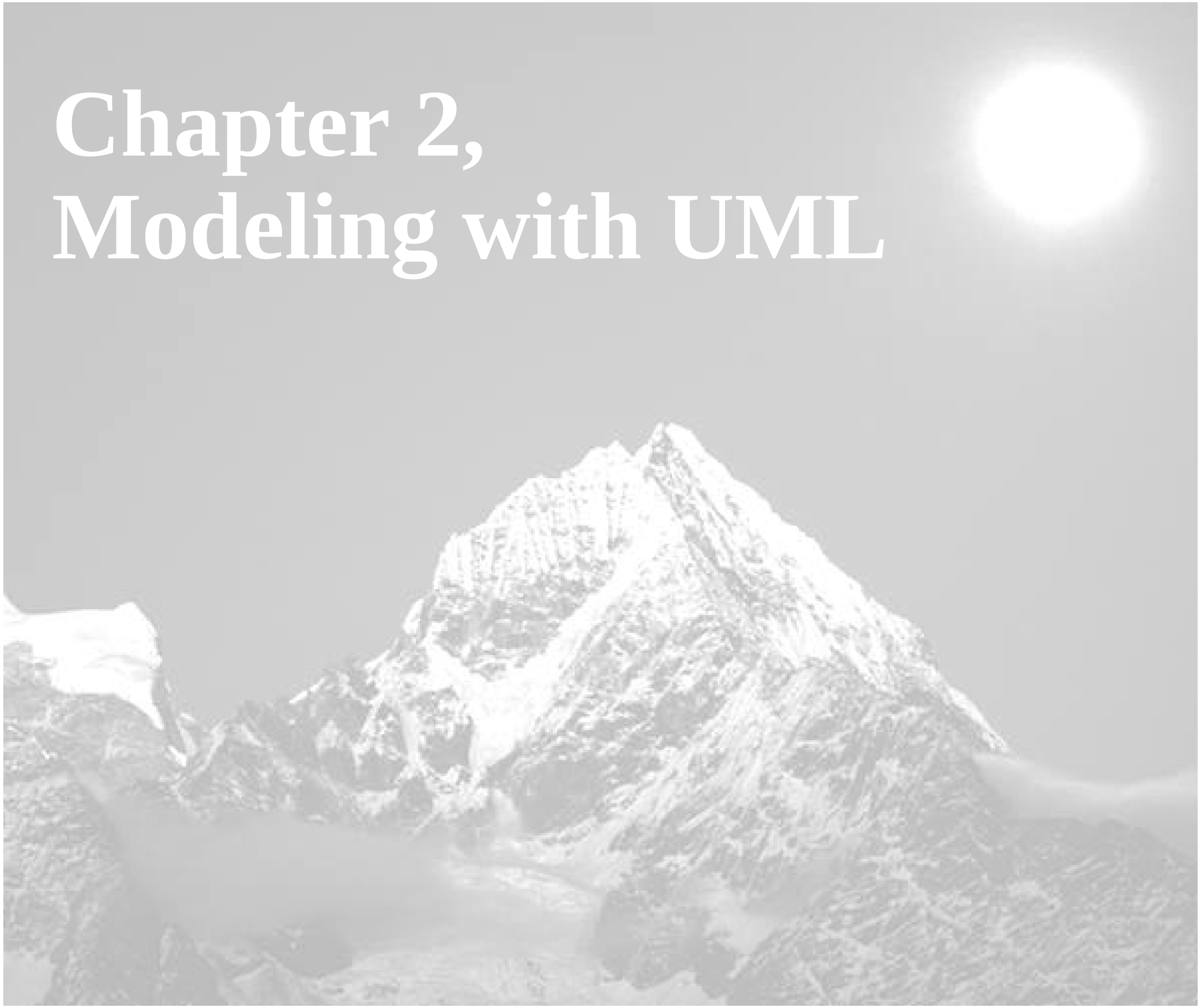
Object-Oriented Software Engineering
Conquering Complex and Changing Systems



Chapter 2, Modeling with UML

Preliminaries (1)

Students from other departments than Informatik:

How do I get a Schein for this lecture?

- Hörerschein: just ask (mailto:dutoit@in.tum.de).
- Vorlesung & Übung Schein: Feb 16, written exam.

Bachelor students:

Are there mandatory homeworks or a written exam in this lecture?

- Optional homeworks, but no mandatory homeworks.
- Written exam on Feb 16

Preliminaries (2)

Praktikum registration:

http://www12.in.tum.de/projects/STARS2001/

before **tonight 20:00**

Hauptseminar Requirements Engineering

Thursdays 13:00-14:00

3 slots are still available

Book: “Object-Oriented Software Engineering: ...”

- **Computerbücher am Obelisk**
- **Kanzler**
- **Lachner**

Preliminaries (3)

Ground rules:

- If you stop understanding me for any reason (content, language, sound system), let me know.
- Ask (many) questions
  - **During the lecture**
  - **After the lecture**
  - **During the Sprechstunde**
  - **Via E-mail**

Overview

- What is modeling?
- What is UML?
- Use case diagrams
- Class diagrams
- Sequence diagrams
- Activity diagrams
- Summary

Motivation

- Realistic and useful systems are ***large*** and ***complex***.
  - **Unix System V: 1 mio SLOC (source lines of code)**
  - **HiPath telephone switch: 8.5 mio SLOC**
  - **Windows2000: 40 mio SLOC**
- Systems require the work of ***many*** people (developers, testers, managers, clients, users, etc.).
- Systems have an extended life cycle, hence they ***evolve***.
- 1 mio SLOC with 100 persons ≠ 10 k SLOC with 1 person

