Modeling with UML: Basic Notations

Software Engineering I
Lecture 2
7 November 2006

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Overview

- Odds and Ends
- Modeling
- The UML notation
- Use case diagrams
- Class diagrams
- Sequence diagrams
- Activity diagrams

Odds and Ends (1)

- Reading for this Week:
  - Chapter 1 and 2, Bruegge&Dutoit, Object-Oriented Software Engineering
- **Software Engineering I Portal**
  - http://wwwbruegge.in.tum.de/static/contribute/Lehrstuhl/SoftwareTechnikWiSe05.htm
- **Lectures Slides:**
  - Will be sent to you via e-mail if you are registered for this class.

Lecture Schedule

Always subject to Change!

Tuesdays 12:15-13:45

✓ Oct 24: Introduction

- Oct 31: Modeling with UML
  moved to Nov 7
- Nov 7: Project Organization
  moved to January
- Nov 14: Functional Modeling
- Nov 21: Dynamic Modeling
- Nov 28: Architectural Styles
- Nov 30: Reuse
- Dec 5: No lecture
- Dec 12: Design Patterns
- Dec 19: Object Constraint Language

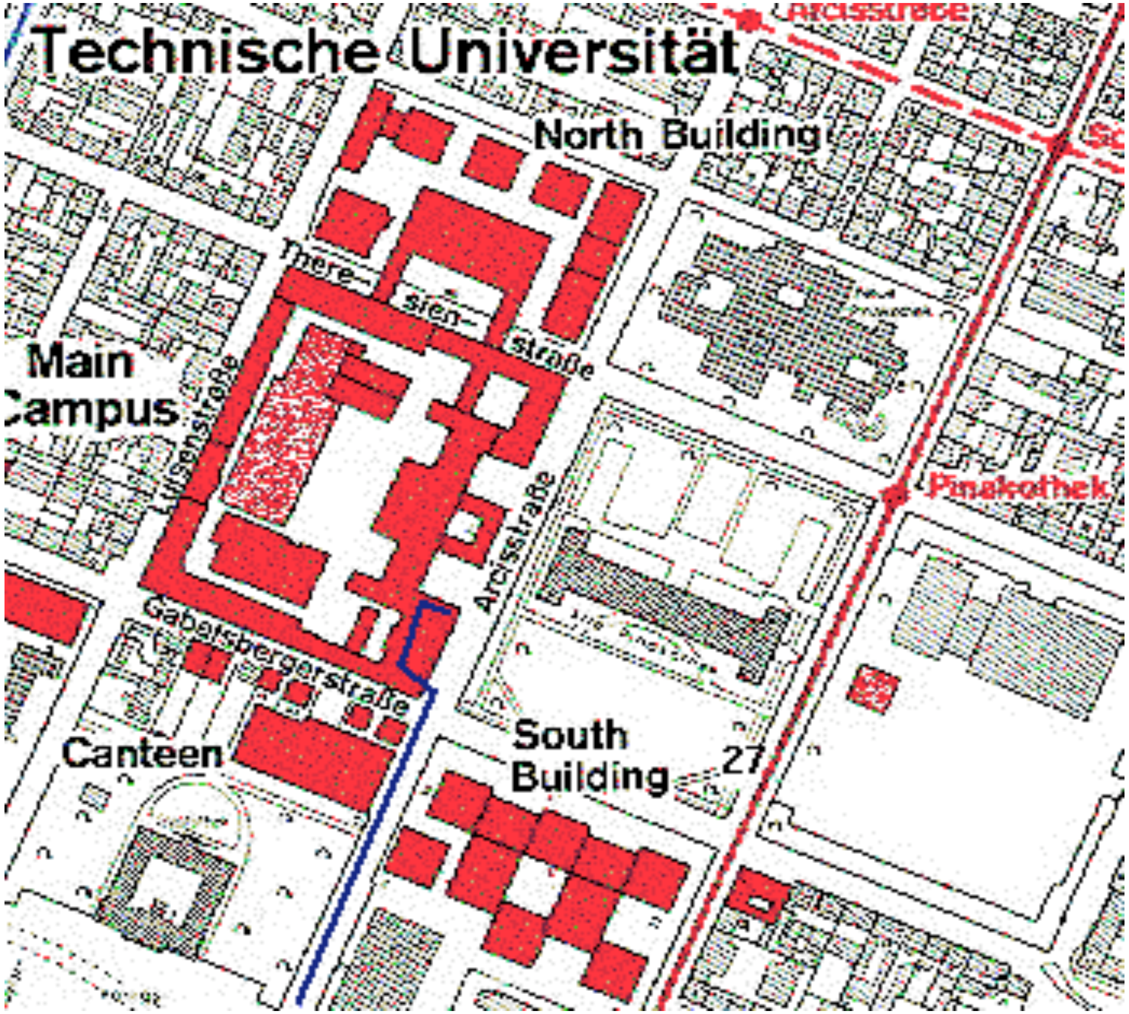
Wednesday 9:15-10:00

- Oct 25: Introduction ctd
- Nov 1: Holiday (Allerheiligen)
- Nov 8: Requirements Elicitation
- Nov 15: Object Modeling
- Nov 22: Design Goals
- Nov 29: Addressing Design Goals
- Dec 6: No lecture
- Dec 13: Interface Specification
- Dec 20: Mid-term

What is modeling?

- Modeling consists of building an abstraction of reality
- Abstractions are simplifications because:
  - They ignore irrelevant details and
  - They only represent the relevant details
- What is relevant or irrelevant depends on the purpose of the model.
- Models can be used for 2 purposes:
  - Gain insight into the past and presence
  - Predict future behavior.

Example of a Model: A Street Map



Why should we model Software?

- Software is used in many appliances and everyday objects
- Software is getting increasingly more complex
  - Windows 2000: ~ 40 millions lines of code
  - A single programmer cannot manage this amount of code in its entirety
- Code is not easily understandable by developers who did not write it
- We need simpler representations for complex systems
  - Modeling is a mean for dealing with complexity.

What is a “good” Model?

