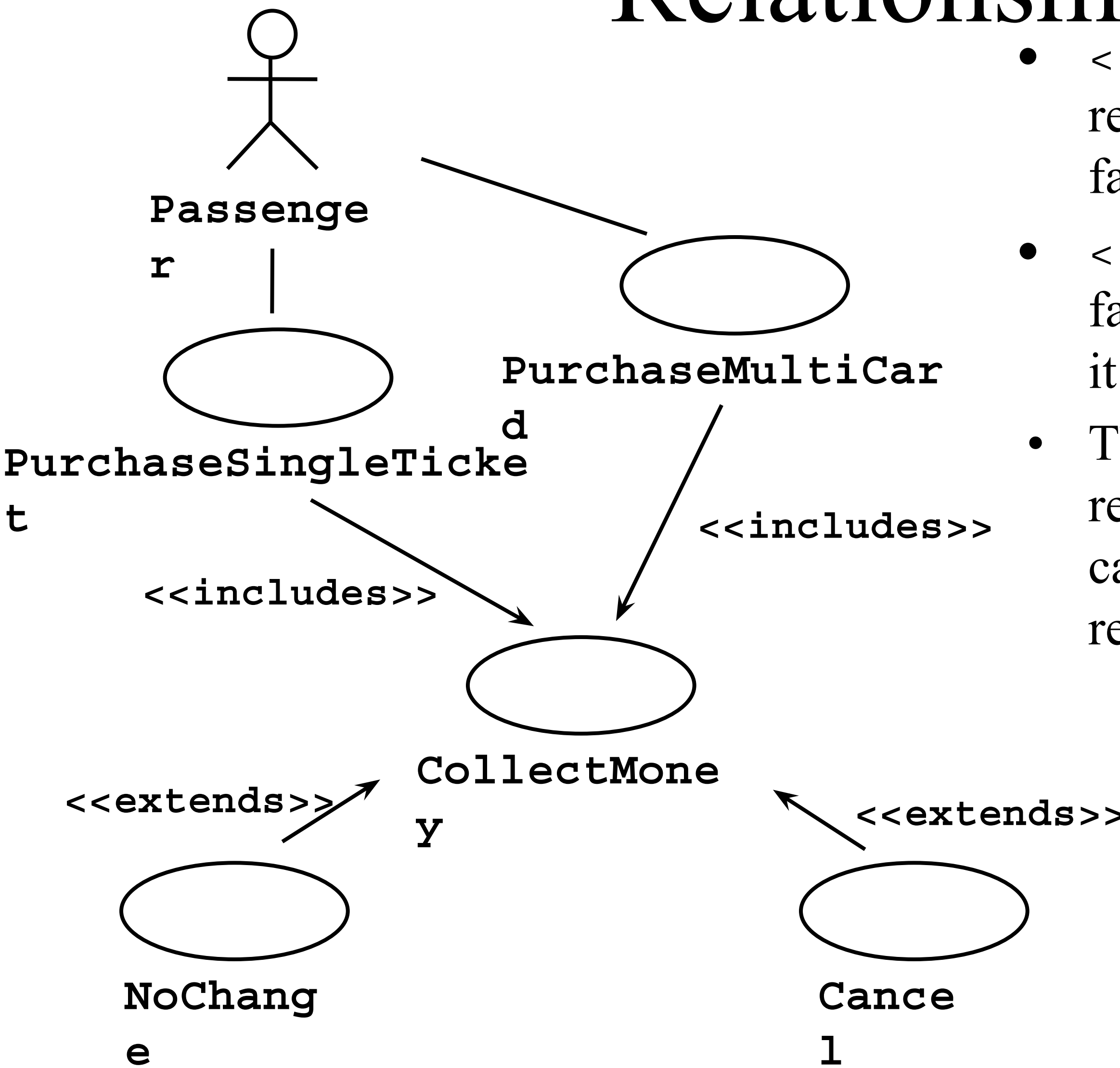
Exceptional cases!

The <<*extends*>> Relationship



- `<<extends>>` relationships represent exceptional or seldom invoked cases.
- The exceptional event flows are factored out of the main event flow for clarity.
- Use cases representing exceptional flows can extend more than one use case.
- The direction of a `<<extends>>` relationship is to the extended use case

The <<*includes*>> Relationship



- `<<includes>>` relationship represents behavior that is factored out of the use case.
- `<<includes>>` behavior is factored out for reuse, not because it is an exception.
- The direction of a `<<includes>>` relationship is to the using use case (unlike `<<extends>>` relationships).

Use Cases are useful to…

- Determining requirements
  - New use cases often generate new requirements as the system is analyzed and the design takes shape.
- Communicating with clients
  - Their notational simplicity makes use case diagrams a good way for developers to communicate with clients.
- Generating test cases
  - The collection of scenarios for a use case may suggest a suite of test cases for those scenarios.

Use Case Diagrams: Summary

- Use case diagrams represent external behavior
- Use case diagrams are useful as an index into the use cases
- Use case descriptions provide meat of model, not the use case diagrams.
- All use cases need to be described for the model to be useful.

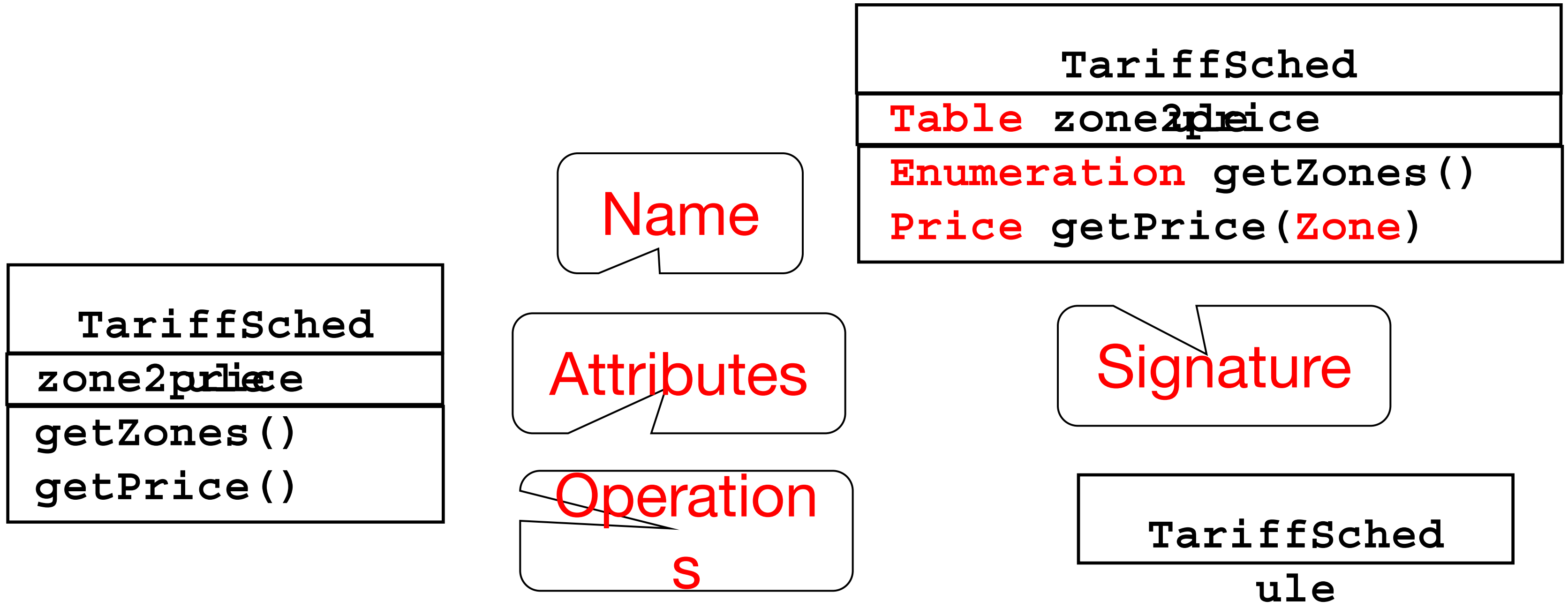
Class Diagrams

- Gives an overview of a system by showing its classes and the relationships among them.
  - Class diagrams are static
  - they display what interacts but not what happens when they do interact
- Also shows attributes and operations of each class
- Good way to describe the overall architecture of system components

Class Diagram Perspectives

- We draw Class Diagrams under three perspectives
  - Conceptual
    - Software independent
    - Language independent
  - Specification
    - Focus on the interfaces of the software
  - Implementation
    - Focus on the implementation of the software

Classes – Not Just for Code



- A ***class*** represent a concept
- A class encapsulates state ***(attributes)*** and behavior ***(operations).***
- Each attribute has a ***type***.
- Each operation has a ***signature***.
- The class name is the only mandatory information.

Instances

```
tarif_1974:TariffSchedule
zone2price = {
{'1', .20},
{'2', .40},
{'3', .60}}
```

- An ***instance*** represents a phenomenon.
- The name of an instance is <u>underlined</u> and can contain the class of the instance.
- The attributes are represented with their ***values***.

UML Class Notation

- A class is a rectangle divided into three parts
  - Class name
  - Class attributes (i.e. data members, variables)
  - Class operations (i.e. methods)
- Modifiers
  - Private: -
  - Public: +
  - Protected: #
  - Static: Underlined (i.e. shared among all members of the class)
- Abstract class: Name in italics

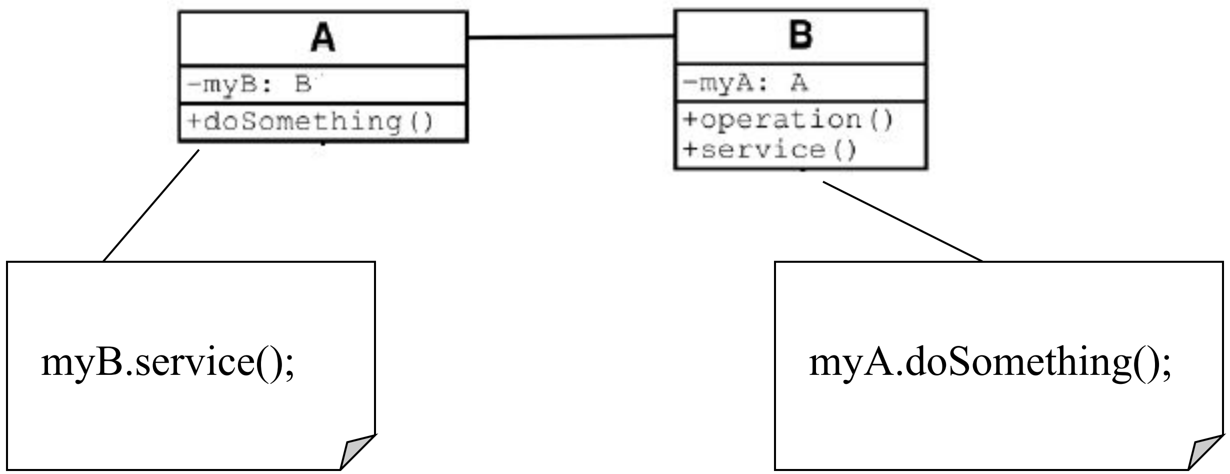
Employee
-Name : string +ID : long #Salary : double
+getName() : string +setName() -calcInternalStuff(in x : byte, in y : decimal)