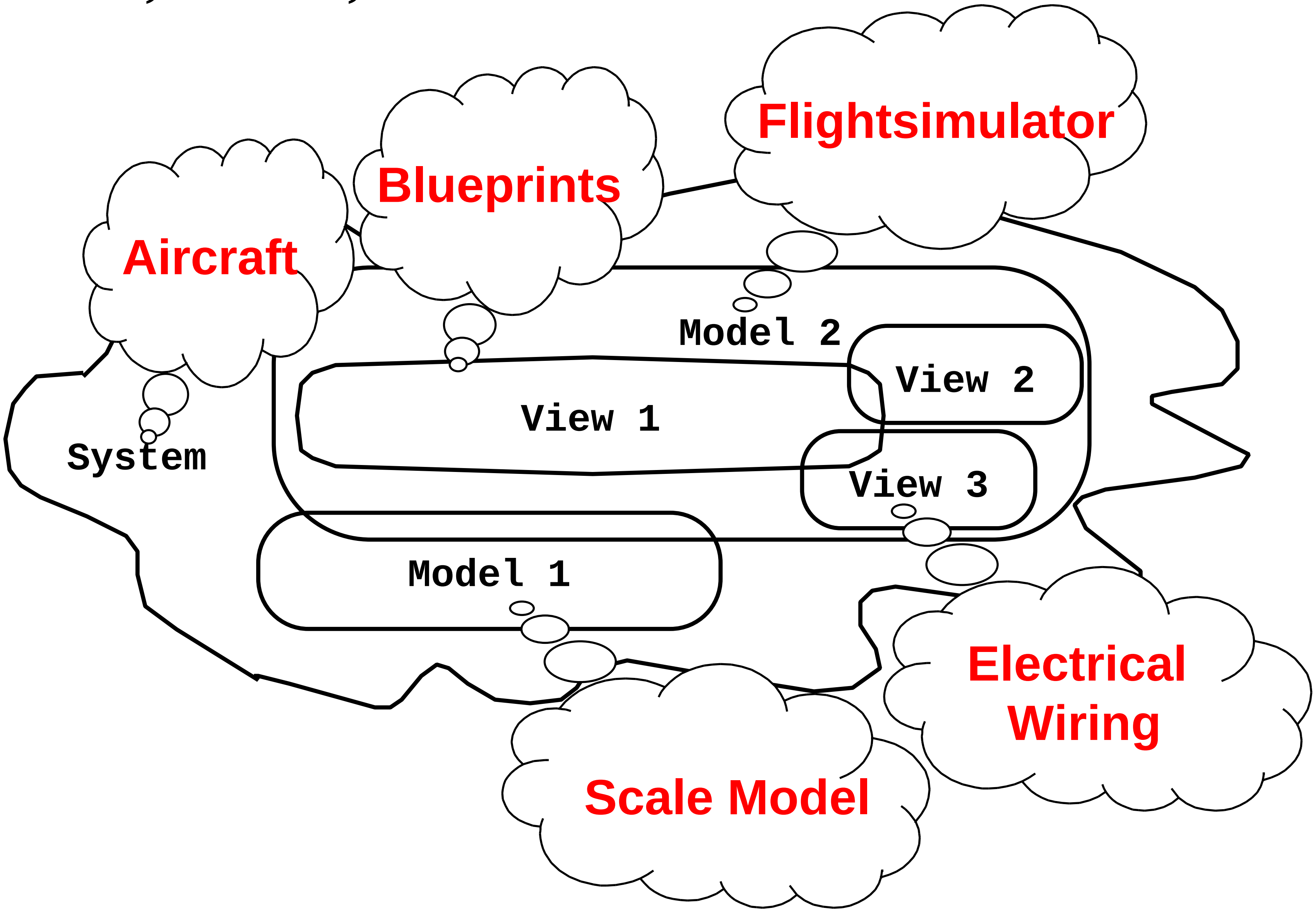
-> Modeling

Systems, Models, and Views

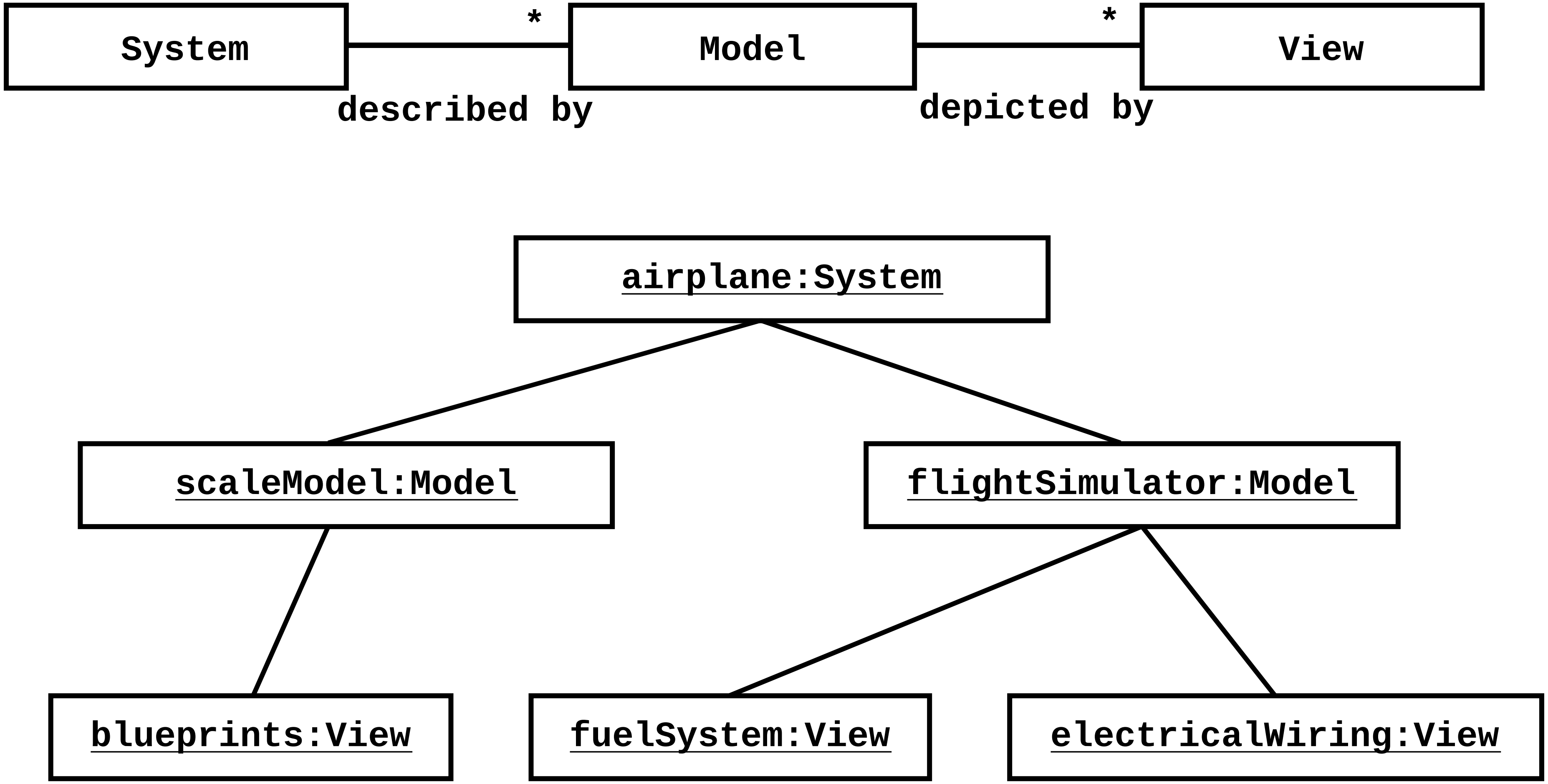
- *Model:* Abstraction describing a system (or a subset)
- *View:* Selected aspects of a model
- *Notation*: Set of rules for representing views

- Views and models of a single system can overlap each other

Systems, Models, and Views



Models, Views, and Systems (UML)

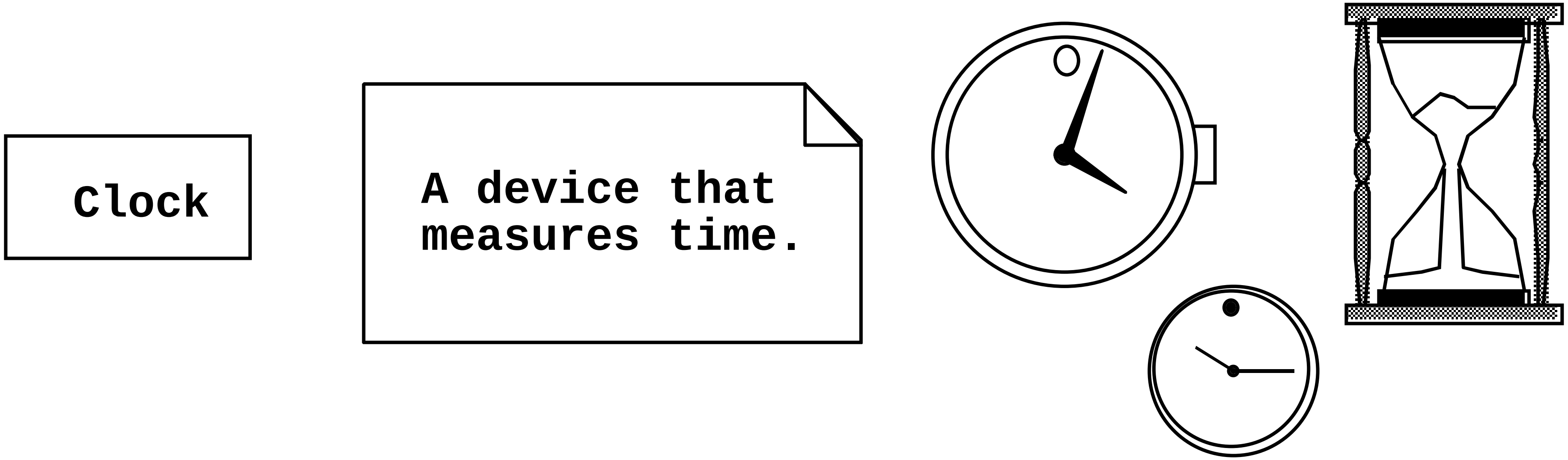


Concepts and Phenomena

- *Phenomenon*: An object in the world of a domain as you perceive it, for example:
  - **The lecture you are attending**
  - **My blue watch**
- *Concept*: Describes the properties of phenomena that are common, for example:
  - **Lectures on software engineering**
  - **Blue watches**
- A concept is a 3-tuple:
  - ***Name:*** **distinguishes it from other concepts.**
  - ***Purpose:*** **properties that determine if a phenomenon is a member**
  - ***Members:*** **phenomena which are part of the concept.**

Concepts and Phenomena

Name **Purpose** **Members**



Clock

A device that measures time.

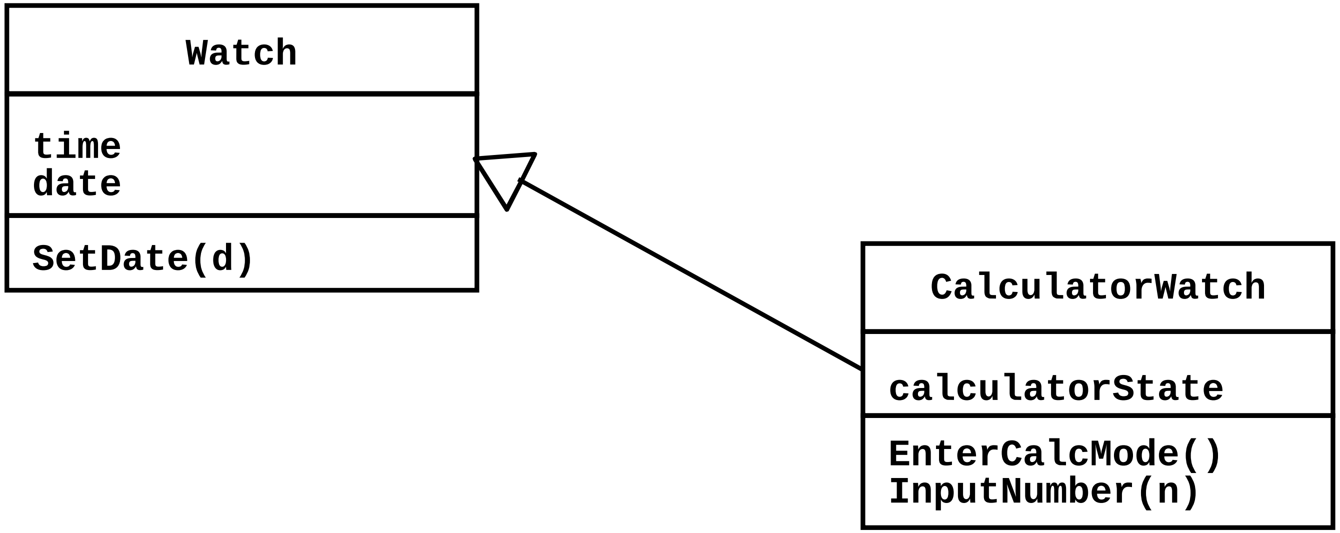
- *Abstraction*: Classification of phenomena into concepts
- *Modeling*: Development of abstractions to answer specific questions about a set of phenomena while ignoring irrelevant details.

Concepts In Software: Type and Instance

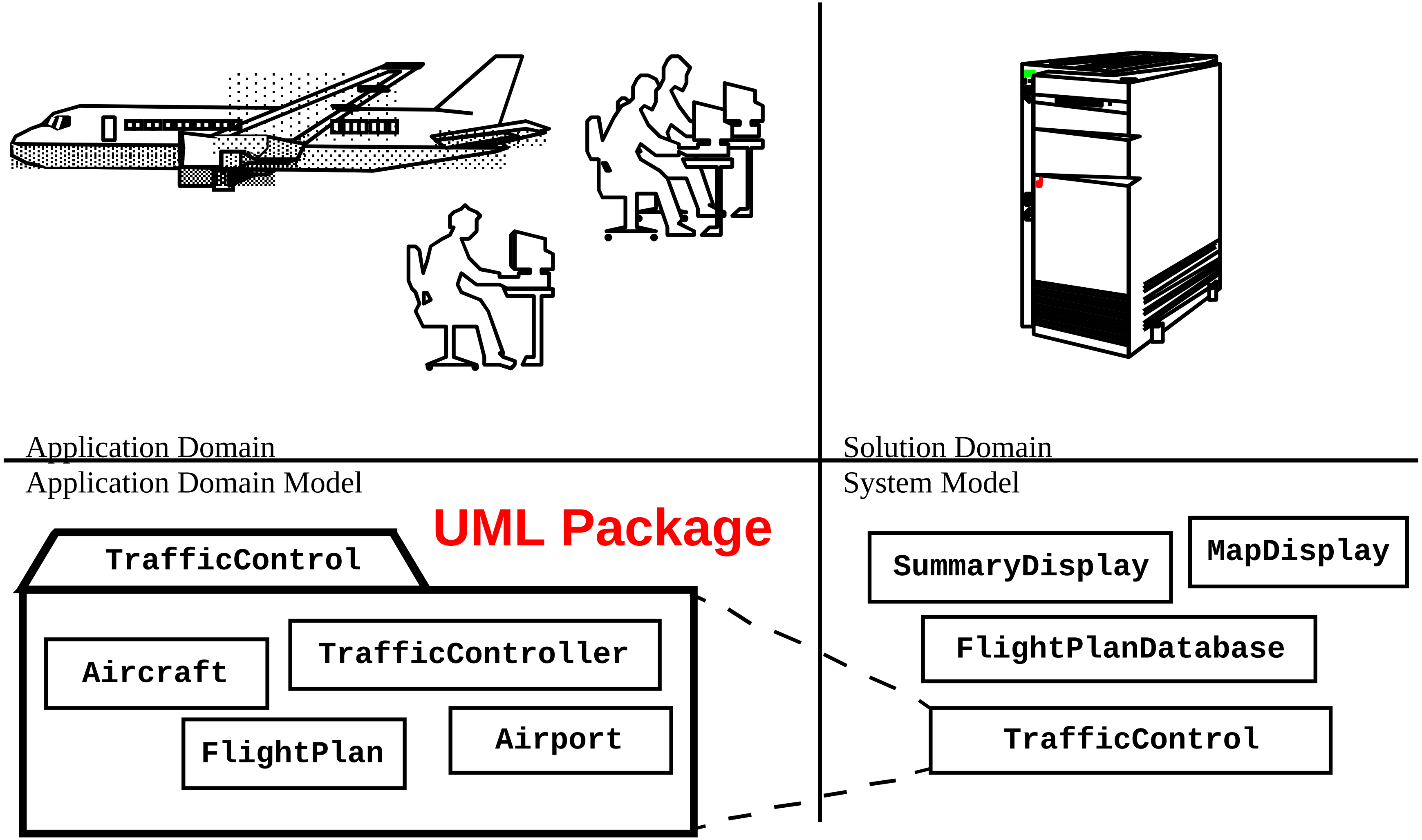
- Type:
  - **An abstraction in the context of programming languages**
  - **Name: int, Purpose: integral number, Members: `0, -1, 1, 2, -2, . . .`**
- Instance:
  - **Member of a specific type**
- The type of a variable represents all possible instances the variable can take.
- The relationship between “type” and “instance” is similar to that of “concept” and “phenomenon.”
- Abstract data type:
  - **Special type whose implementation is hidden from the rest of the system.**