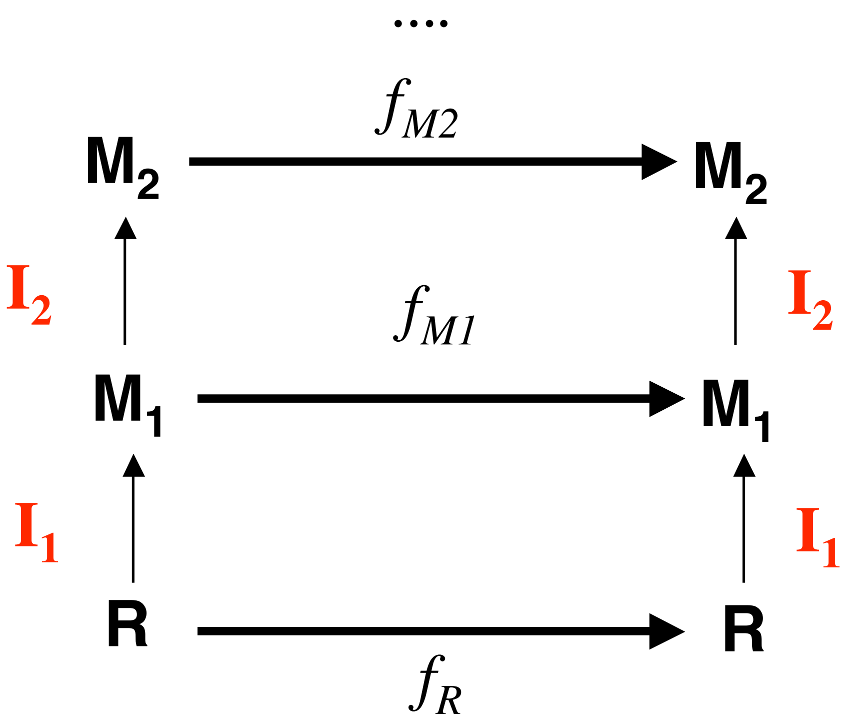
- Interpretation I: Maps entities in R to entities in M
  - f_M: Relationship between entities in M
  - f_R: Relationship between entities in R

- Relationships that are valid in reality R are also valid in the model M.
- For a good model, the following is true:

$$
\begin{tikzcd}
M \arrow[r, "f_M"] & M \\
R \arrow[u, "I"] \arrow[r, "f_R"'] & R \arrow[u, "I"']
\end{tikzcd}
$$

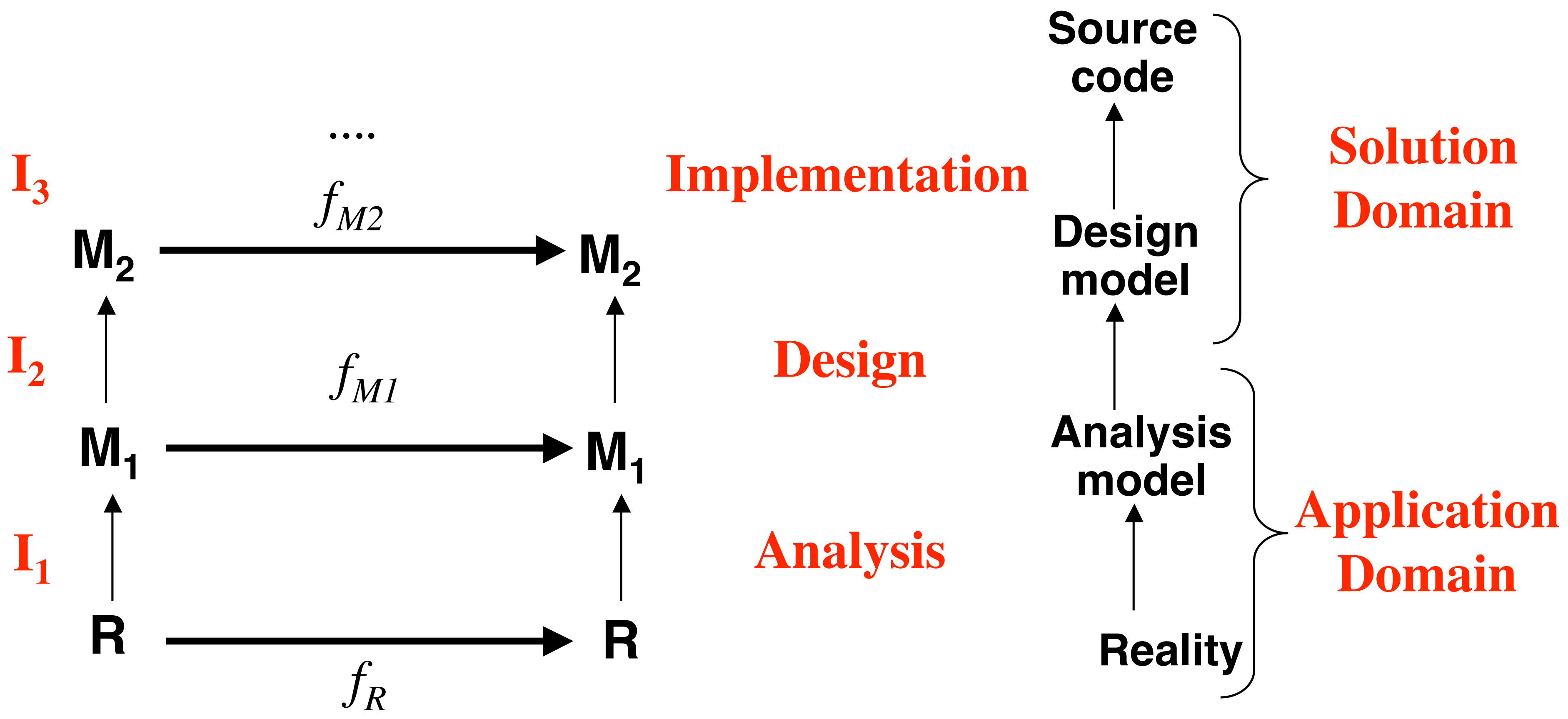
Model of Models of Models...

- Modeling is relative.
  - One can regard a model again as reality and make another model of it (with more abstractions)



The development of software systems can be seen as a sequence of transformations and validations of models: Analysis, System Design, Implementation

Software Development is a Sequence of Transformations



Models must be falsifiable

- Karl Popper ("Objective Knowledge):
  - There is no absolute truth when trying to understand reality
  - One can only build theories, that are "true" until somebody finds a counter example
- Falsification: The act of disproving a theory or hypothesis
- The truth of a theory is never certain. We must use phrases like:
  - "by our best judgement", "using state-of-the-art knowledge"
- In software engineering any model is a theory:
  - We build models and try to find counter examples by:
    - Requirements validation, user interface testing, review of the design, source code testing, system testing, etc.
- Testing: The act of disproving a model.