UML Class Notation

- Lines or arrows between classes indicate relationships
  - Association
    - A relationship between instances of two classes, where one class must know about the other to do its work, e.g. client communicates to server
    - indicated by a straight line or arrow
  - Aggregation
    - An association where one class belongs to a collection, e.g. instructor part of Faculty
    - Indicated by an empty diamond on the side of the collection
  - Composition
    - Strong form of Aggregation
    - Lifetime control; components cannot exist without the aggregate
    - Indicated by a solid diamond on the side of the collection
  - Inheritance
    - An inheritance link indicating one class a superclass relationship, e.g. bird is part of mammal
    - Indicated by triangle pointing to superclass

Binary Association

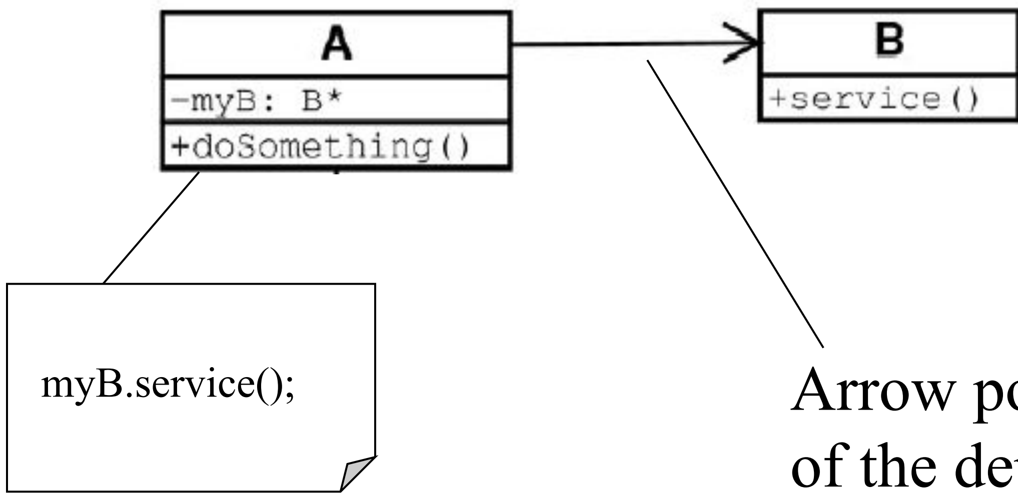
Binary Association: Both entities "Know About" each other



Optionally, may create an Associate Class

Unary Association

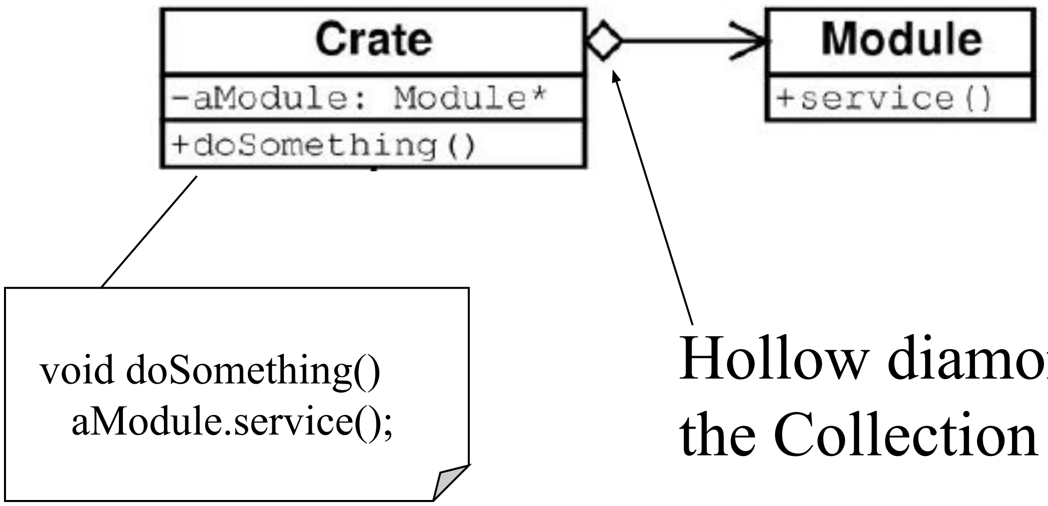
A knows about B, but B knows nothing about A



Arrow points in direction of the dependency

Aggregation

Aggregation is an association with a "collection-member" relationship



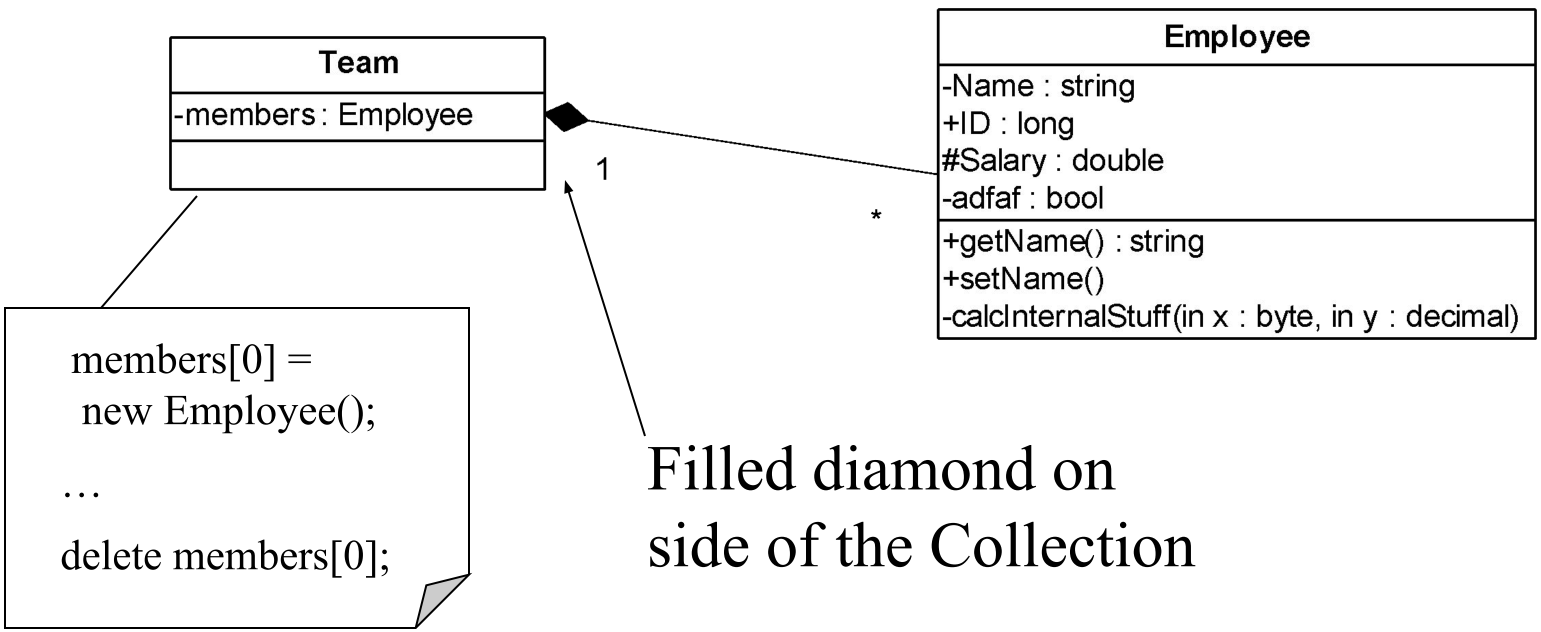
Hollow diamond on
the Collection side

No sole ownership implied

Composition

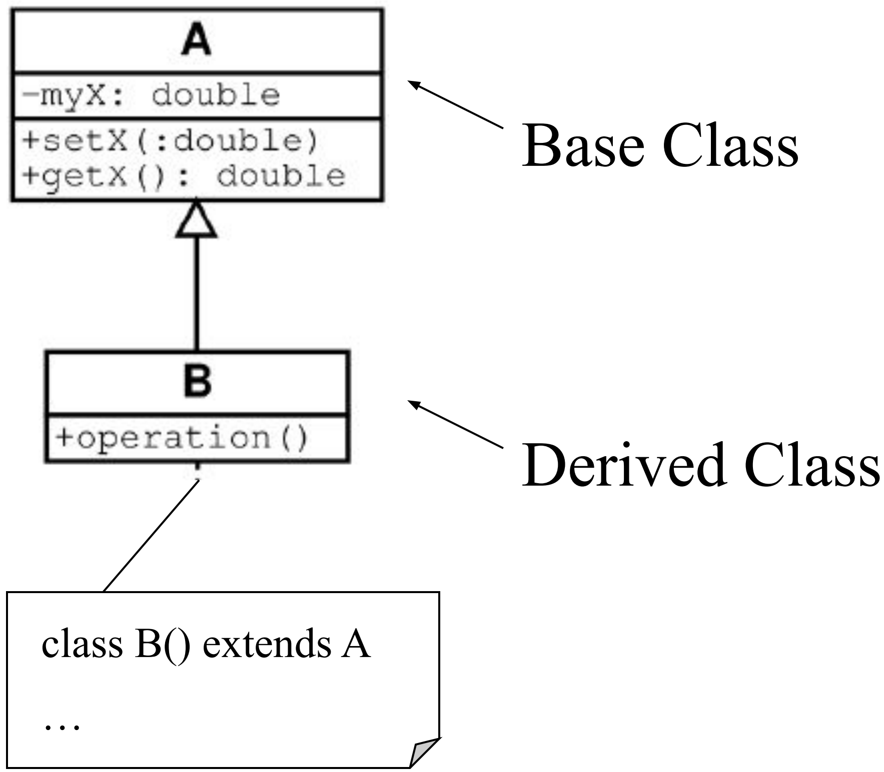
Composition is Aggregation with:

- Lifetime Control (owner controls construction, destruction)
- Part object may belong to only one whole object