Class

- Class:
  - **An abstraction in the context of object-oriented languages**
- Like an abstract data type, a class encapsulates both state (variables) and behavior (methods)
- Unlike abstract data types, classes can be defined in terms of other classes using inheritance



Object-Oriented Modeling



Application Domain

Solution Domain

Application Domain Model

System Model

UML Package

TrafficControl

Aircraft

TrafficController

FlightPlan

Airport

SummaryDisplay

MapDisplay

FlightPlanDatabase

TrafficControl

Application and Solution Domain

- Application Domain (Requirements Analysis):
  - **The environment in which the system is operating**
- Solution Domain (System Design, Object Design):
  - **The available technologies to build the system**

What is UML?

- UML (Unified Modeling Language)
  - **An emerging standard for modeling object-oriented software.**
  - **Resulted from the convergence of notations from three leading object-oriented methods:**
    - **OMT (James Rumbaugh)**
    - **OOSE (Ivar Jacobson)**
    - **Booch (Grady Booch)**
- Reference: “The Unified Modeling Language User Guide”, Addison Wesley, 1999.
- Supported by several CASE tools
  - **Rational ROSE**
  - **Together/J**
  - **...**

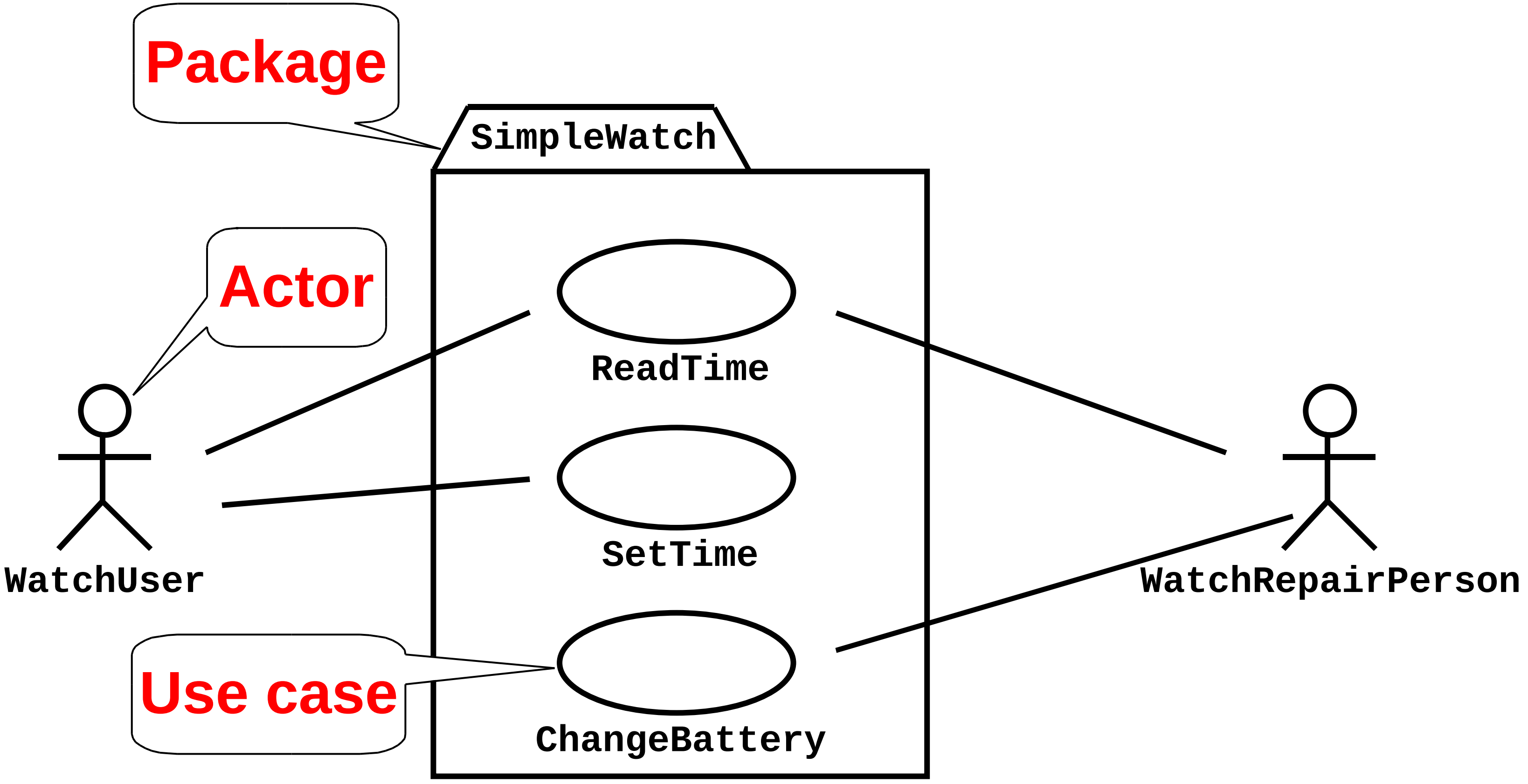
UML and This Course

- You can model 80% of most problems by using about 20% UML.
- In this course, we teach you those 20%.
- Today, we give you a brief overview.
- In subsequent lectures, we will introduce more concepts as needed.

UML First Pass

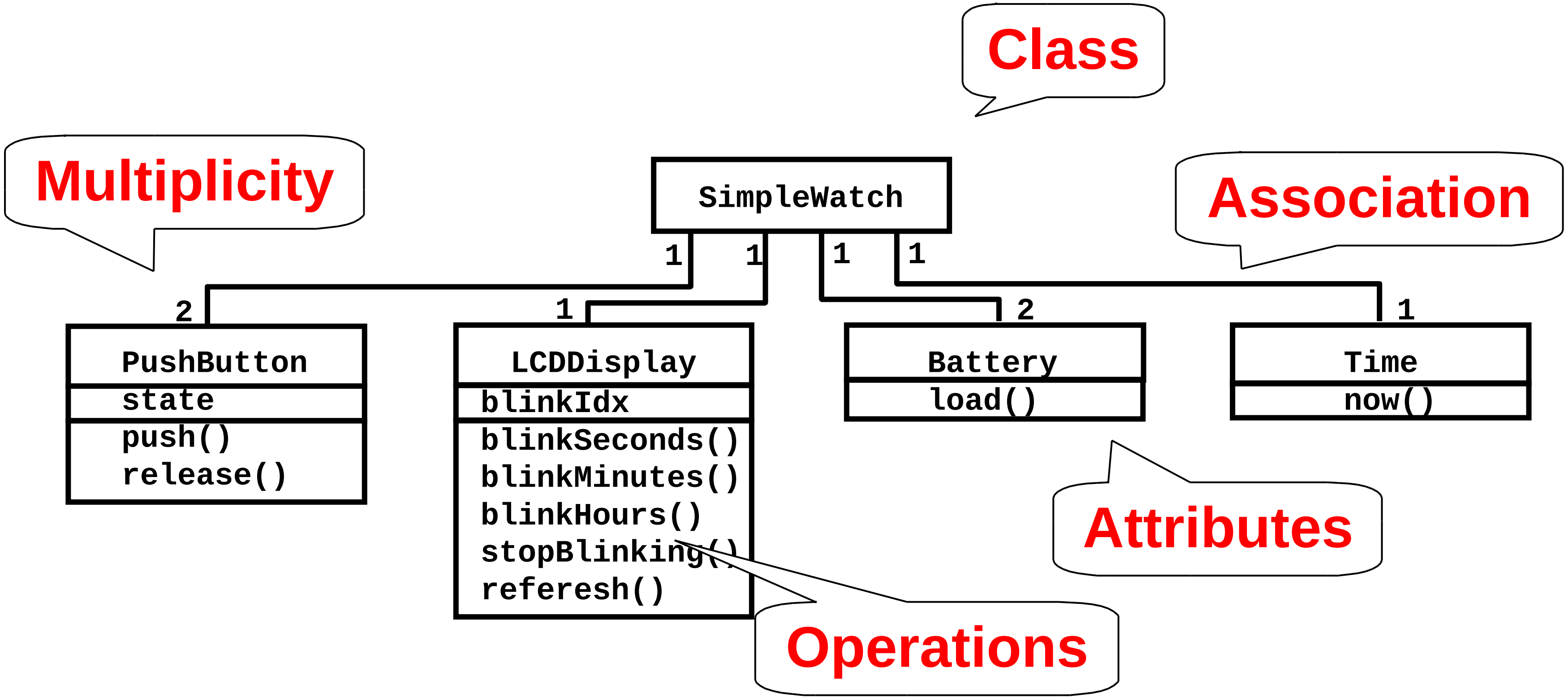
- Use case diagrams
    - **Describe the functional behavior of the system as seen by the user.**
- Class diagrams
    - **Describe the static structure of the system: Objects, Attributes, and Associations.**
- Sequence diagrams
    - **Describe the dynamic behavior between actors and the system and between objects of the system.**
- Statechart diagrams
    - **Describe the dynamic behavior of an individual object as a finite state machine.**
- Activity diagrams
    - **Model the dynamic behavior of a system, in particular the workflow, i.e. a flowchart.**