Concepts and Phenomena

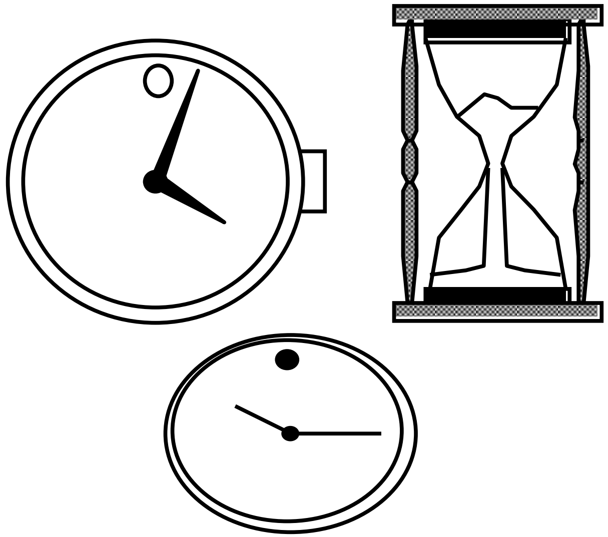
- Phenomenon
  - An object in the world of a domain as you perceive it
    - Examples: This lecture on November 7 at 12:30, my black watch
- Concept
  - Describes the common properties of phenomena
    - Example: All lectures on software engineering
    - Example: All black watches
- A Concept is a 3-tuple:
  - **Name:** The name distinguishes the concept from other concepts
  - **Purpose:** Properties that determine if a phenomenon is a member of a concept
  - **Members:** The set of phenomena which are part of the concept.

Concepts, Phenomena, Abstraction and Modeling

Name | **Purpose** | **Members**

`Watch`

`A device that measures time.`



Definition Abstraction:

- Classification of phenomena into concepts

Definition Modeling:

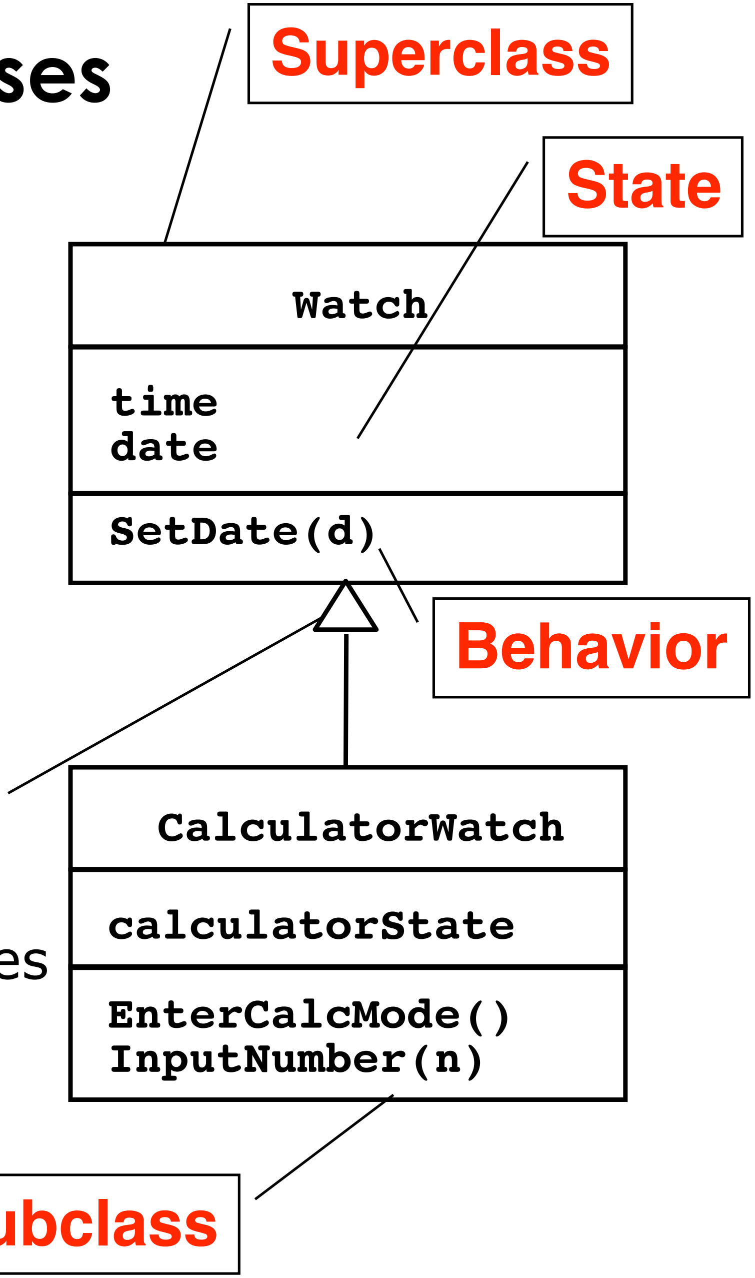
- Development of abstractions to answer specific questions about a set of phenomena while ignoring irrelevant details.

Abstract Data Types & Classes

- **Abstract data type**
  - A type whose implementation is hidden from the rest of the system
- **Class:**
  - An abstraction in the context of object-oriented languages
  - A class encapsulates state and behavior
    - Example: Watch

Unlike abstract data types, subclasses can be defined in terms of other classes using inheritance

- Example: CalculatorWatch



Type and Instance

- Type:
  - An concept 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 of the variable

The following relationships are similar:

Type <-> Variable
Concept <-> Phenomenon
Class <-> Object

Systems

- A *system* is an organized set of communicating parts
  - Natural system: A system whose ultimate purpose is not known
  - Engineered system: A system which is designed and built by engineers for a specific purpose
- The parts of the system can be considered as systems again
  - In this case we call them *subsystems*

Examples of natural systems:

- Universe, earth, ocean

Examples of engineered systems:

- Airplane, watch, GPS

Examples of subsystems:

- Jet engine, battery, satellite.