Inheritance

Standard concept of inheritance

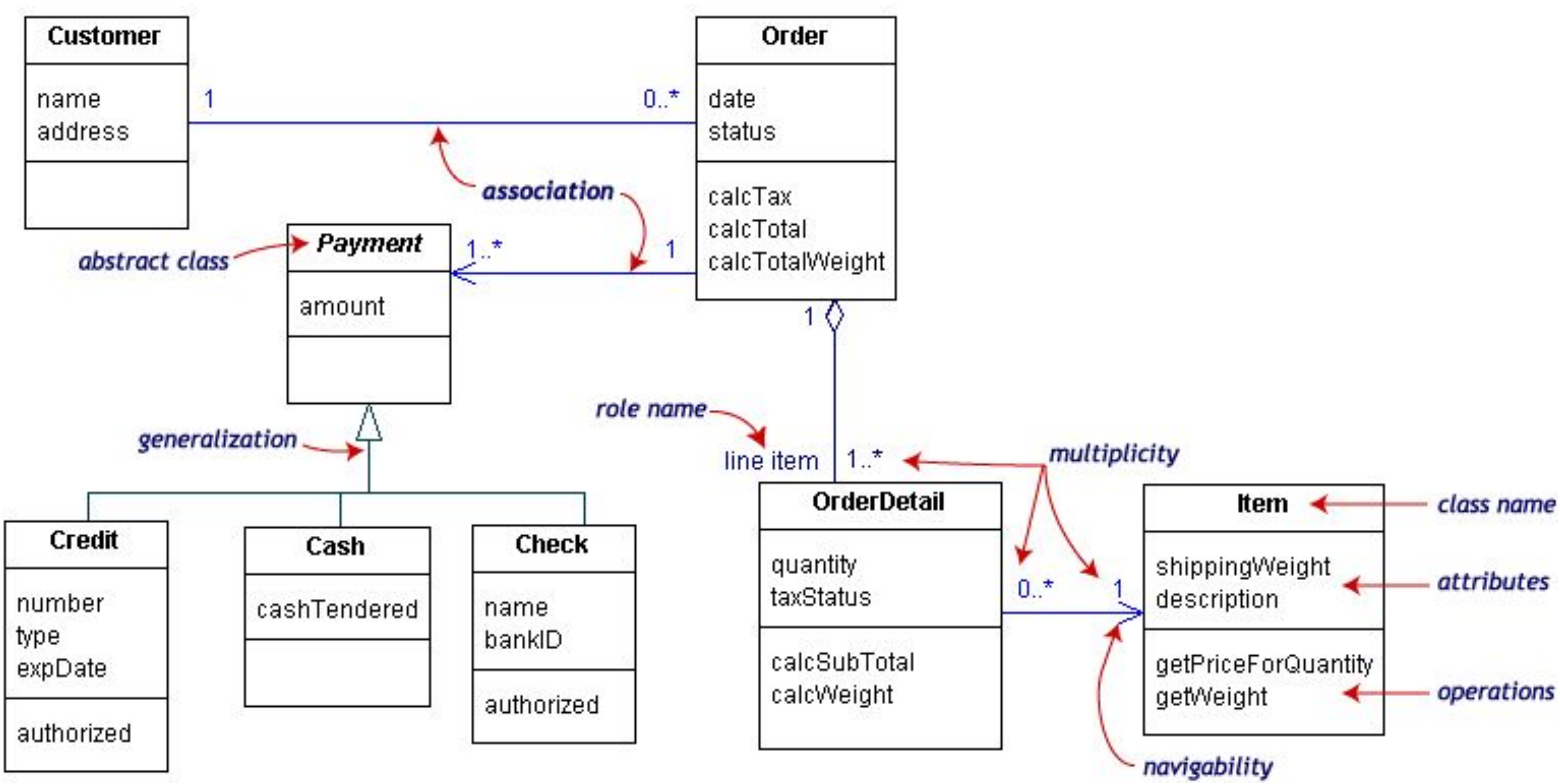


UML Multiplicities

Links on associations to specify more details about the relationship

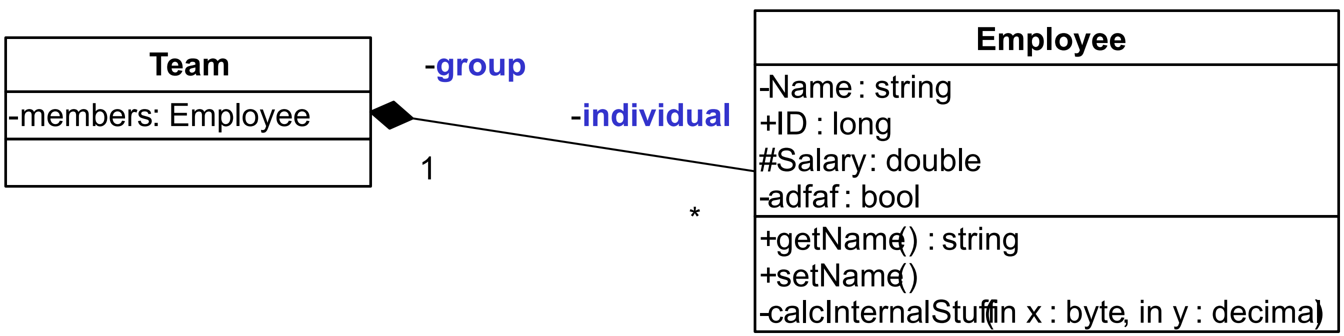
Multiplicities	**Meaning**
0..1	zero or one instance. The notation ***n . . m*** indicates ***n*** to ***m*** instances.
0..* *or* *****	no limit on the number of instances (including none).
1	exactly one instance
1..*	at least one instance

UML Class Example



Association Details

- Can assign names to the ends of the association to give further information



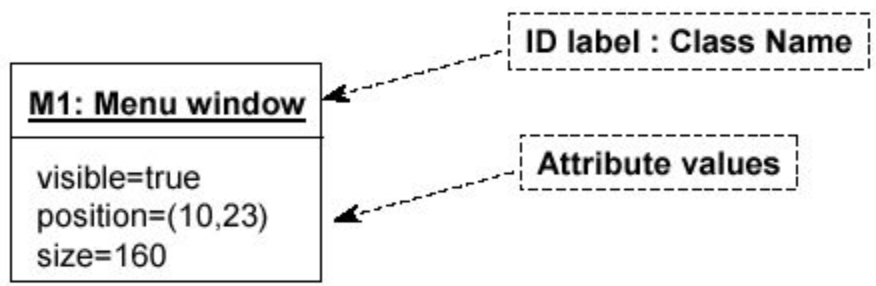
Object Diagrams

- Shows instances of Class Diagrams and links among them
  - An object diagram is a snapshot of the objects in a system
    - At a point in time
    - With a selected focus
      - Interactions – Sequence diagram
      - Message passing – Collaboration diagram
      - Operation – Deployment diagram

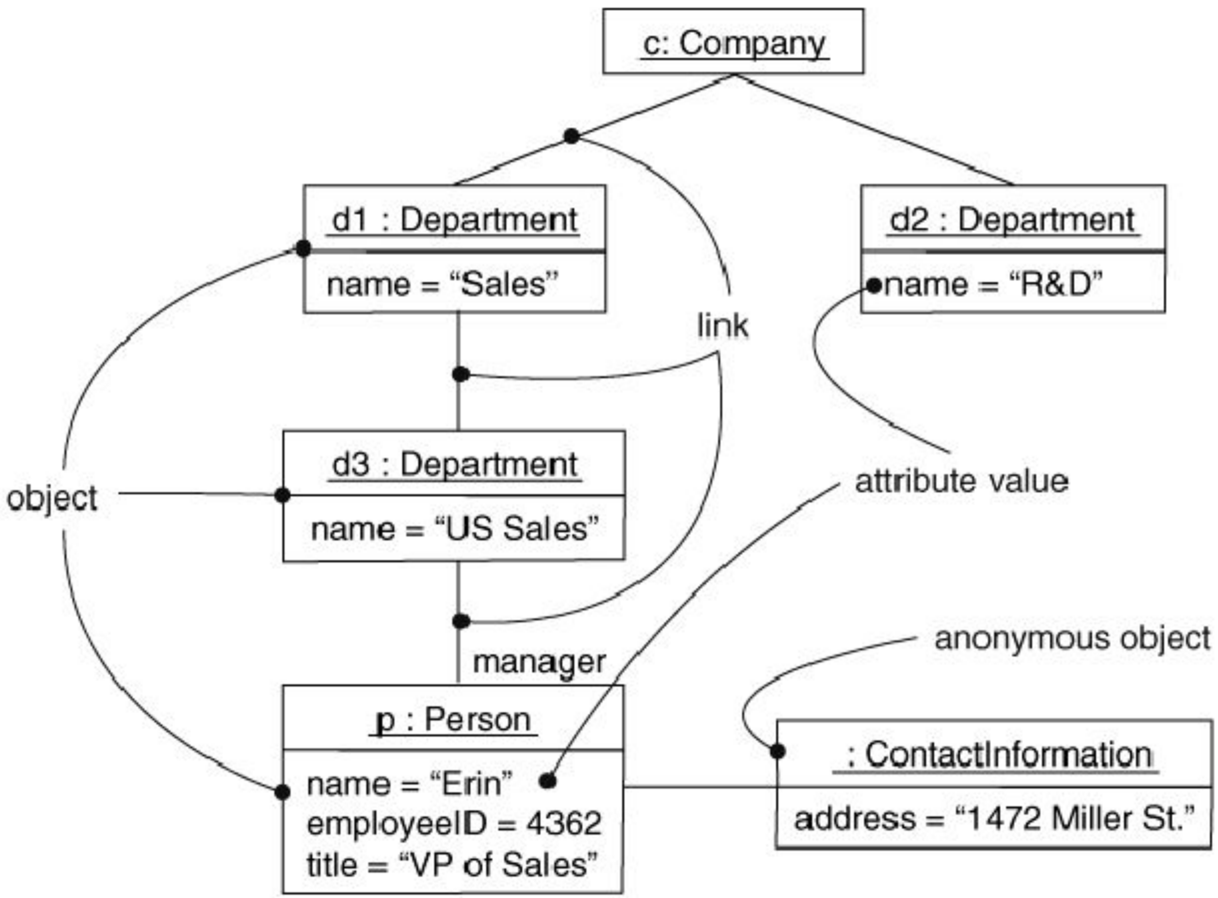
Object Diagrams

- Format is
  - Instance name : Class name
  - Attributes and Values

  - Example:



Objects and Links

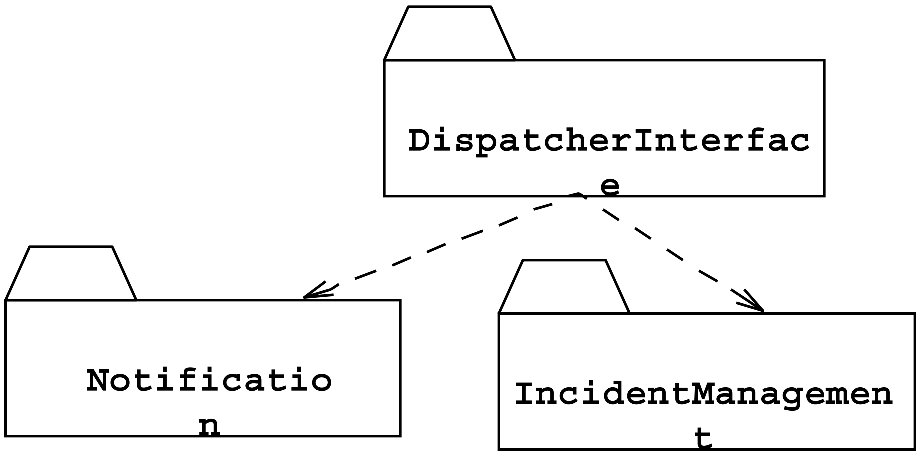


Can add association type and also message type

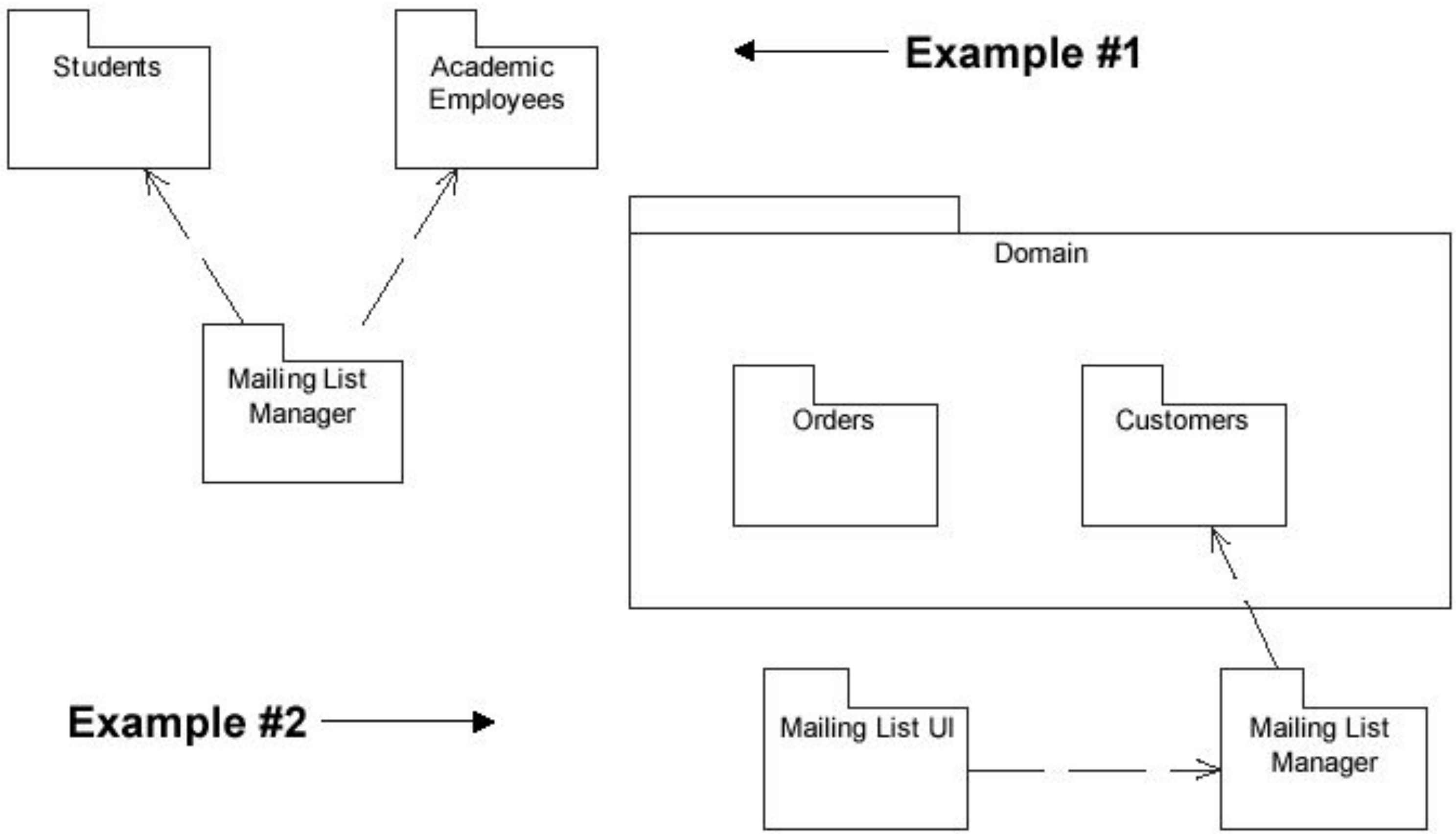
Package Diagrams

- To organize complex class diagrams, you can group classes into packages. A package is a collection of logically related UML elements
- Notation
  - Packages appear as rectangles with small tabs at the top.
  - The package name is on the tab or inside the rectangle.
  - The dotted arrows are dependencies. One package depends on another if changes in the other could possibly force changes in the first.
  - Packages are the basic grouping construct with which you may organize UML models to increase their readability

Package Example



More Package Examples



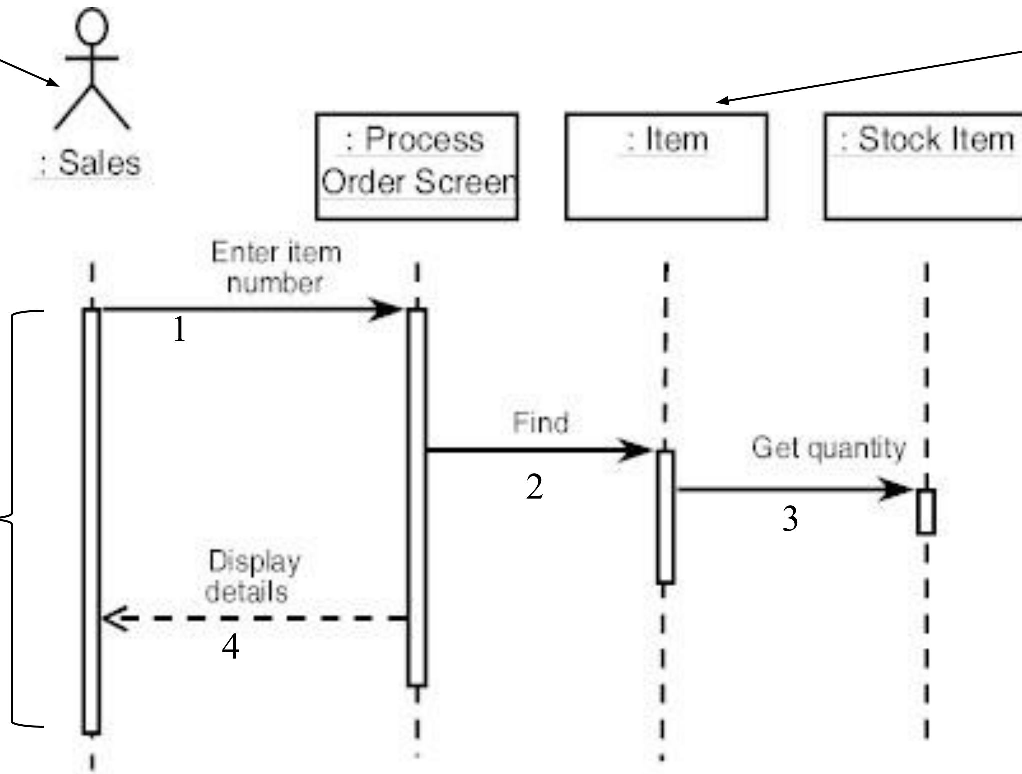
Interaction Diagrams

- Interaction diagrams are dynamic -- they describe how objects collaborate.
- A Sequence Diagram:
  - Indicates what messages are sent and when
  - Time progresses from top to bottom
  - Objects involved are listed left to right
  - Messages are sent left to right between objects in sequence

Sequence Diagram Format

Actor from
Use Case

Objects

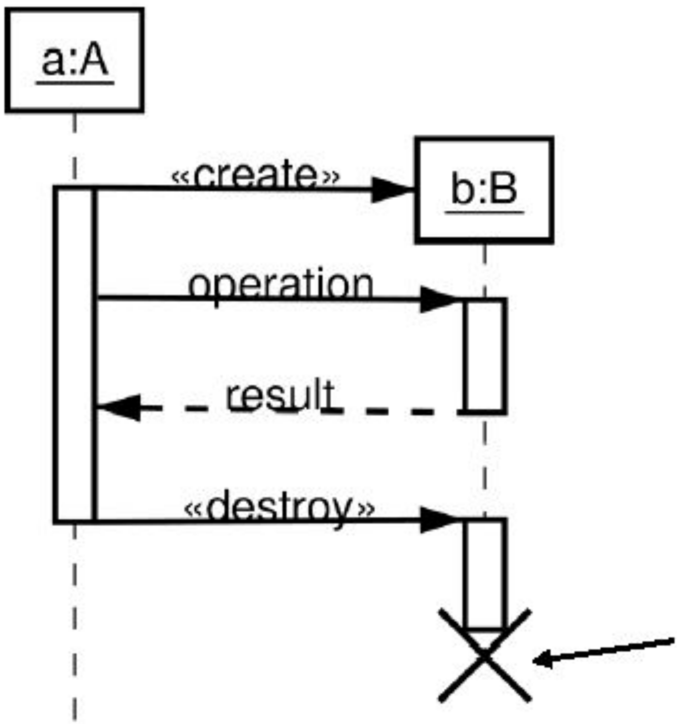


Activation

Lifeline

Calls = Solid Lines
Returns = Dashed Lines

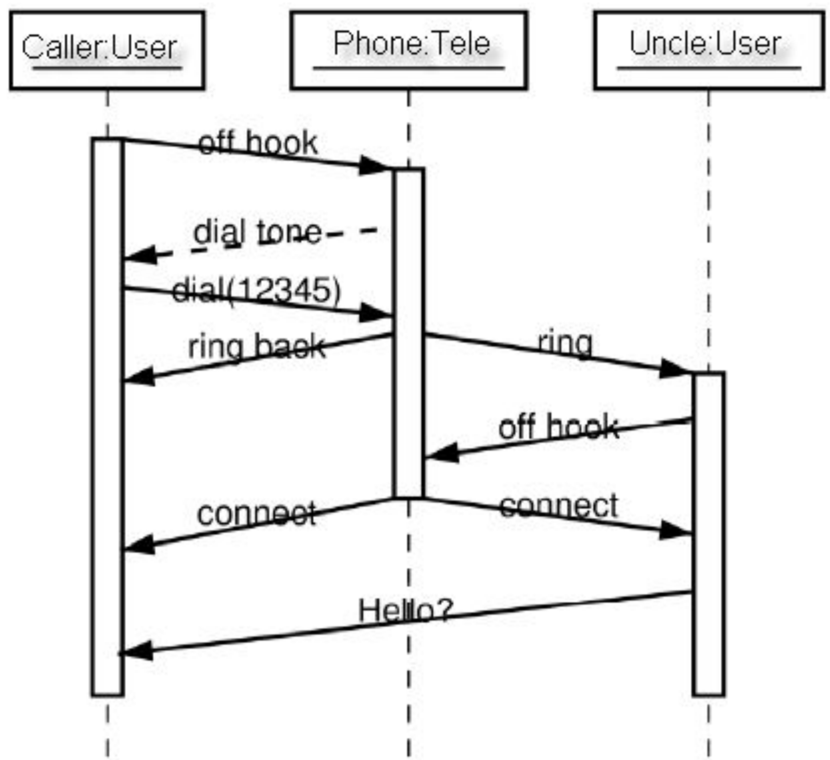
Sequence Diagram : Destruction



Shows Destruction of b
(and Construction)