UML First Pass: Use Case Diagrams



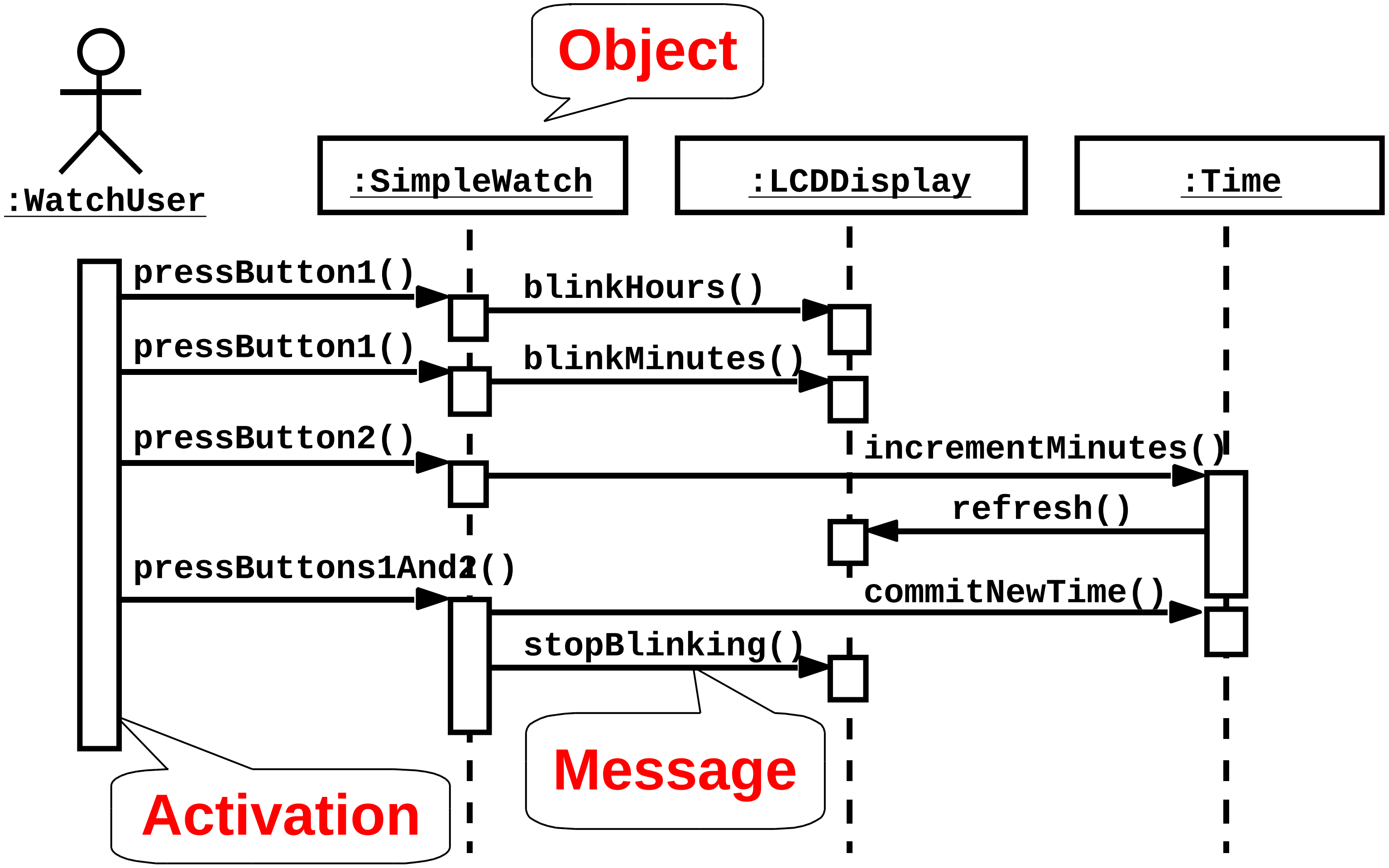
Use case diagrams represent the functionality of the system from user's point of view

UML First Pass: Class Diagrams



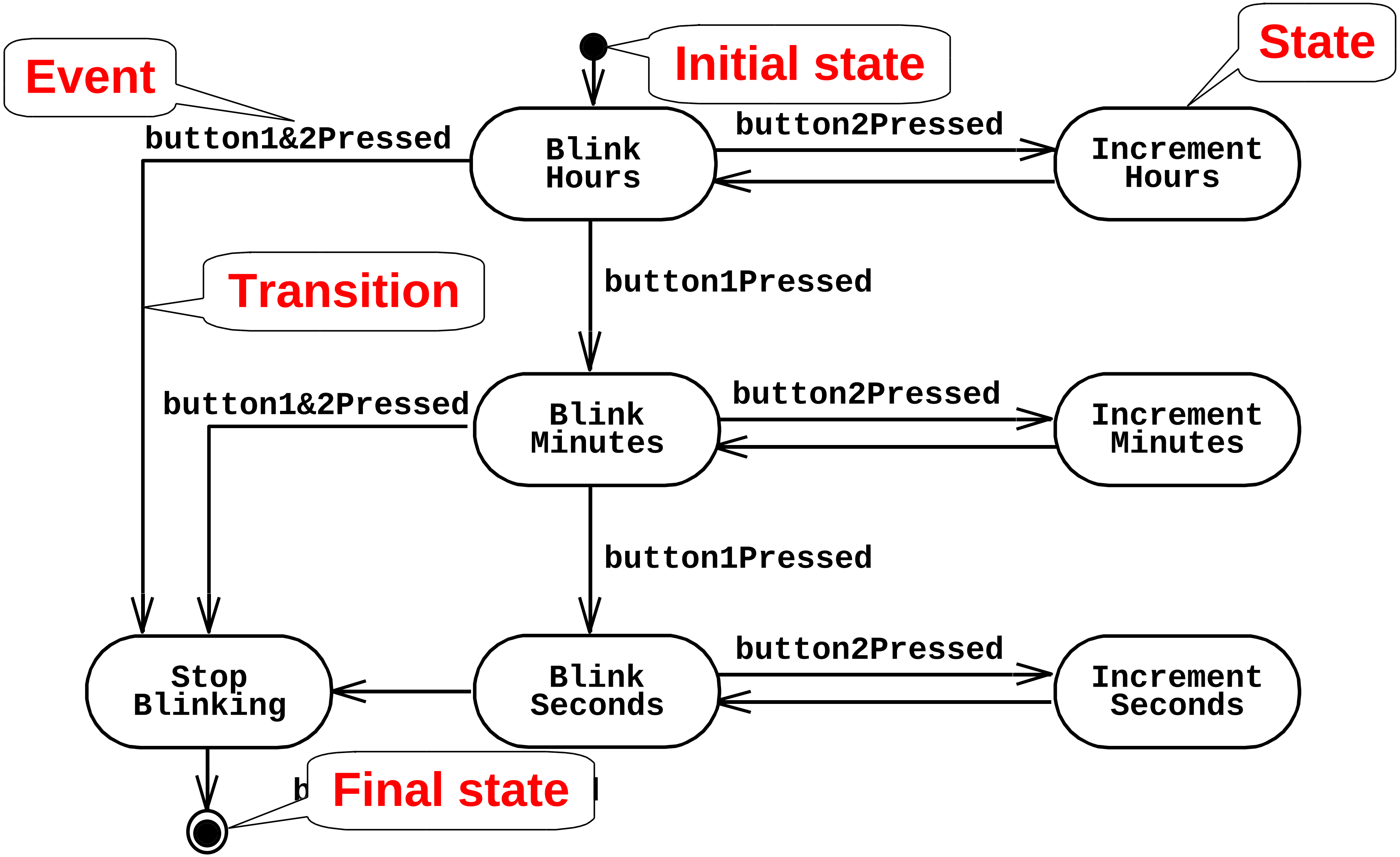
Class diagrams represent the structure of the system

UML First Pass: Sequence Diagram



Sequence diagrams represent the behavior as interactions

UML First Pass: Statechart Diagrams



Other UML Notations

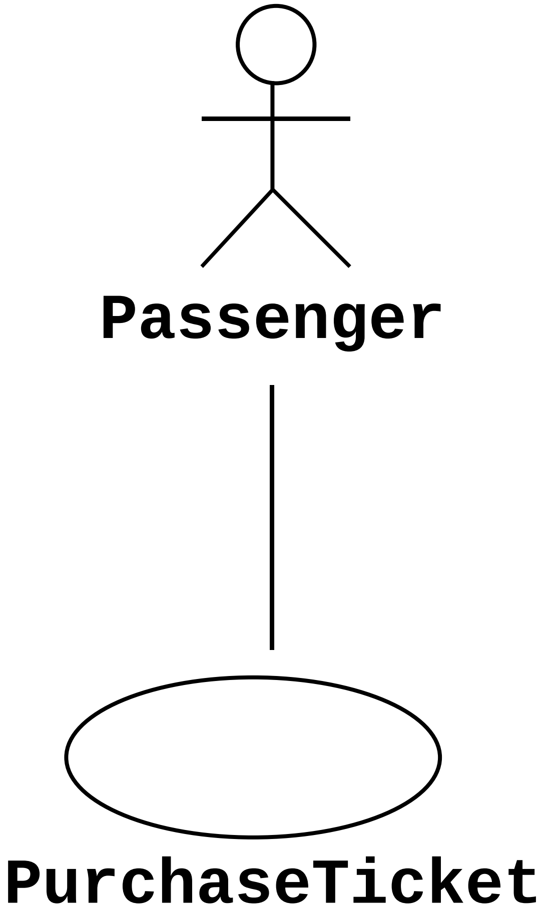
UML provide other notations that we will be introduced in subsequent lectures, as needed.

- Implementation diagrams
  - **Component diagrams**
  - **Deployment diagrams**
  - **Introduced in lecture on System Design**
- Object Constraint Language (OCL)
  - **Introduced in lecture on Object Design**

UML Core Conventions

- Rectangles are classes or instances
- Ovals are functions or use cases
- Instances are denoted with an underlined names
  - **`myWatch:SimpleWatch`**
  - **`joe:Firefighter`**
- Types are denoted with nonunderlined names
  - **`SimpleWatch`**
  - **`Firefighter`**
- Diagrams are graphs
  - **Nodes are entities**
  - **Arcs are relationships between entities**

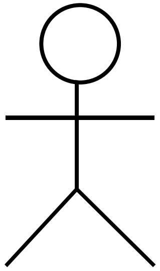
UML Second Pass: Use Case Diagrams



Used during requirements elicitation to represent external behavior

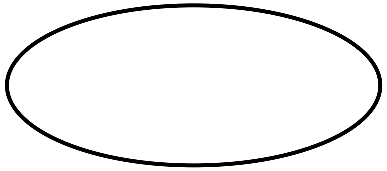
- ***Actors*** represent roles, that is, a type of user of the system
- ***Use cases*** represent a sequence of interaction for a type of functionality
- The use case model is the set of all use cases. It is a complete description of the functionality of the system and its environment

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



PurchaseTicket

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 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.