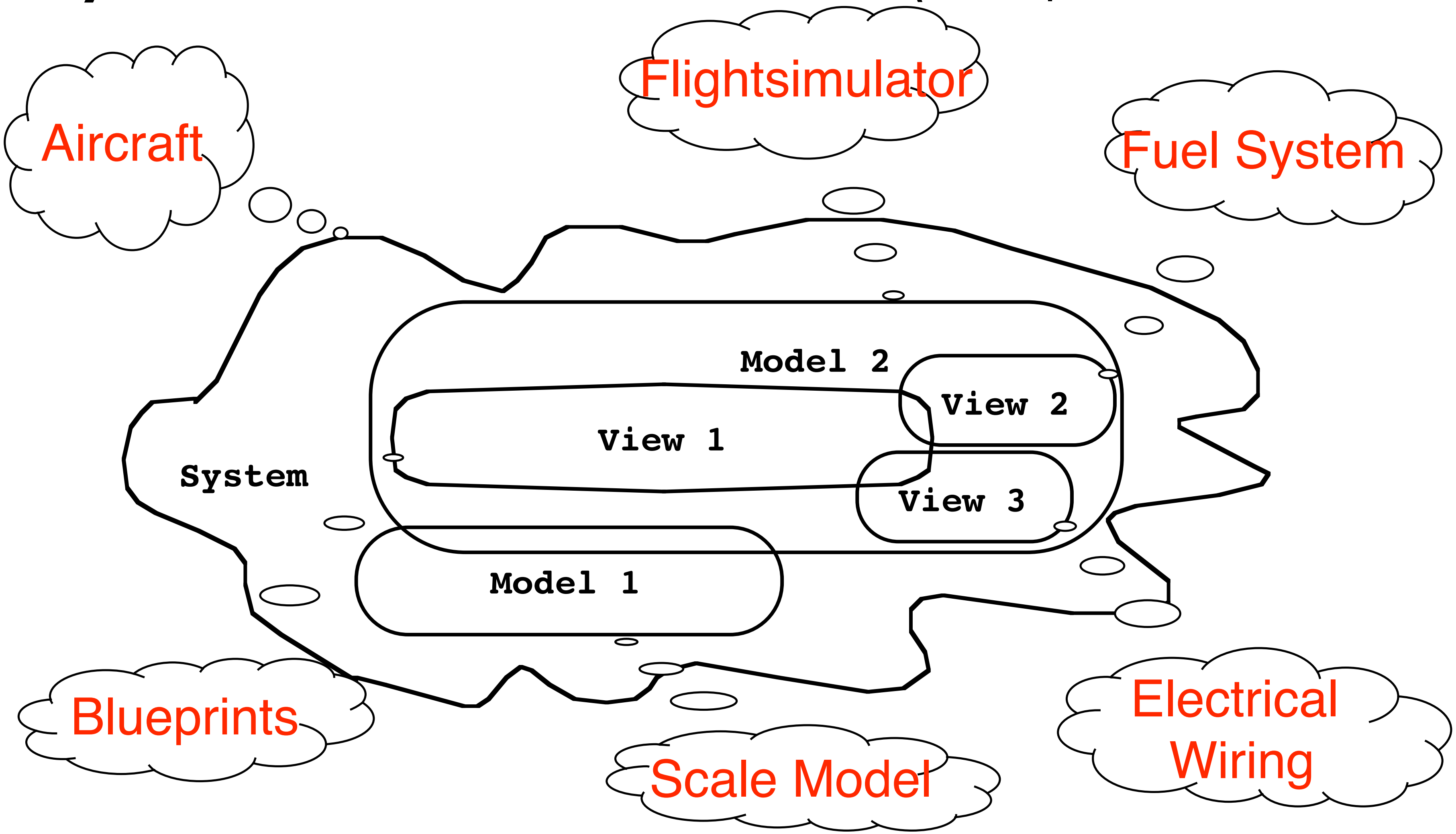
Systems, Models and Views

- A ***model*** is an abstraction describing a system or a subsystem
- A ***view*** depicts selected aspects of a model
- A ***notation*** is a set of graphical or textual rules for depicting models and views: formal notations, “r

System: Airplane

Models:	**Views:**
Flight simulator	Blueprint of
Scale model	Electrical wi
	Fuel system
	Sound wave created by airplane

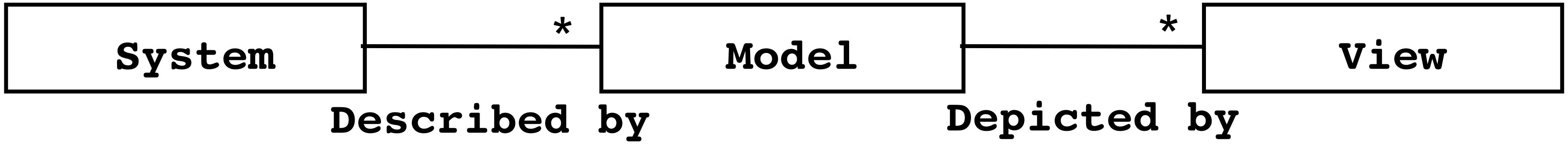
Systems, Models and Views ("Napkin" Notation)