Sequence Diagram : Timing

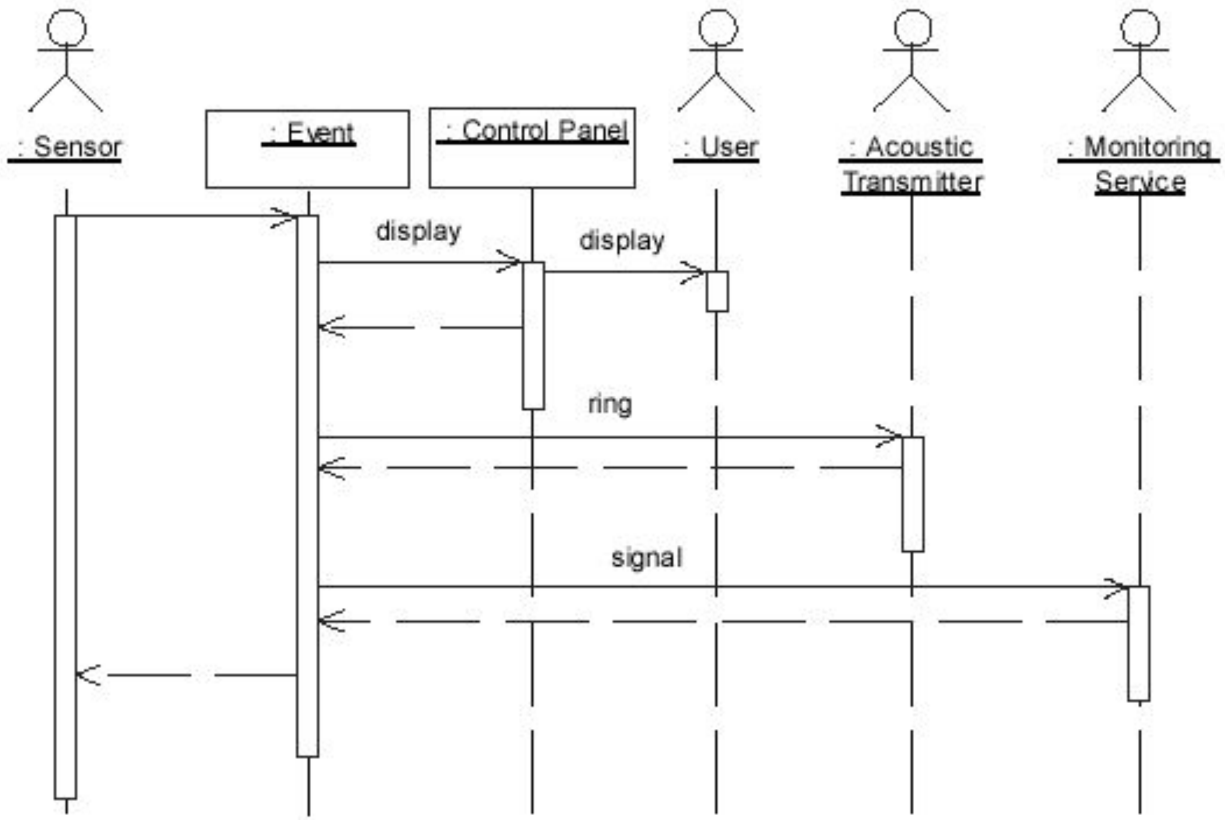
Slanted Lines show propagation delay of messages
Good for modeling real-time systems



If messages cross this is usually problematic – race conditions

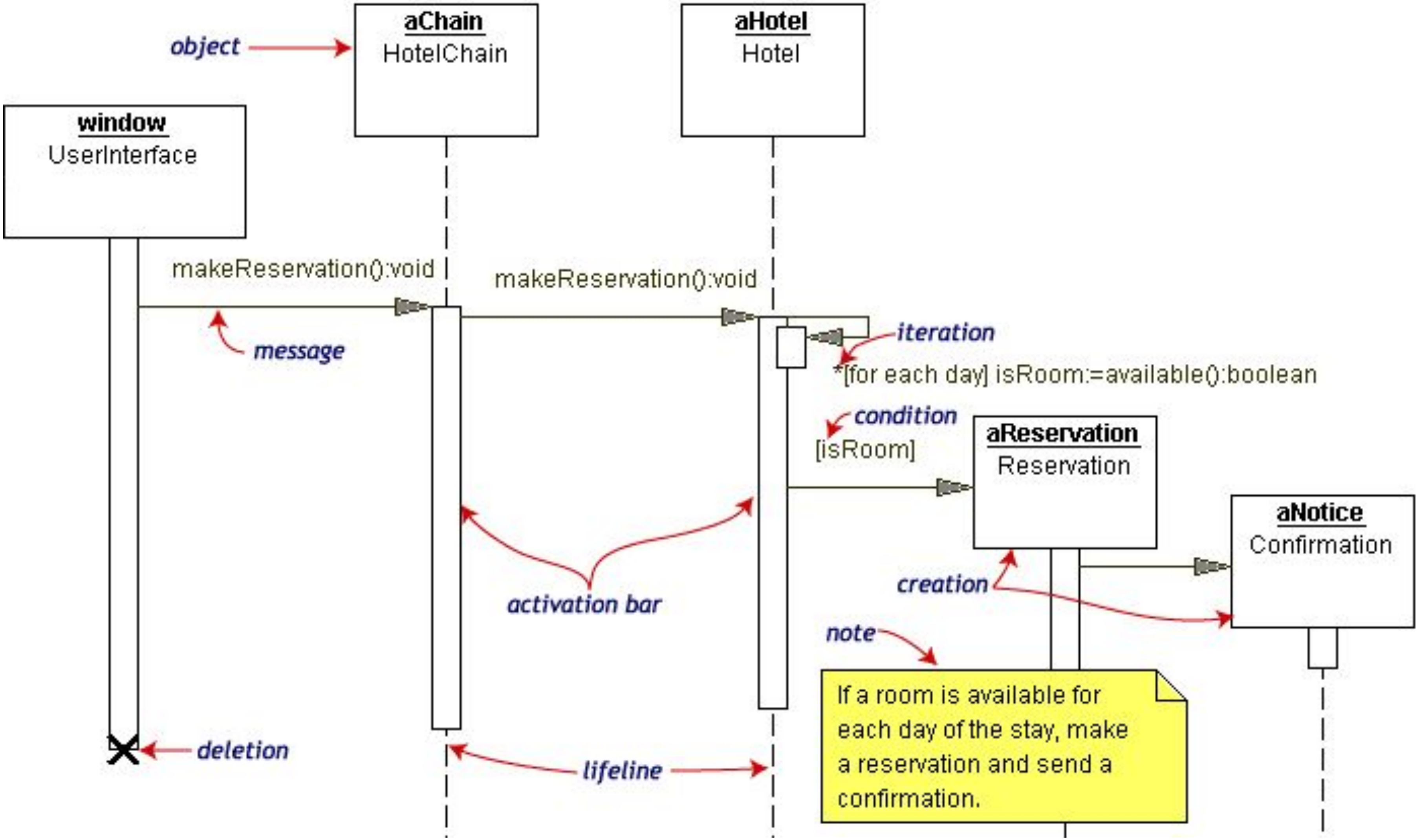
Sequence Example: Alarm System

- When the alarm goes off, it rings the alarm, puts a message on the display, notifies the monitoring service



Sequence Diagram Example

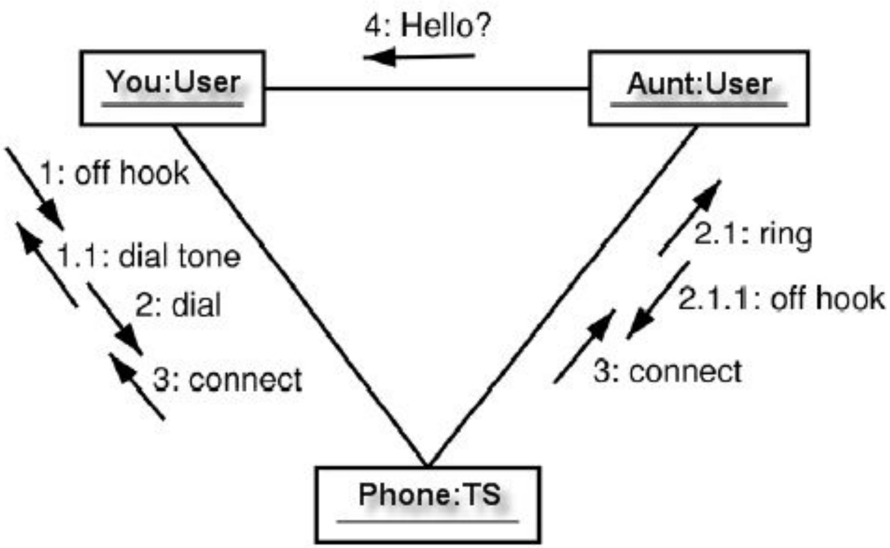
Hotel Reservation

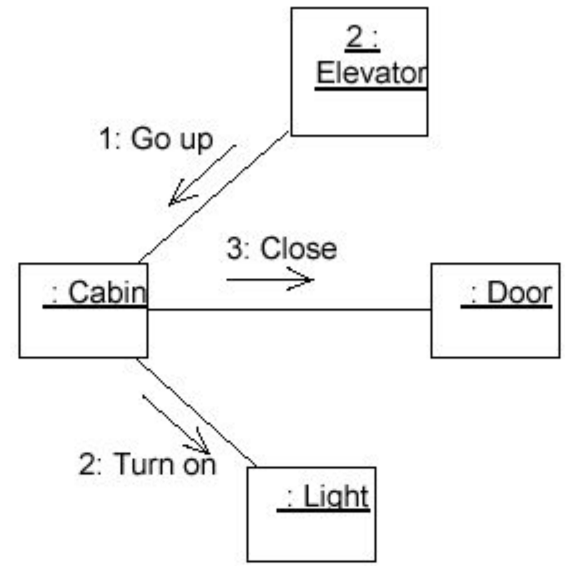


Collaboration Diagram

- Collaboration Diagrams show similar information to sequence diagrams, except that the vertical sequence is missing. In its place are:
  - Object Links - solid lines between the objects that interact
  - On the links are Messages - arrows with one or more message name that show the direction and names of the messages sent between objects
- Emphasis on static links as opposed to sequence in the sequence diagram