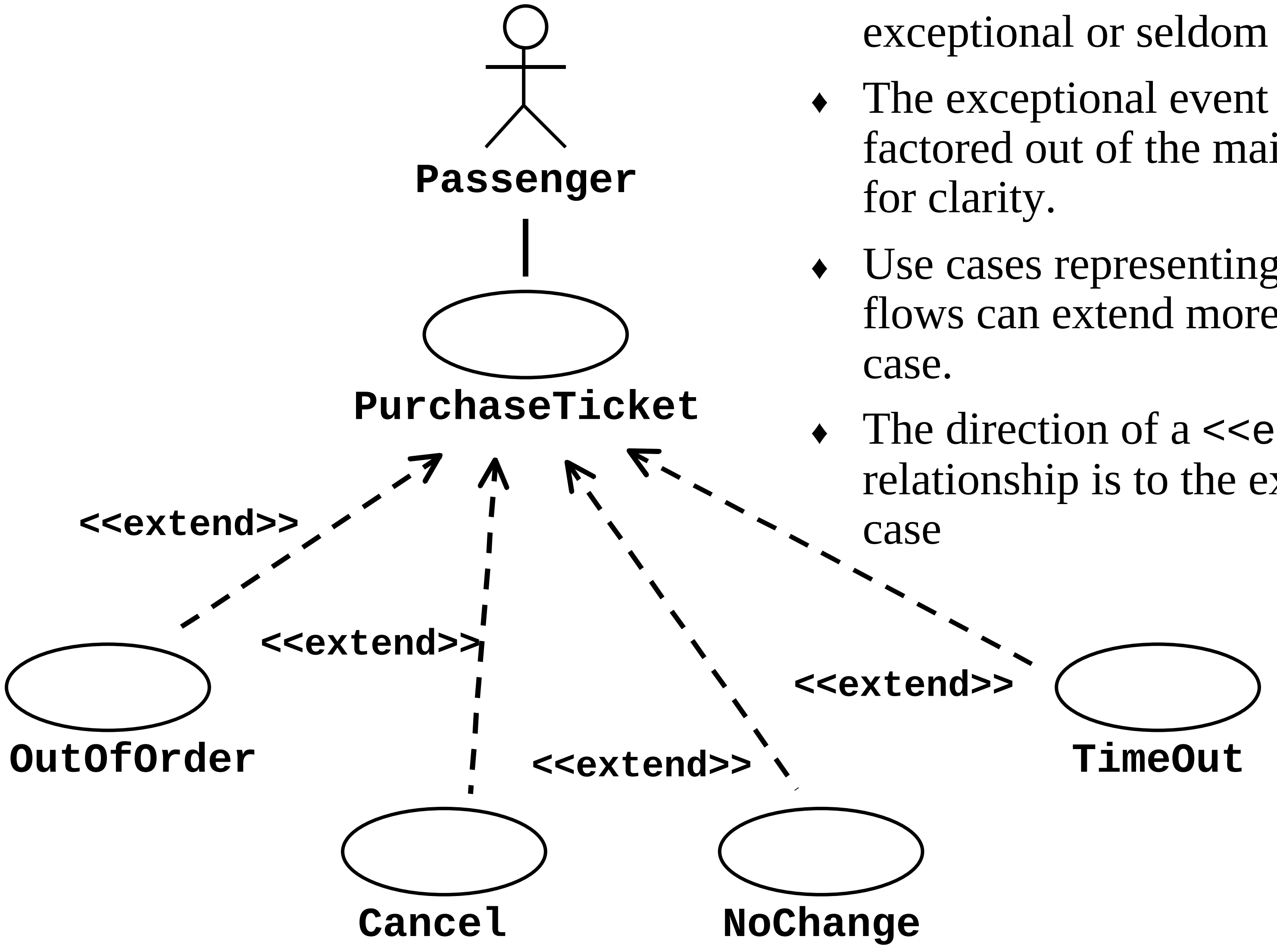
Event flow:

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?

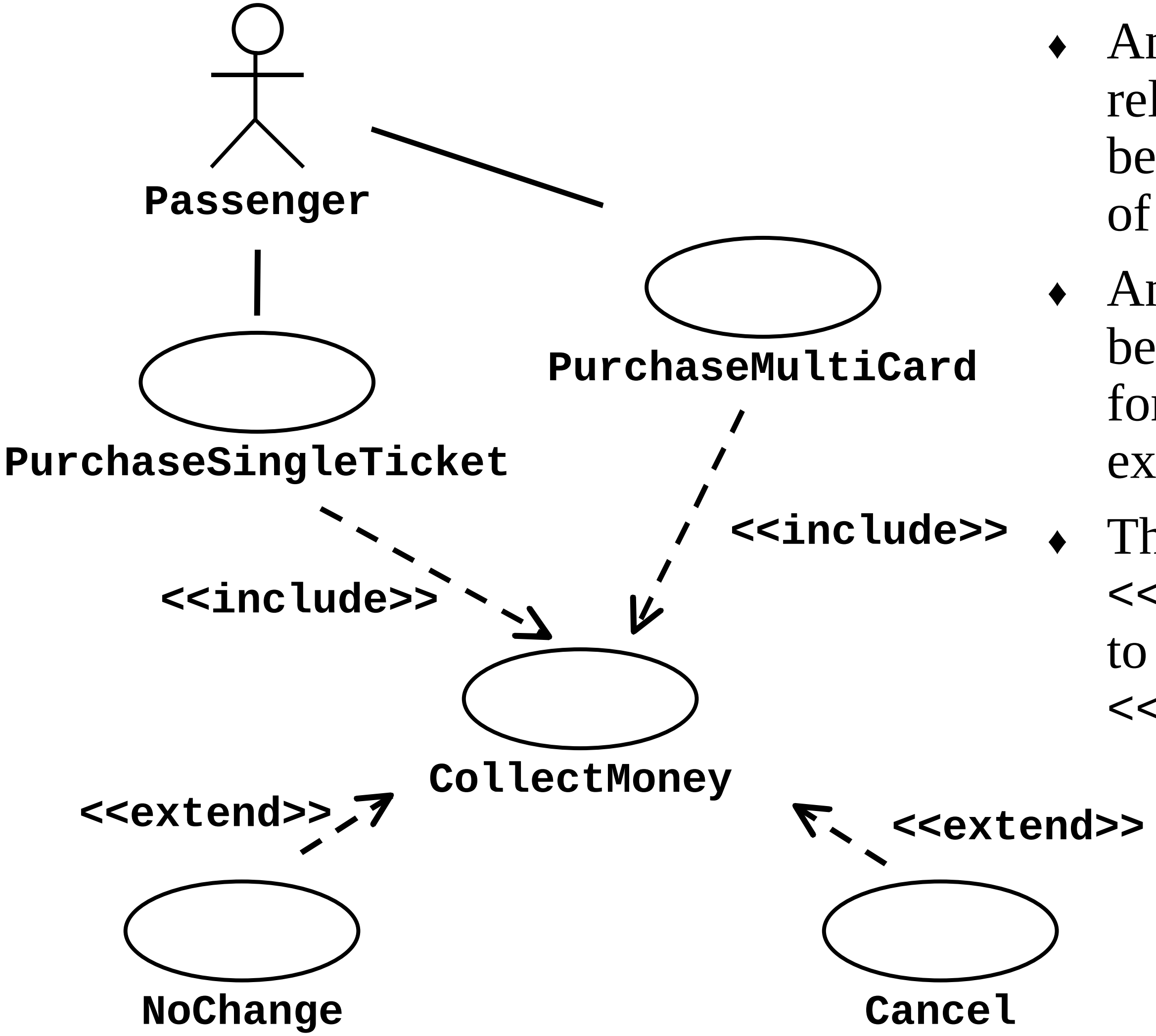
Exceptional cases!

The <<extend>> *Relationship*



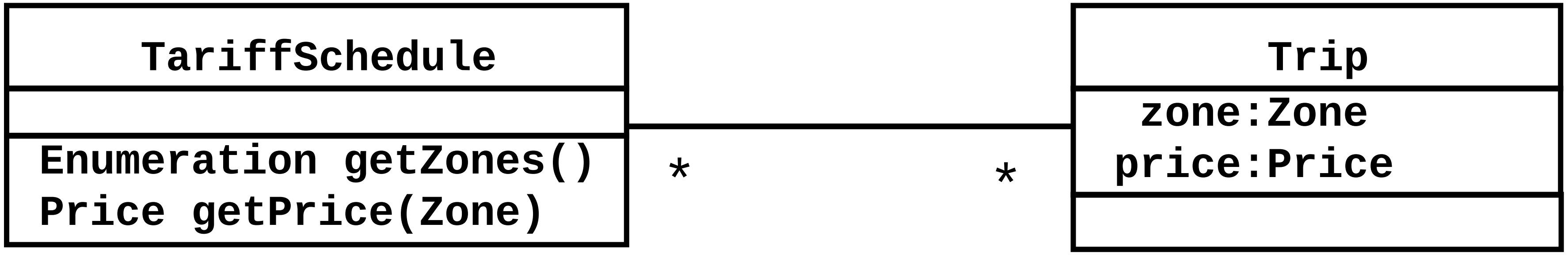
- <<extend>> relationships represent exceptional or seldom invoked cases.
- The exceptional event flows are factored out of the main event flow for clarity.
- Use cases representing exceptional flows can extend more than one use case.
- The direction of a <<extend>> relationship is to the extended use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