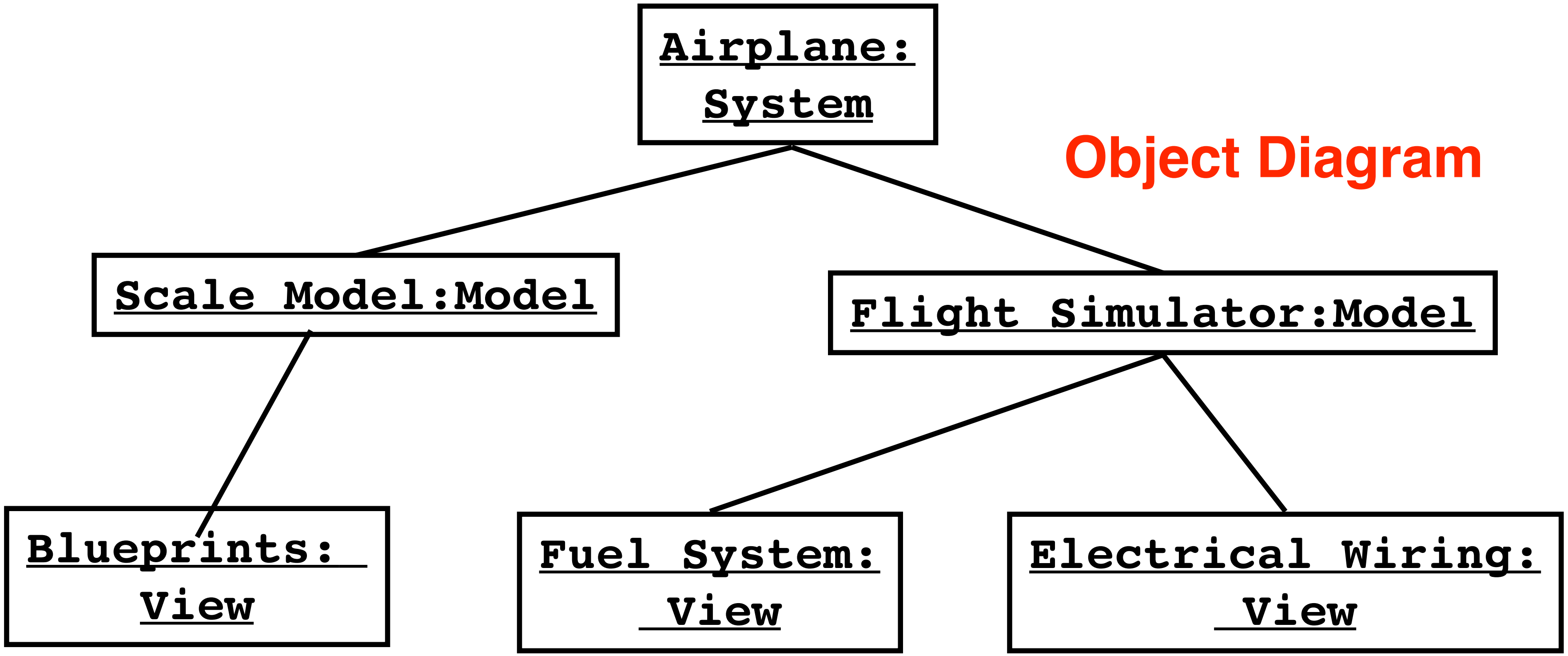


Views and models of a complex system usually overlap

Systems, Models and Views (UML Notation)

Class Diagram





Model-Driven Development

1. Build a platform-independent model of an applications functionality and behavior
   a) Describe model in modeling notation (UML)
   b) Convert model into platform-specific model
2. Generate executable from platform-specific model

Advantages:

- Code is generated from model ("mostly")
- Portability and interoperability

- Model Driven Architecture effort:
  - http://www.omg.org/mda/
- OMG: Object Management Group

Model-driven Software Development

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

Analysis results in analysis object model (UML Class Diagram):

Implementation results in source code (Java):

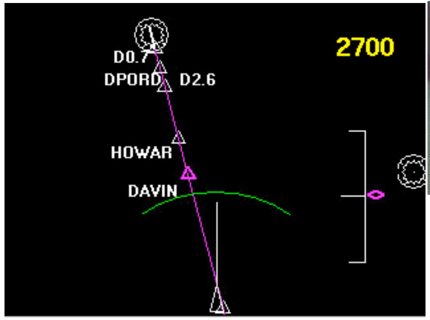
```
public class StockExchange {
    public m_Company = new Vector();
  };
public class Company  {
  public int m_tickerSymbol;
  public Vector m_StockExchange = new Vector();
};
```

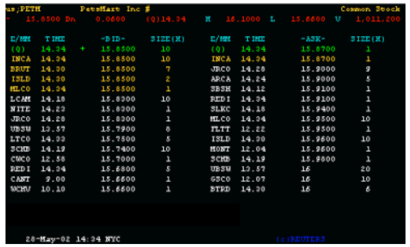
Application vs Solution Domain

- Application Domain (Analysis):
  - The environment in which the system is operating
- Solution Domain (Design, Implementation):
  - The technologies used to build the system
- Both domains contain abstractions that we can use for the construction of the system model.

Object-oriented Modeling

Application Domain
(Phenomena)





Solution Domain
(Phenomena)

System Model (Concepts) *(Analysis)*

UML Package

TrafficControl

Aircraft

TrafficController

Airport

FlightPlan

System Model (Concepts) *(Design)*

MapDisplay

Summary Display

FlightPlanDatabase

TrafficControl

What is UML?

- UML (Unified Modeling Language)
  - Nonproprietary standard for modeling software systems, OMG
  - Convergence of notations used in object-oriented methods
    - OMT (James Rumbaugh and collegues)
    - Booch (Grady Booch)
    - OOSE (Ivar Jacobson)
- Current Version 2.0
  - Information at the OMG portal http://www.uml.org/
- Commercial tools: Rational (IBM),Together (Borland), Visual Architect (business processes, BCD)
- Open Source tools: ArgoUML, StarUML, Umbrello
- Commercial and Opensource: PoseidonUML (Gentleware)

UML: First Pass

- You can model 80% of most problems by using about 20 % UML
- We teach you those 20%

- 80-20 rule: Pareto principle
  - http://www.ephorie.de/hindle_pareto-prinzip.htm