Collaboration Diagram



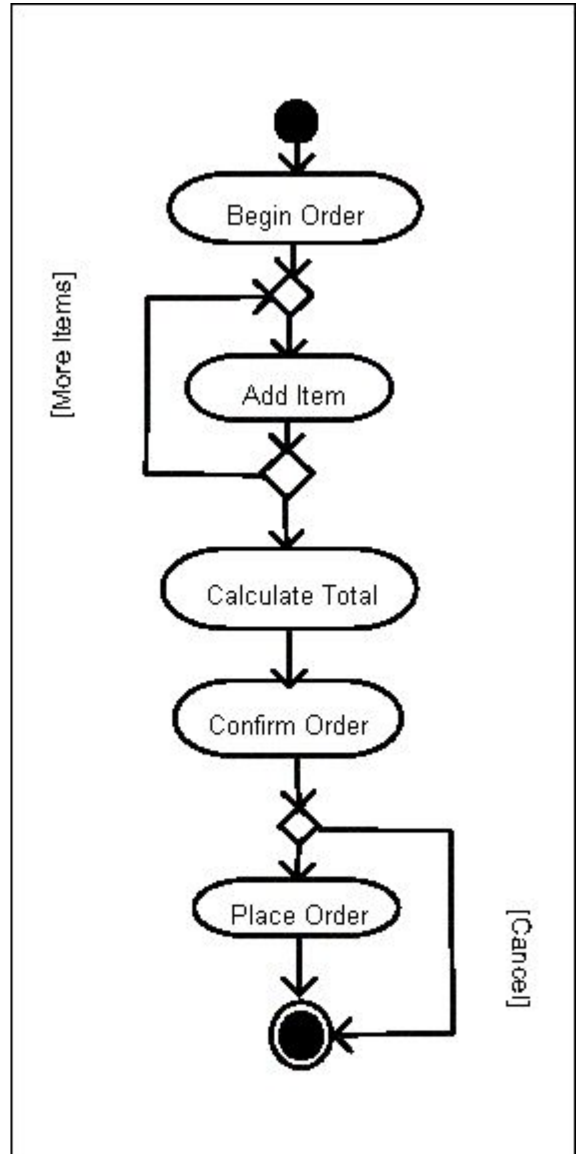


Activity Diagrams

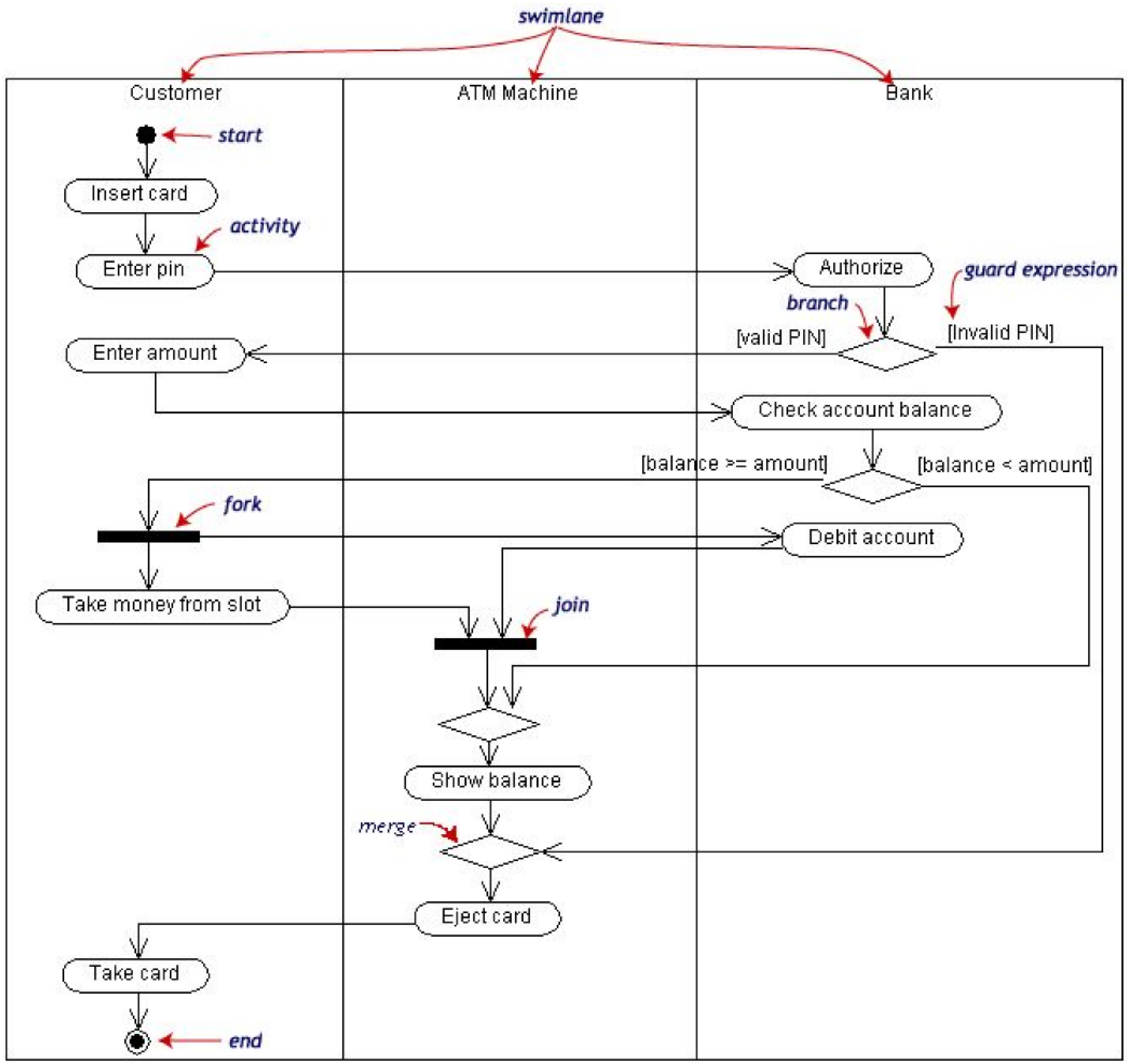
- Fancy flowchart
  - Displays the flow of activities involved in a single process
  - States
    - Describe what is being processed
    - Indicated by boxes with rounded corners
  - Swim lanes
    - Indicates which object is responsible for what activity
  - Branch
    - Transition that branch
    - Indicated by a diamond
  - Fork
    - Transition forking into parallel activities
    - Indicated by solid bars
  - Start and End

Sample Activity Diagram

- Ordering System
- May need multiple diagrams from other points of view



Activity Diagram Example



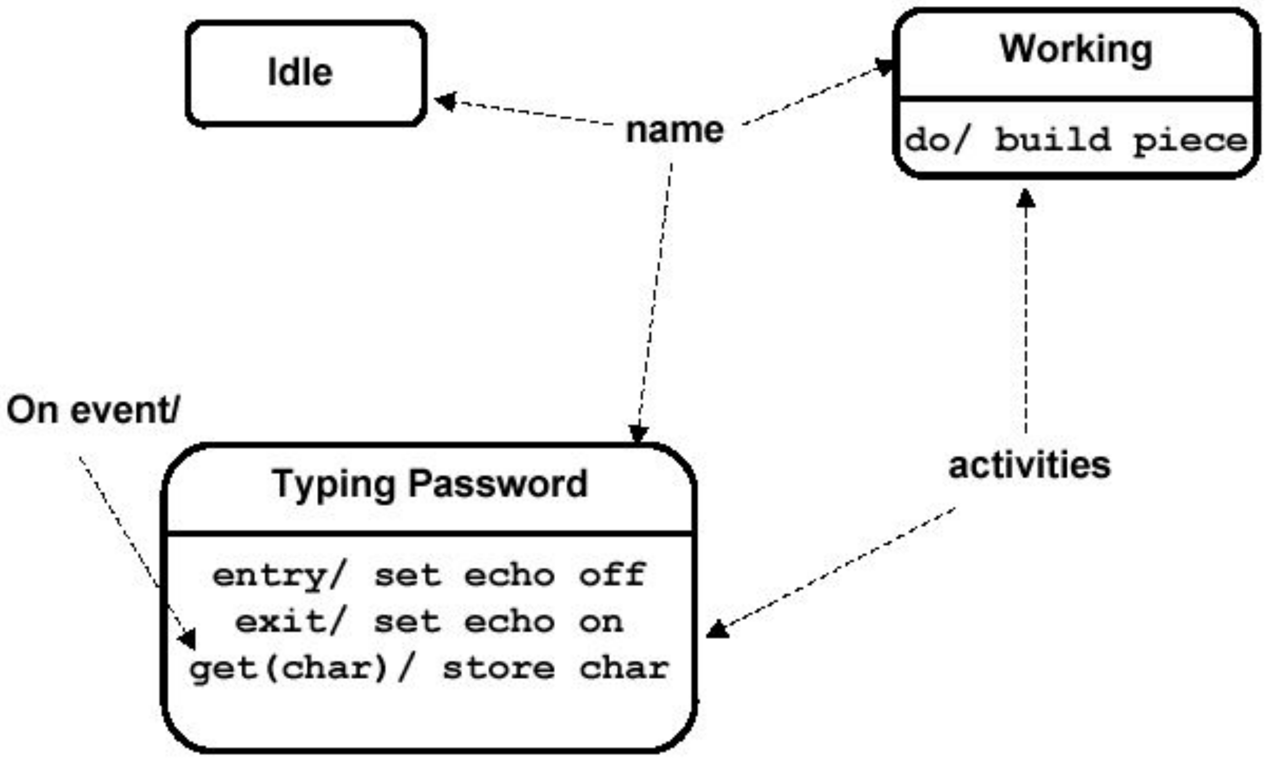
State Transition Diagrams

- Shows the possible states of the object and the transitions that cause a change in state
  - i.e. how incoming calls change the state
- Notation
  - States are rounded rectangles
  - Transitions are arrows from one state to another. Events or conditions that trigger transitions are written beside the arrows.
  - Initial and Final States indicated by circles as in the Activity Diagram
    - Final state terminates the action; may have multiple final states