The <<include>> Relationship



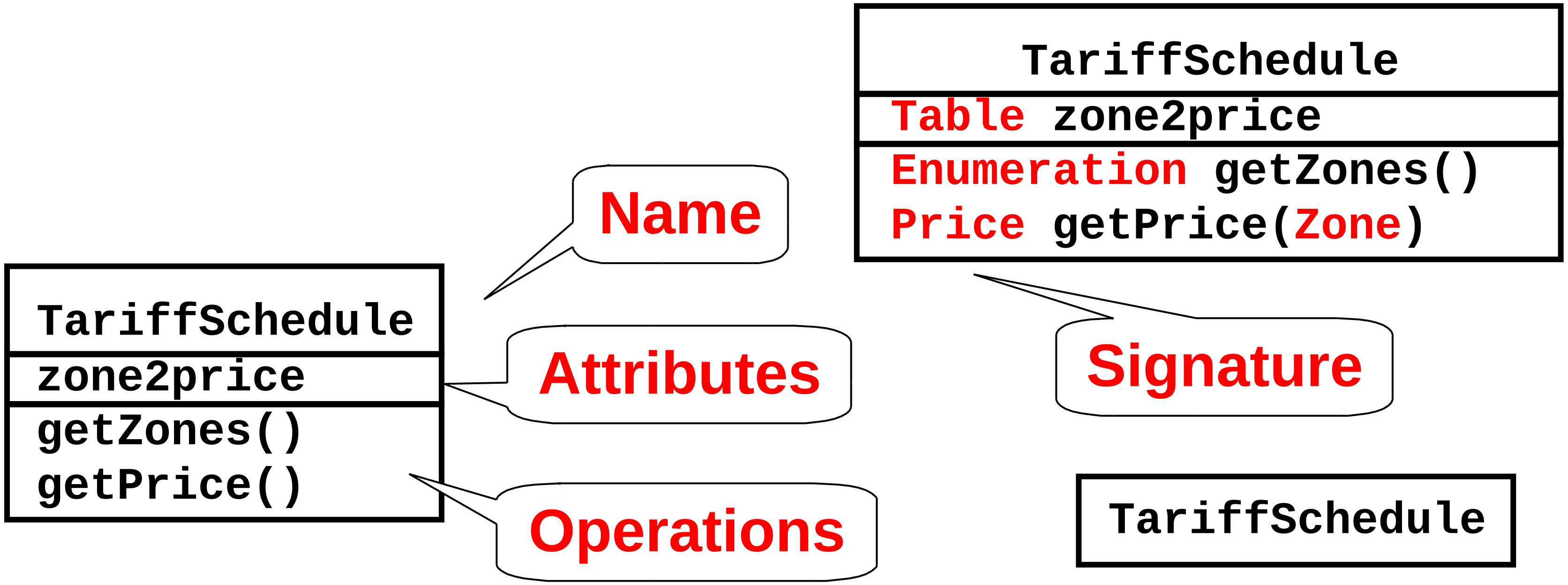
- An `<<include>>` relationship represents behavior that is factored out of the use case.
- An `<<include>>` represents behavior that is factored out for reuse, not because it is an exception.
- The direction of a `<<include>>` relationship is to the using use case (unlike `<<extend>>` relationships).

Class Diagrams



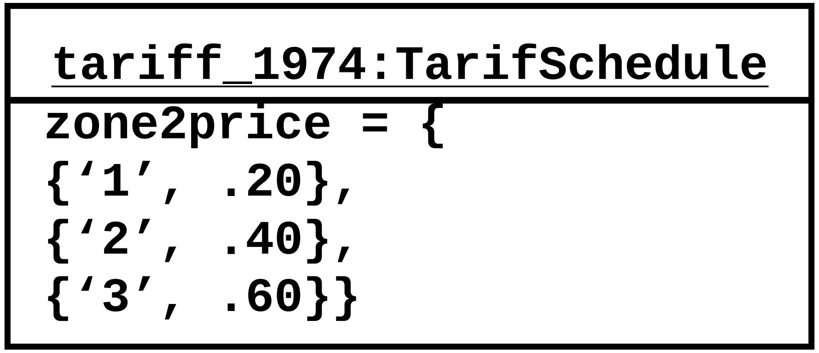
- Class diagrams represent the structure of the system.
- Class diagrams are used
  - **during requirements analysis to model problem domain concepts**
  - **during system design to model subsystems and interfaces**
  - **during object design to model classes.**

Classes



- 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



tariff_1974:TarifSchedule

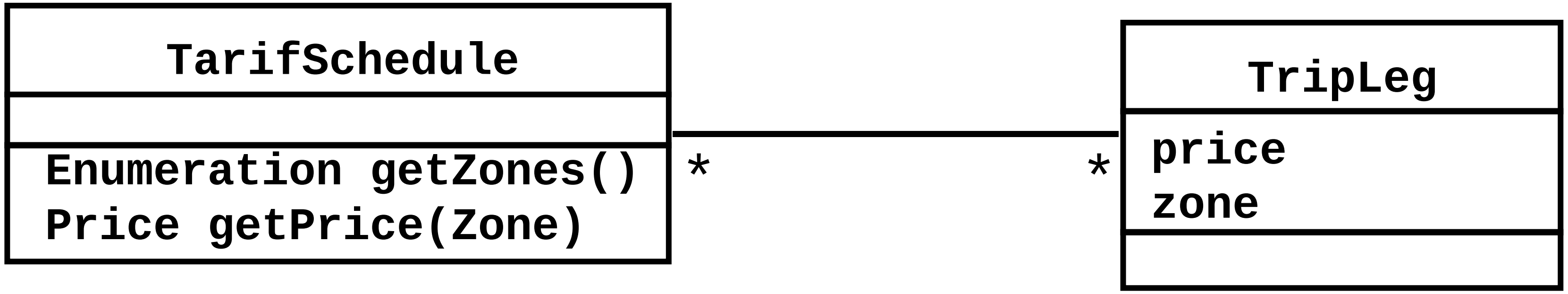
```
zone2price = {
{‘1’, .20},
{‘2’, .40},
{‘3’, .60}}
```

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

Actor vs. Instances

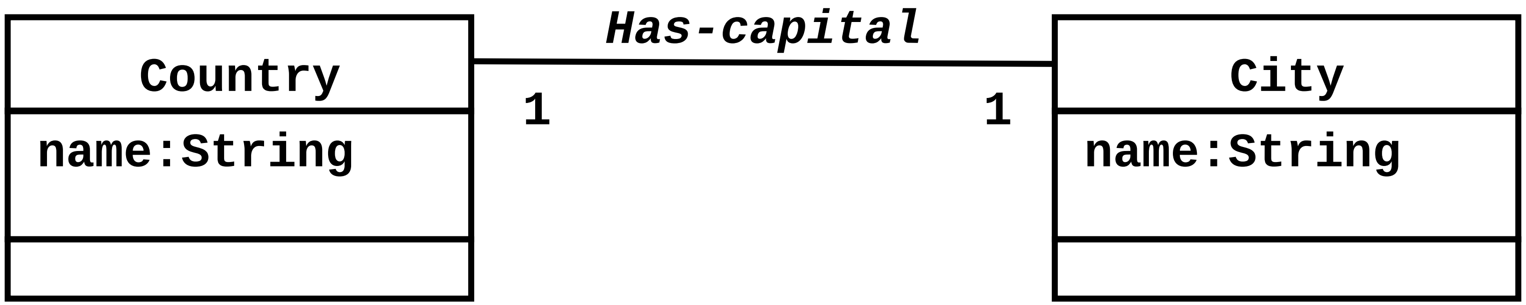
- What is the difference between an actor and a class and an instance?
- Actor:
  - **An entity outside the system to be modeled, interacting with the system (“Pilot”)**
- Class:
  - **An abstraction modeling an entity in the problem domain, inside the system to be modeled (“Cockpit”)**
- Object:
  - **A specific instance of a class (“Joe, the inspector”).**

Associations

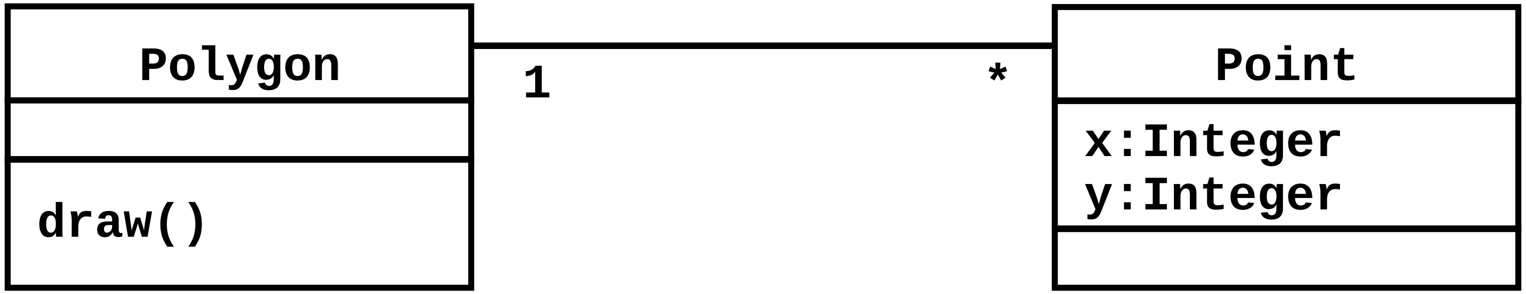


- Associations denote relationships between classes.
- The multiplicity of an association end denotes how many objects the source object can legitimately reference.

1-to-1 and 1-to-Many Associations



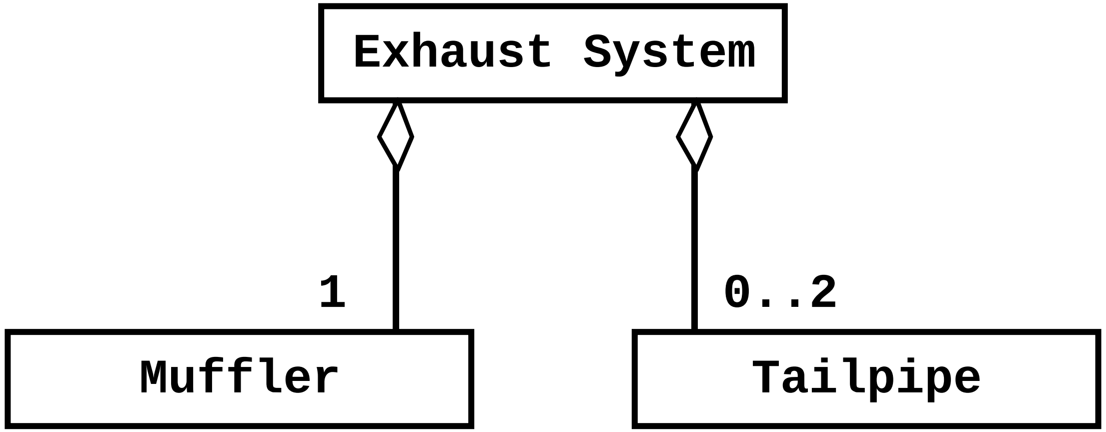
1-to-1 association



1-to-many association

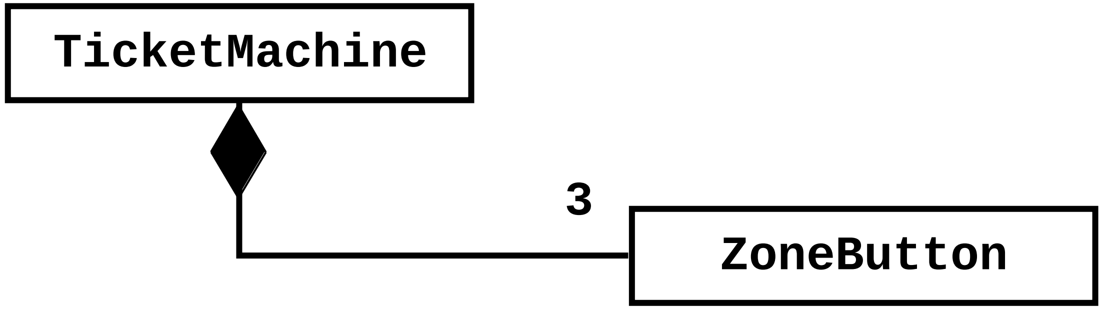
Aggregation

- An ***aggregation*** is a special case of association denoting a “consists of” hierarchy.
- The ***aggregate*** is the parent class, the ***components*** are the children class.