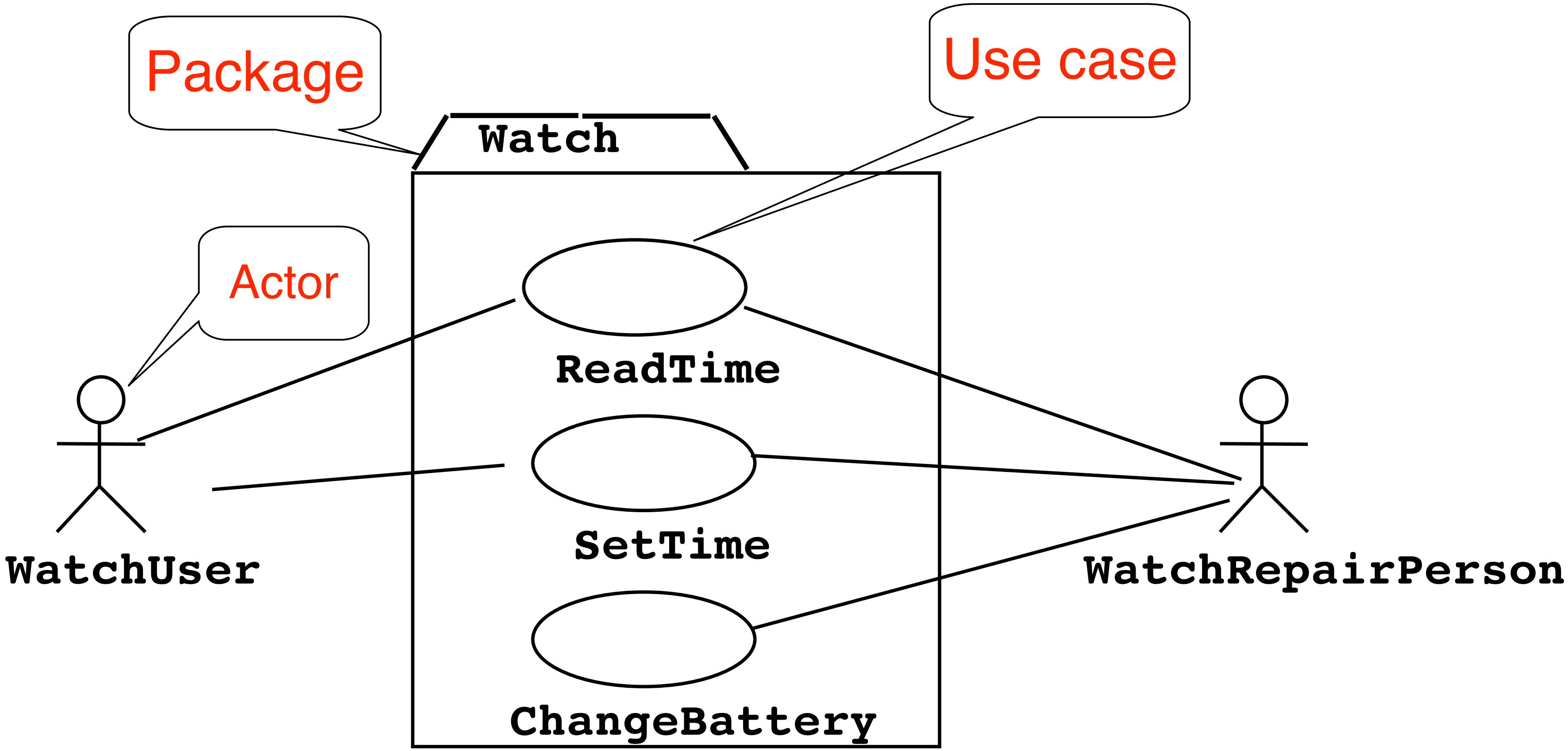
UML First Pass

- 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, associations
- Sequence diagrams
  - Describe the dynamic behavior between objects of the system
- Statechart diagrams
  - Describe the dynamic behavior of an individual object
- Activity diagrams
  - Describe the dynamic behavior of a system, in particular the workflow.

UML Core Conventions

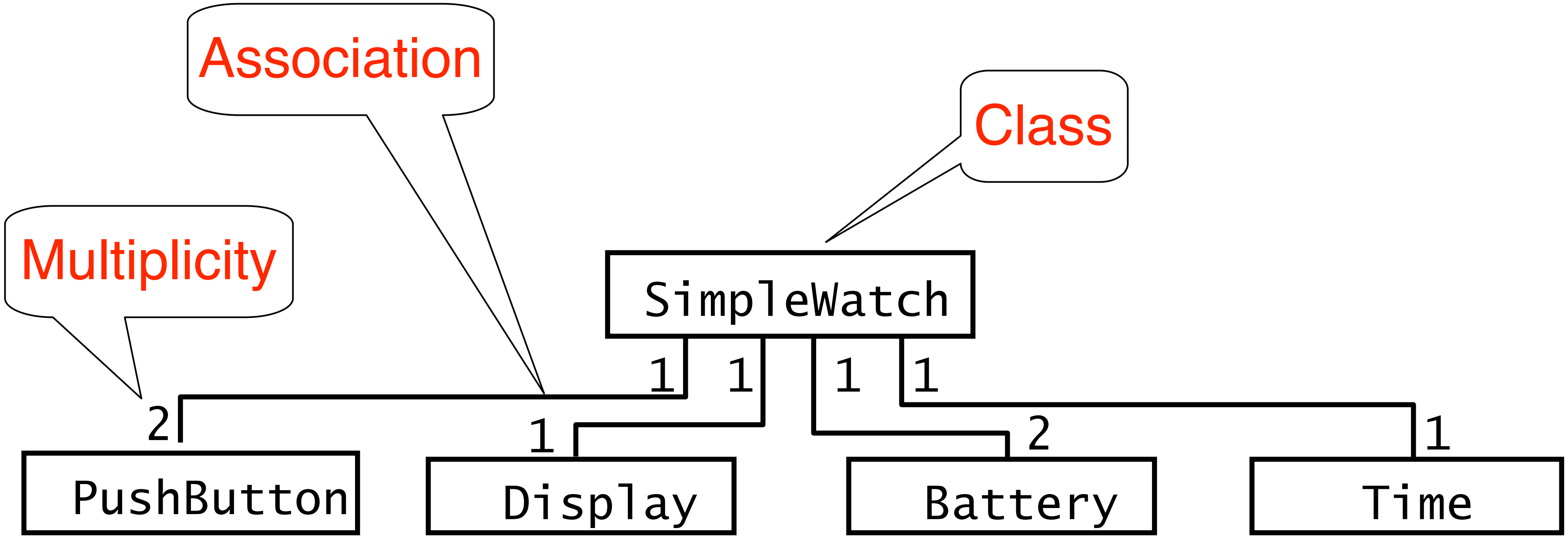
- All UML Diagrams denote graphs of nodes and edges
  - Nodes are entities and drawn as rectangles or ovals
  - Rectangles denote classes or instances
  - Ovals denote functions
- Names of Classes are not underlined
  - `SimpleWatch`
  - `Firefighter`
- Names of Instances are underlined
  - <u>`myWatch:SimpleWatch`</u>
  - <u>`Joe:Firefighter`</u>
- An edge between two nodes denotes a relationship between the corresponding entities