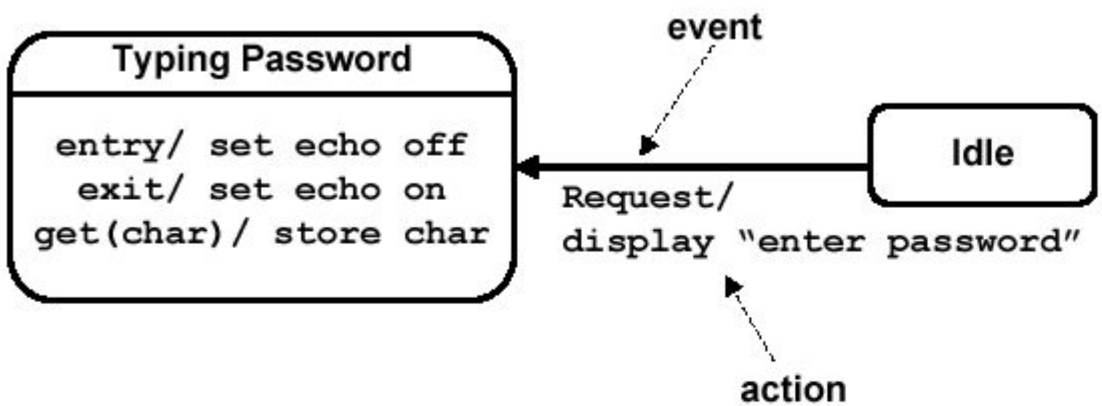
State Representation

- The set of properties and values describing the object in a well defined instant are characterized by
  - Name
  - Activities (executed inside the state)
    - Do/ activity
  - Actions (executed at state entry or exit)
    - Entry/ action
    - Exit/ action
  - Actions executed due to an event
    - Event [Condition] / Action ^Send Event

Notation for States

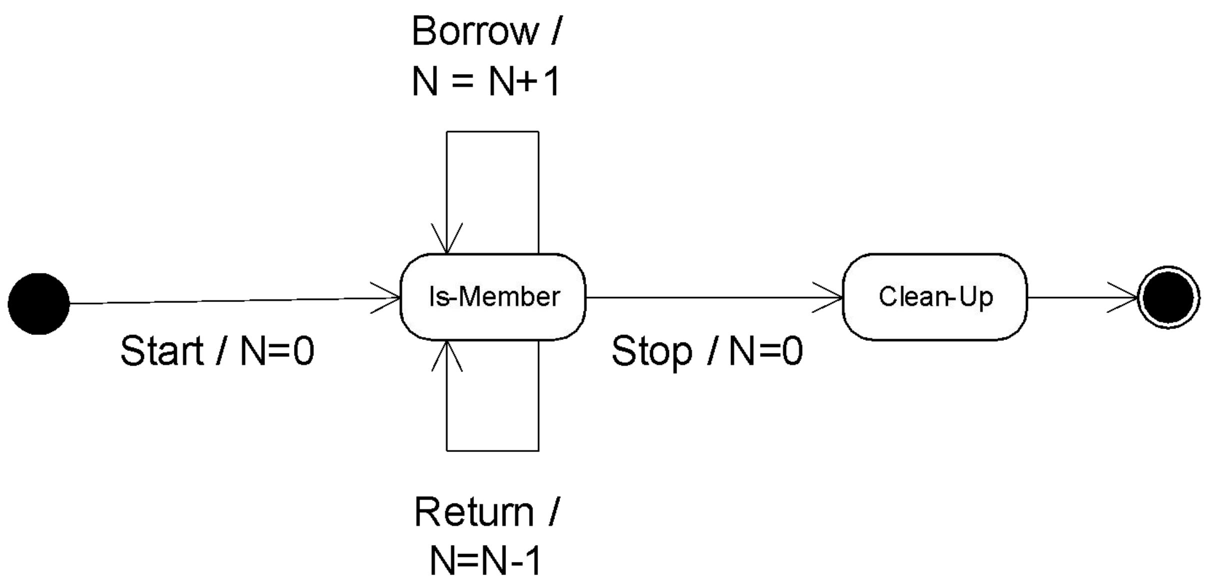


Simple Transition Example



State Charts – Local Variables

- State Diagrams can also store their own local variables, do processing on them
- Library example counting books checked out and returned

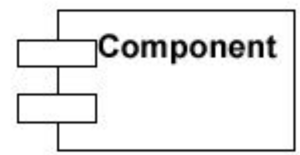


Component Diagrams

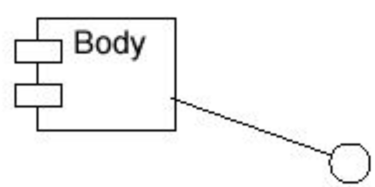
- Shows various components in a system and their dependencies, interfaces
- Explains the structure of a system
- Usually a physical collection of classes
  - Similar to a Package Diagram in that both are used to group elements into logical structures
  - With Component Diagrams all of the model elements are private with a public interface whereas Package diagrams only display public items.

Component Diagram Notation

- Components are shown as rectangles with two tabs at the upper left

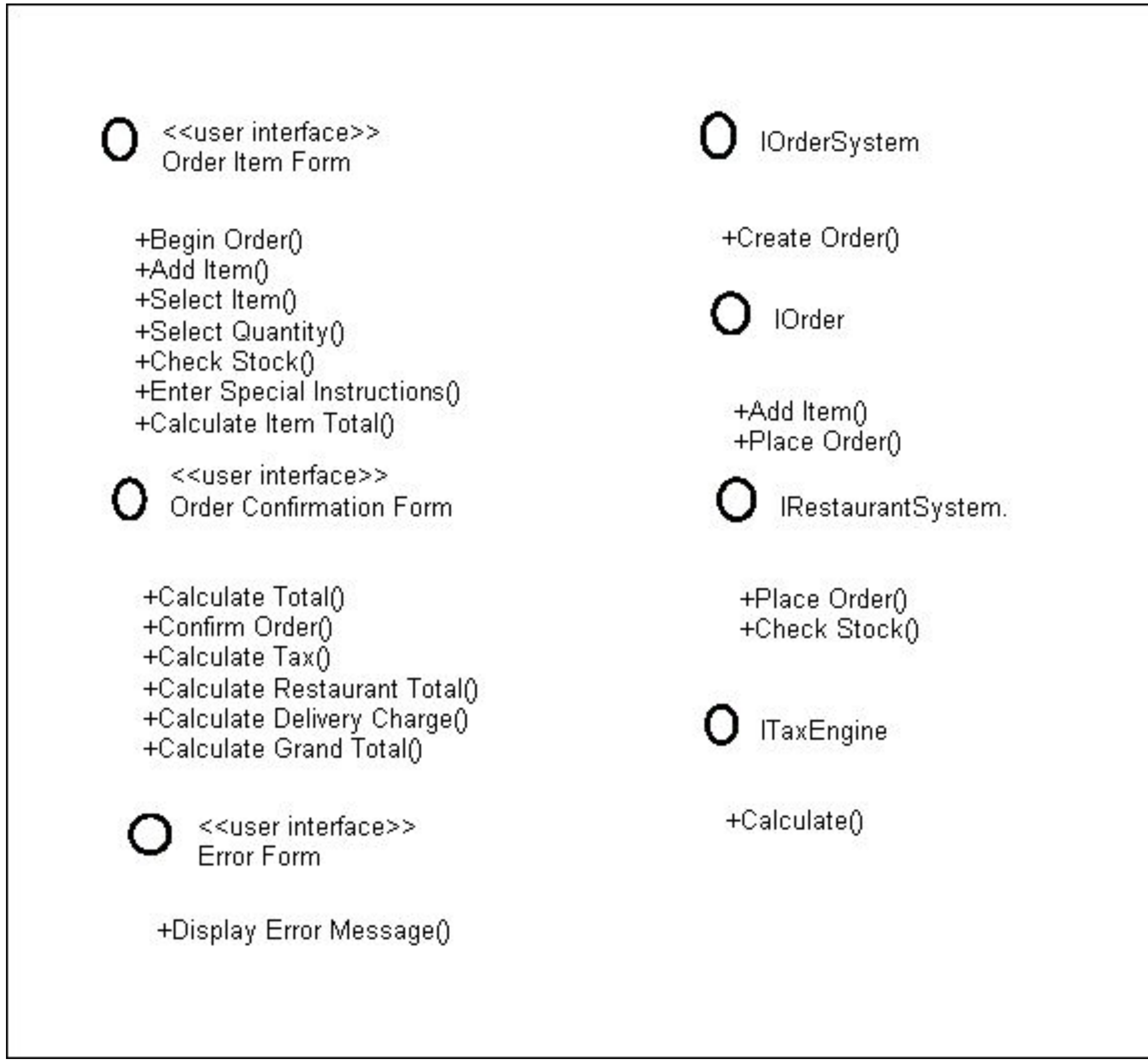


- Dashed arrows indicate dependencies
- Circle and solid line indicates an interface to the component



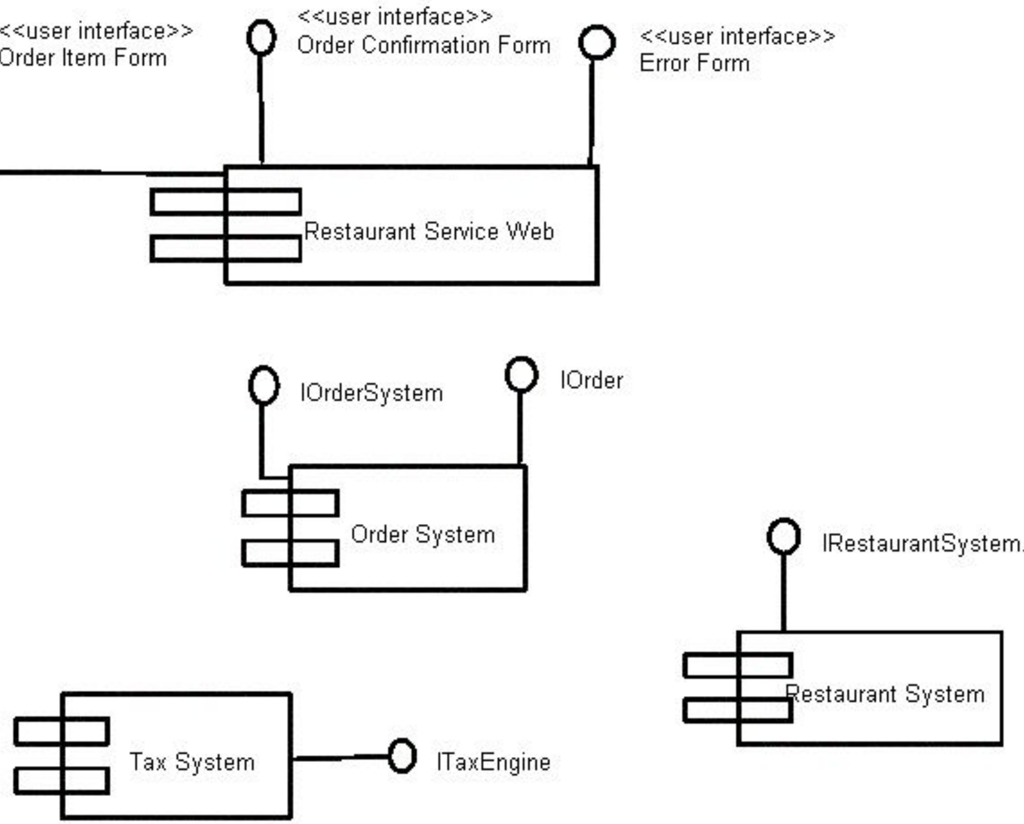
Component Example - Interfaces

- Restaurant ordering system
- Define interfaces first – comes from Class Diagrams