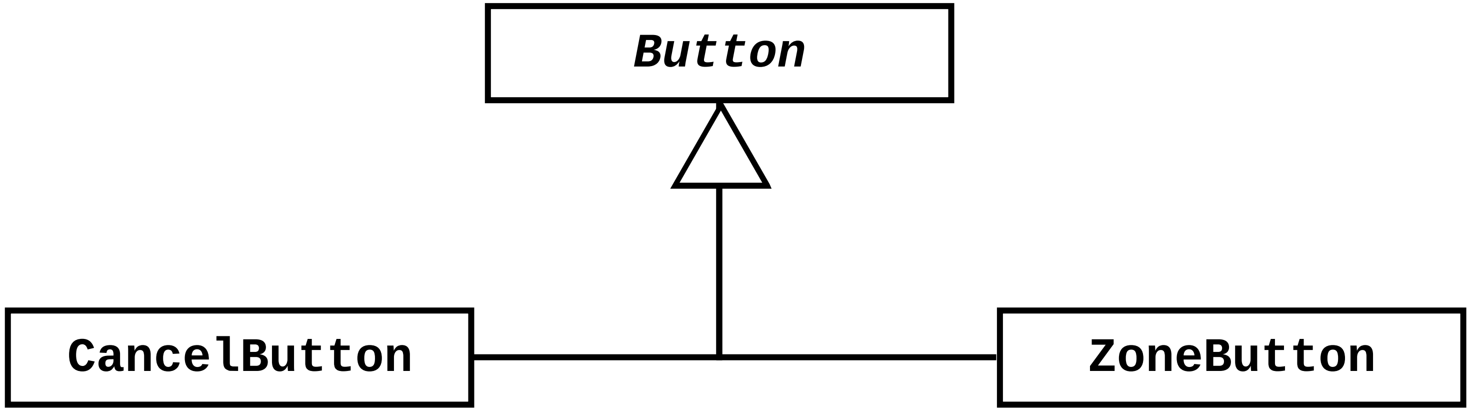


Composition

- A solid diamond denote ***composition***, a strong form of aggregation where components cannot exist without the aggregate.



Generalization



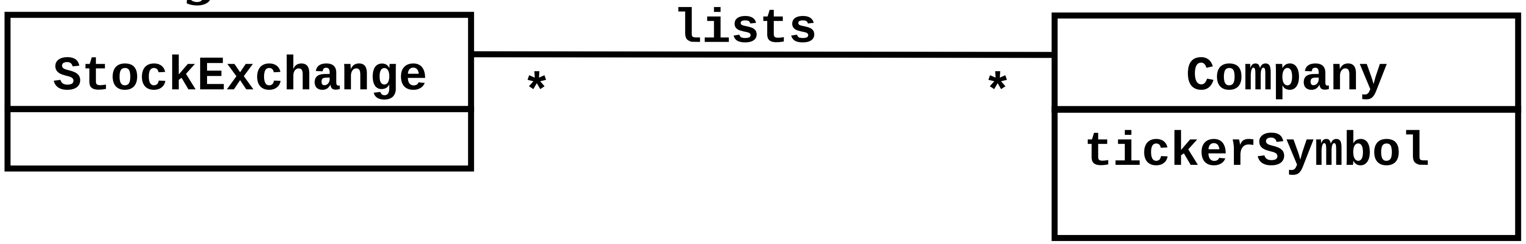
- Generalization relationships denote inheritance between classes.
- The children classes inherit the attributes and operations of the parent class.
- Generalization simplifies the model by eliminating redundancy.

From Problem Statement to Code

Problem Statement

A stock exchange lists many companies. Each company is identified by a ticker symbol

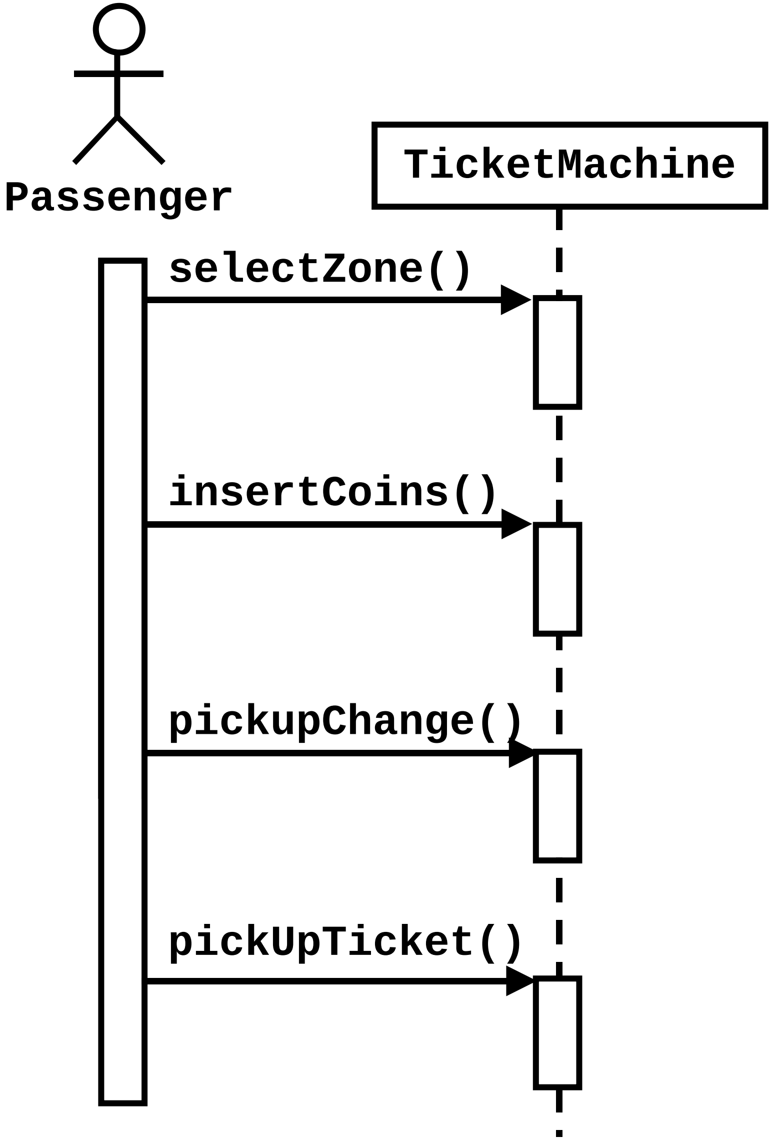
Class Diagram



Java Code

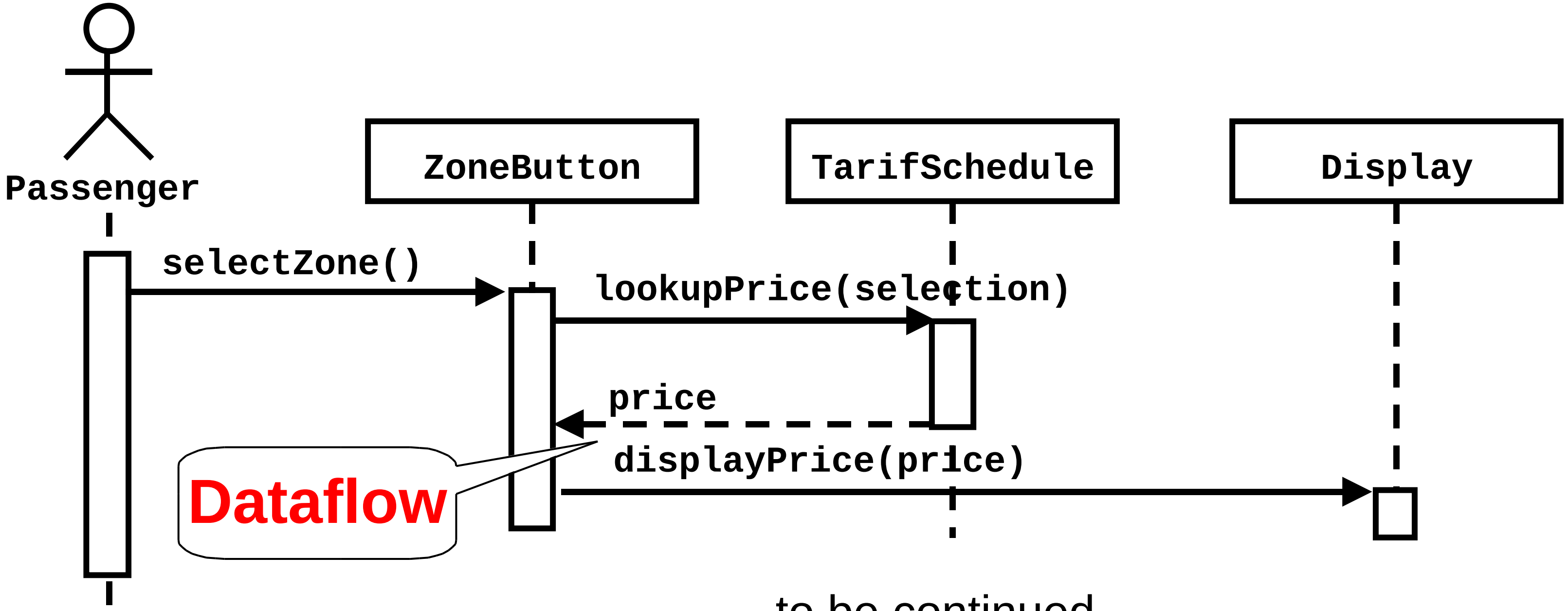
```
public class StockExchange {
    public Vector m_Company = new Vector();
};
public class Company {
    public int m_tickerSymbol;
    public Vector m_StockExchange = new Vector();
};
```

UML Sequence Diagrams



- Used during requirements analysis
  - **To refine use case descriptions**
  - **to find additional objects (“participating objects”)**
- Used during system design
  - **to refine subsystem interfaces**
- ***Classes*** are represented by columns
- ***Messages*** are represented by arrows
- ***Activations*** are represented by narrow rectangles
- ***Lifelines*** are represented by dashed lines

UML Sequence Diagrams: Nested Messages



…to be continued...