UML first pass: Use case diagrams



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

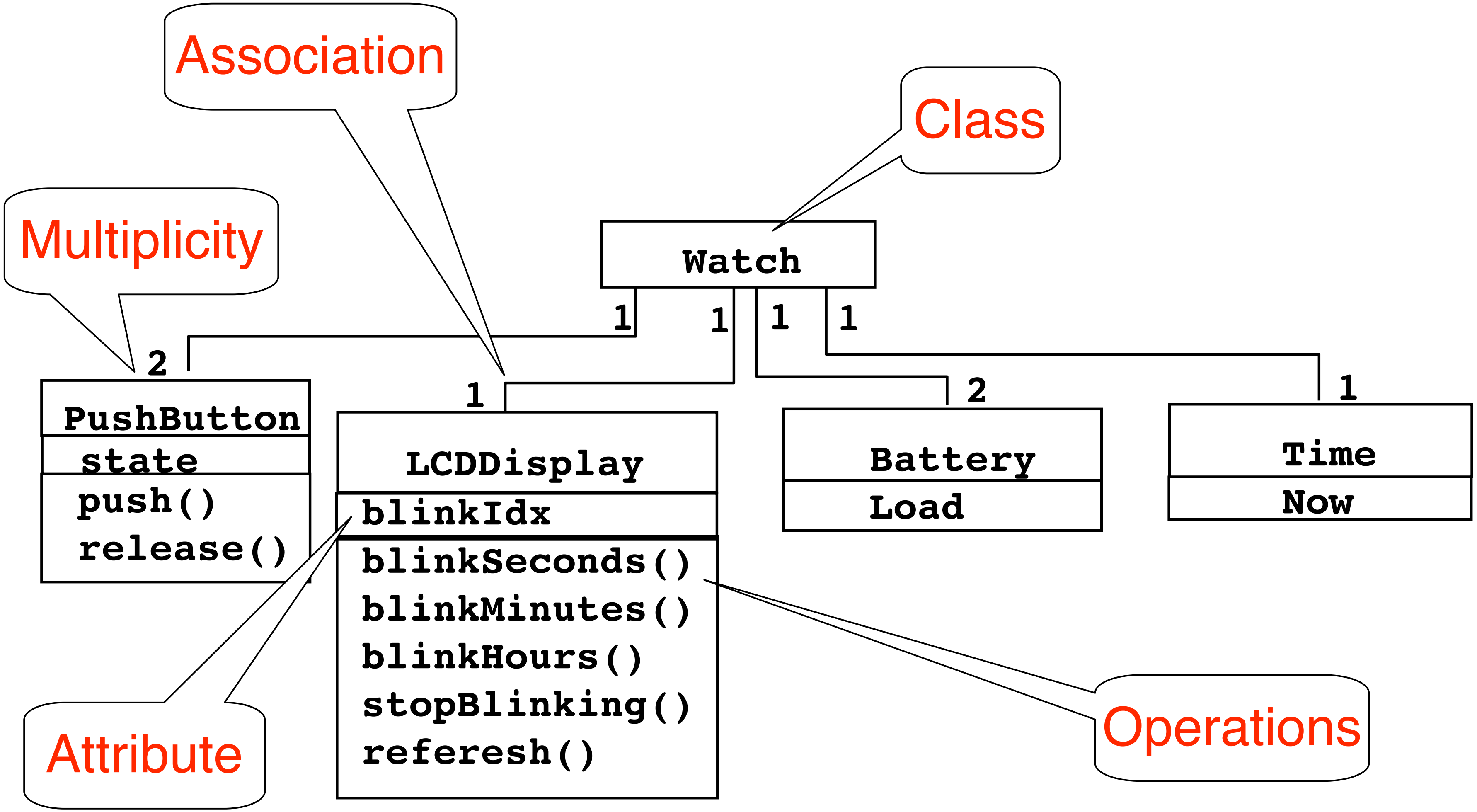
UML first pass: Class diagrams



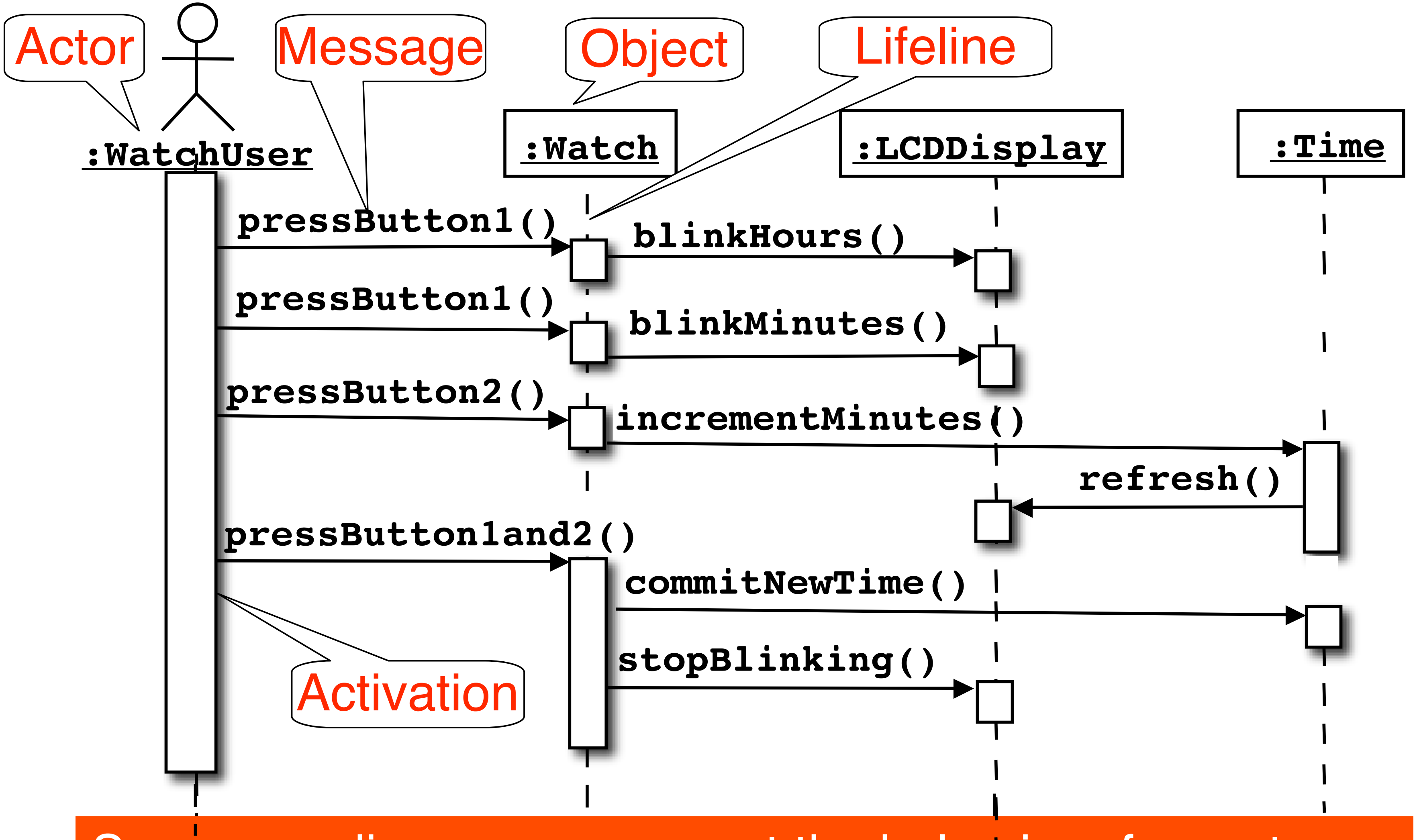
Class diagrams represent the structure of the system