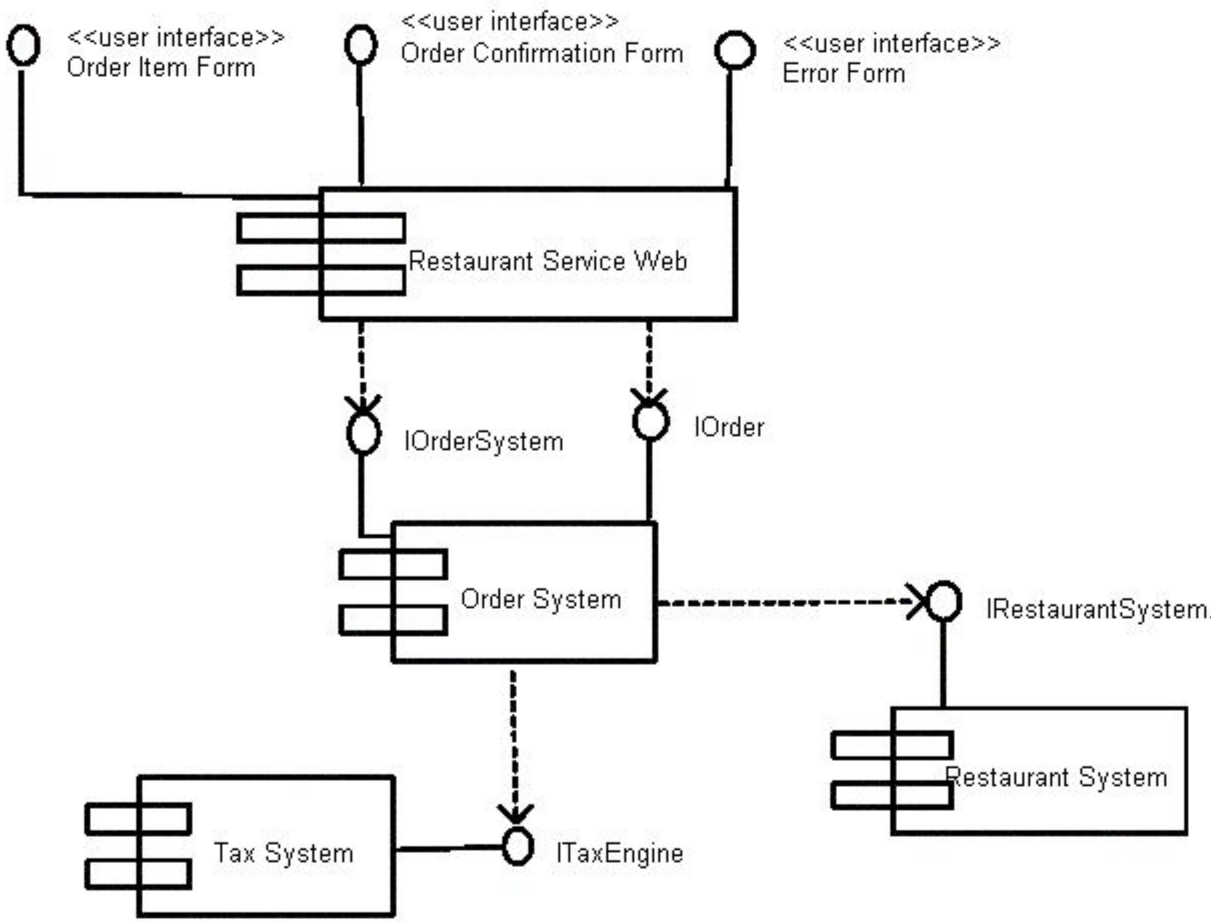
Component Example - Components

- Graphical depiction of components



Component Example - Linking

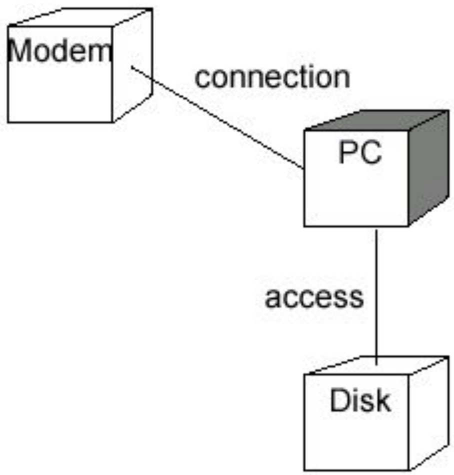
- Linking components with dependencies

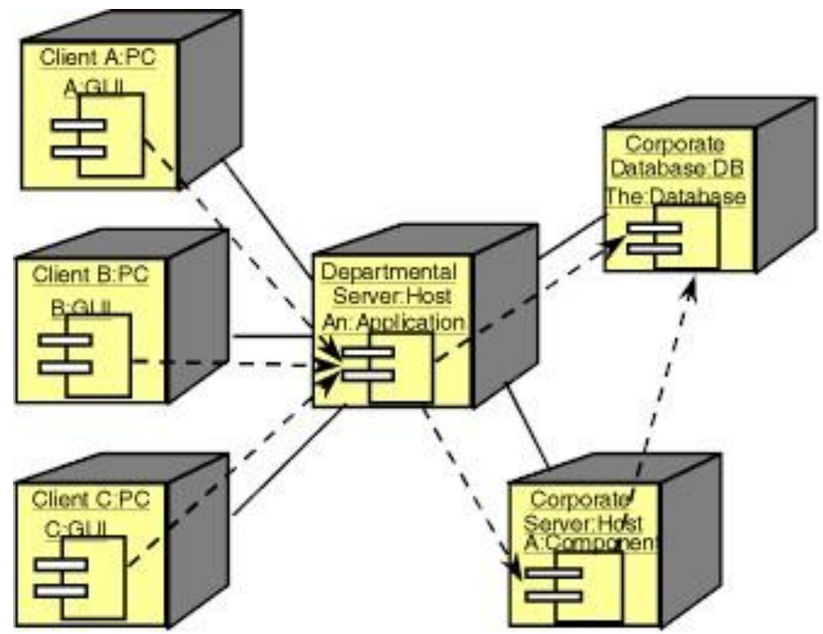


Deployment Diagrams

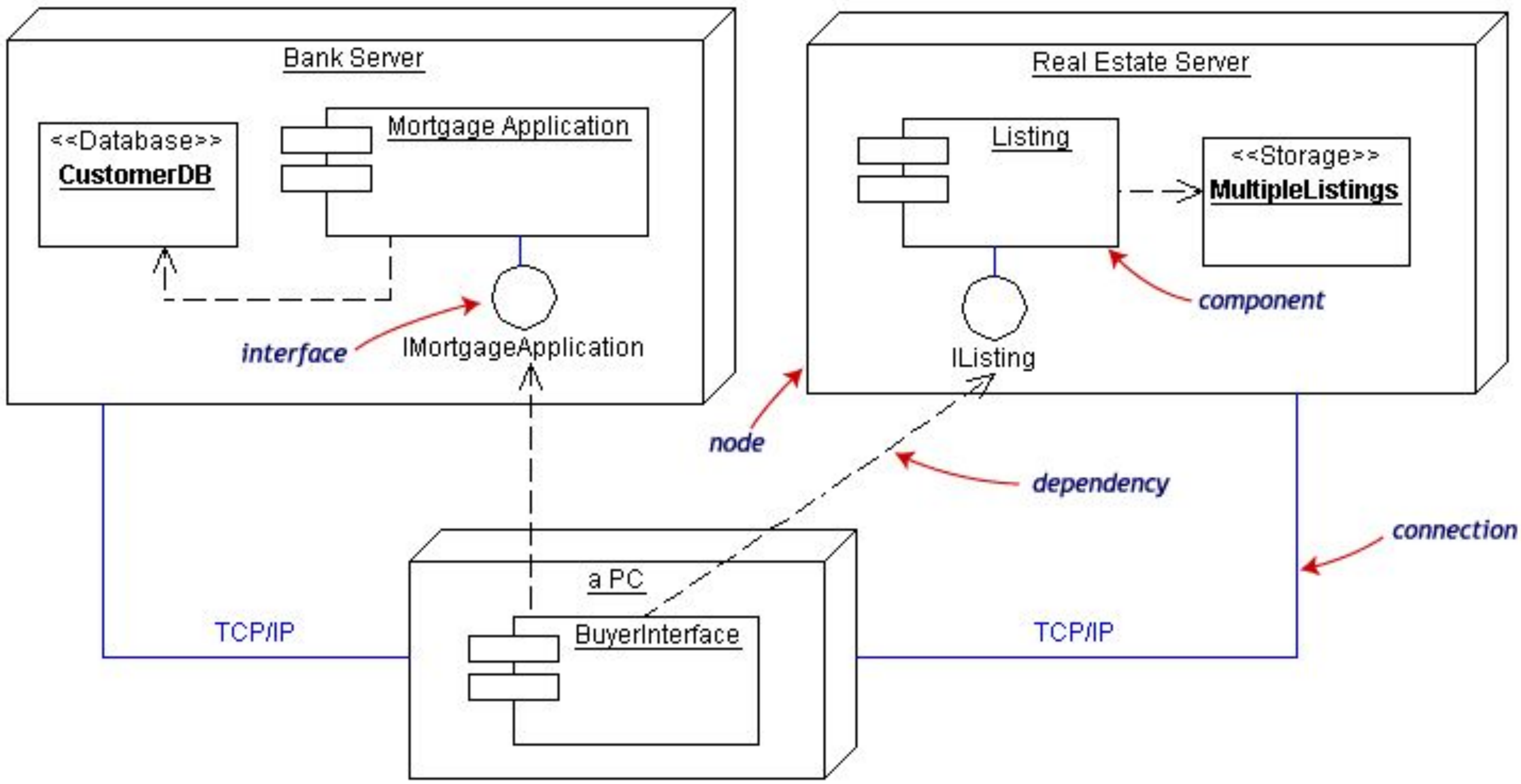
- Shows the physical architecture of the hardware and software of the deployed system
- Nodes
  - Typically contain components or packages
  - Usually some kind of computational unit; e.g. machine or device (physical or logical)
- Physical relationships among software and hardware in a delivered systems
  - Explains how a system interacts with the external environment

Some Deployment Examples





Deployment Example



Often the Component Diagram is combined with the Deployment

Summary and Tools

- UML is a modeling language that can be used independent of development
- Adopted by OMG and notation of choice for visual modeling
  - http://www.omg.org/uml/
- Creating and modifying UML diagrams can be labor and time intensive.
- Lots of tools exist to help
  - Tools help keep diagrams, code in sync
  - Repository for a complete software development project
  - Examples here created with TogetherSoft ControlCenter, Microsoft Visio, Tablet UML
  - Other tools:
    - Rational, Cetus, Embarcadero
    - See http://plg.uwaterloo.ca/~migod/uml.html for a list of tools, some free