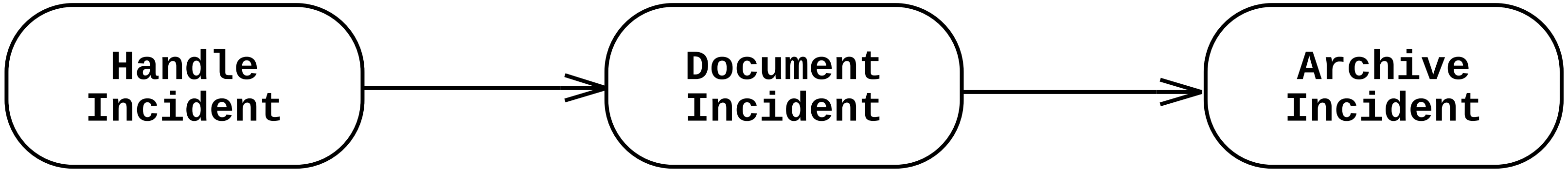
- The source of an arrow indicates the activation which sent the message
- An activation is as long as all nested activations

Sequence Diagram Observations

- UML sequence diagram represent behavior in terms of interactions.
- Complement the class diagrams which represent structure.
- Useful to find participating objects.
- Time consuming to build but worth the investment.

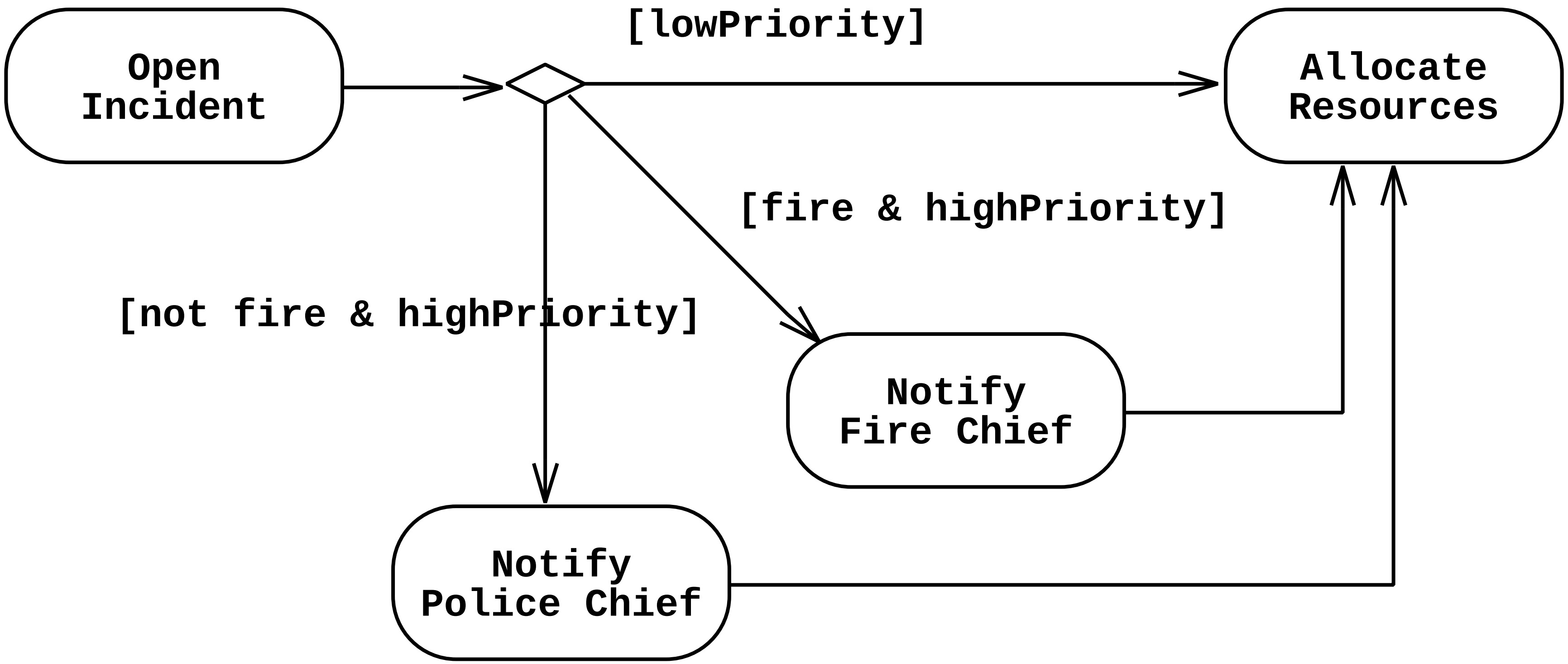
Activity Diagrams

- An activity diagram shows flow control within a system



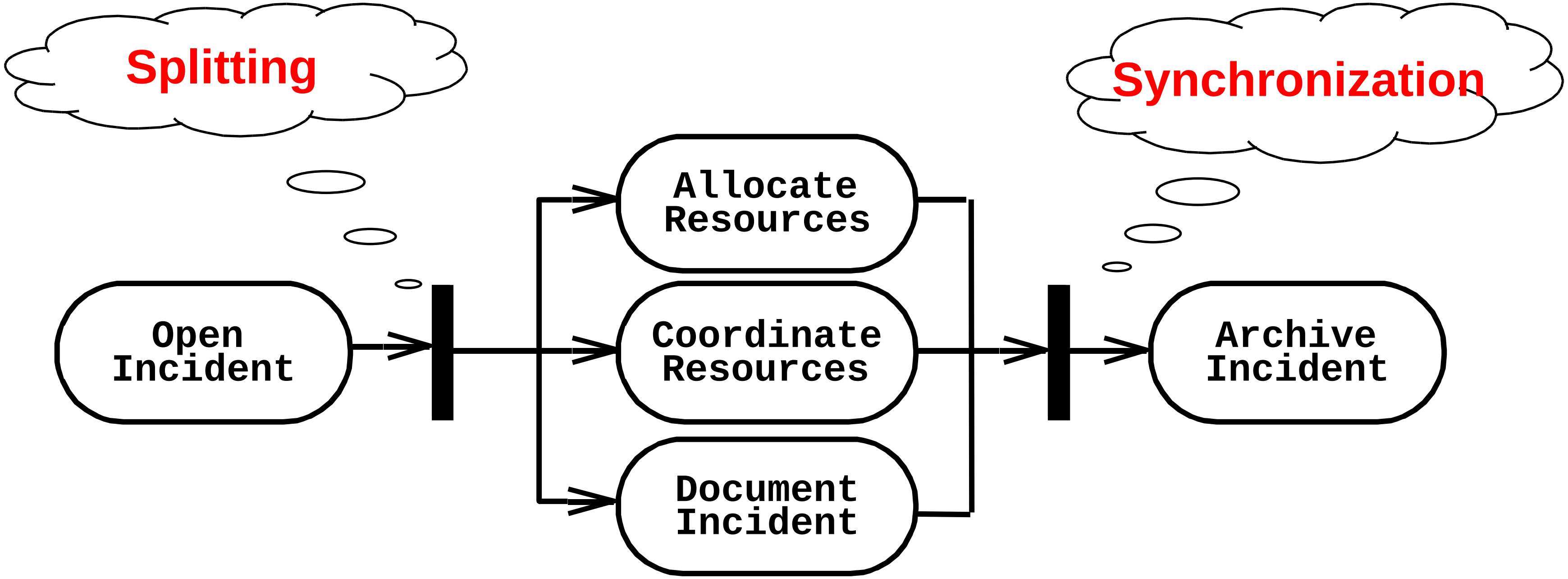
- An activity diagram is a special case of a state chart diagram in which states are activities (“functions”)
- Two types of states:
  - ***Action state:***
    - **Cannot be decomposed any further**
    - **Happens “instantaneously” with respect to the level of abstraction used in the model**
  - ***Activity state:***
    - **Can be decomposed further**
    - **The activity is modeled by another activity diagram**

Activity Diagram: Modeling Decisions



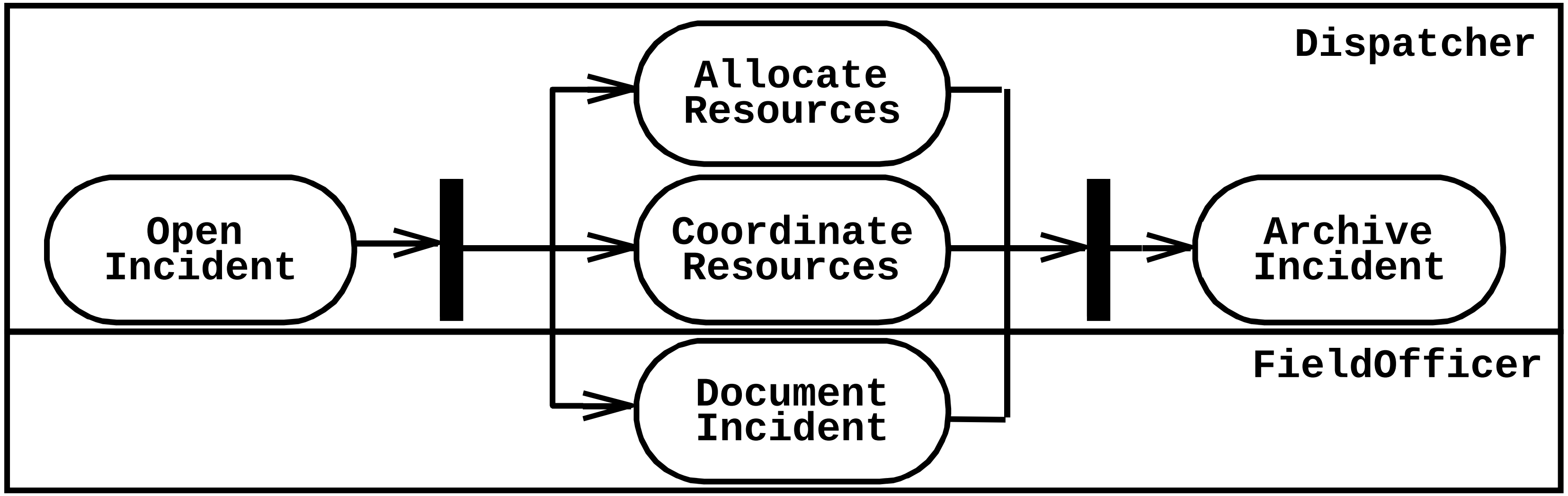
Activity Diagrams: Modeling Concurrency

- Synchronization of multiple activities
- Splitting the flow of control into multiple threads



Activity Diagrams: Swimlanes

- Actions may be grouped into swimlanes to denote the object or subsystem that implements the actions.



Summary

- UML provides a wide variety of notations for representing many aspects of software development
  - **Powerful, but complex language**
  - **Can be misused to generate unreadable models**
  - **Can be misunderstood when using too many exotic features**

- We concentrate only on a few notations:
  - **Functional model: use case diagram**
  - **Object model: class diagram**
  - **Dynamic model: sequence diagrams, statechart and activity diagrams**

Next steps

- UML modeling tool: ***Together/J*** tutorial in November
- UML concepts will be revisited in subsequent lectures.
  - **Requirements lectures: Use case diagrams & Class diagrams**
  - **System design lectures: Deployment diagrams**
  - **Object design lectures: More class diagrams**
  - **...**
- Stay tuned for the Requirements Elicitation lecture