UML first pass: Class diagrams

Class diagrams represent the structure of the system

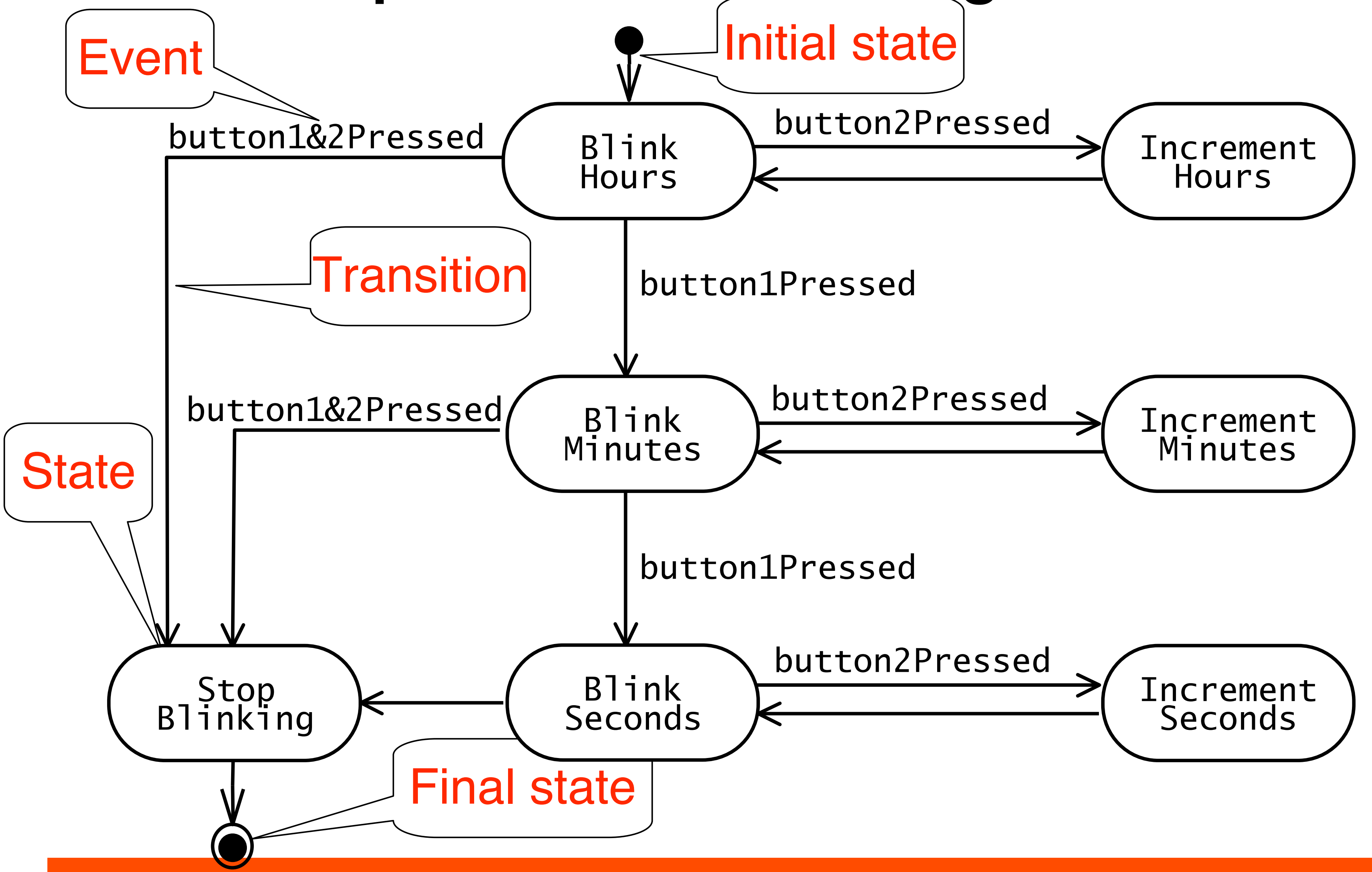


UML first pass: Sequence diagram



Sequence diagrams represent the behavior of a system as messages ("interactions") between *different objects*

UML first pass: Statechart diagrams



Represent behavior of *a single object* with interesting dynamic behavior.

Other UML Notations

UML provides many other notations

- Activity diagrams for modeling work flows
- Deployment diagrams for modeling configurations (for testing and release management)

What should be done first? Coding or Modeling?

- It all depends….
- Forward Engineering
  - Creation of code from a model
  - Start with modeling
  - Greenfield projects
- Reverse Engineering
  - Creation of a model from existing code
  - Interface or reengineering projects
- Roundtrip Engineering
  - Move constantly between forward and reverse engineering
  - Useful when requirements, technology and schedule are changing frequently.

UML Basic Notation Summary

- UML provides a wide variety of notations for modeling many aspects of software systems
- For now we have concentrated on a few notations:
  - Functional model: Use case diagram
  - Object model: Class diagram
  - Dynamic model: Sequence diagrams, statechart

Additional References

- Martin Fowler
  - UML Distilled: A Brief Guide to the Standard Object Modeling Language, 3rd ed., Addison-Wesley, 2003.
- Grady Booch,James Rumbaugh,Ivar Jacobson
  - The Unified Modeling Language User Guide, Addison Wesley, 1999
- Commercial UML tools
  - Rational Rose XDE for Java
    - http://www-306.ibm.com/software/awdtools/developer/java/
  - Together (Eclipse, MS Visual Studio, JBuilder)
    - http://www.borland.com/us/products/together/index.html
- Open Source UML tools
  - http://java-source.net/open-source/uml-modeling
  - ArgoUML,UMLet,Violet, …