Modeling with UML: Basic Notations

Software Engineering I
Lecture 2
18 April 2007

Prof. Bernd Bruegge, Ph.D.
Applied Software Engineering
Technische Universitaet Muenchen

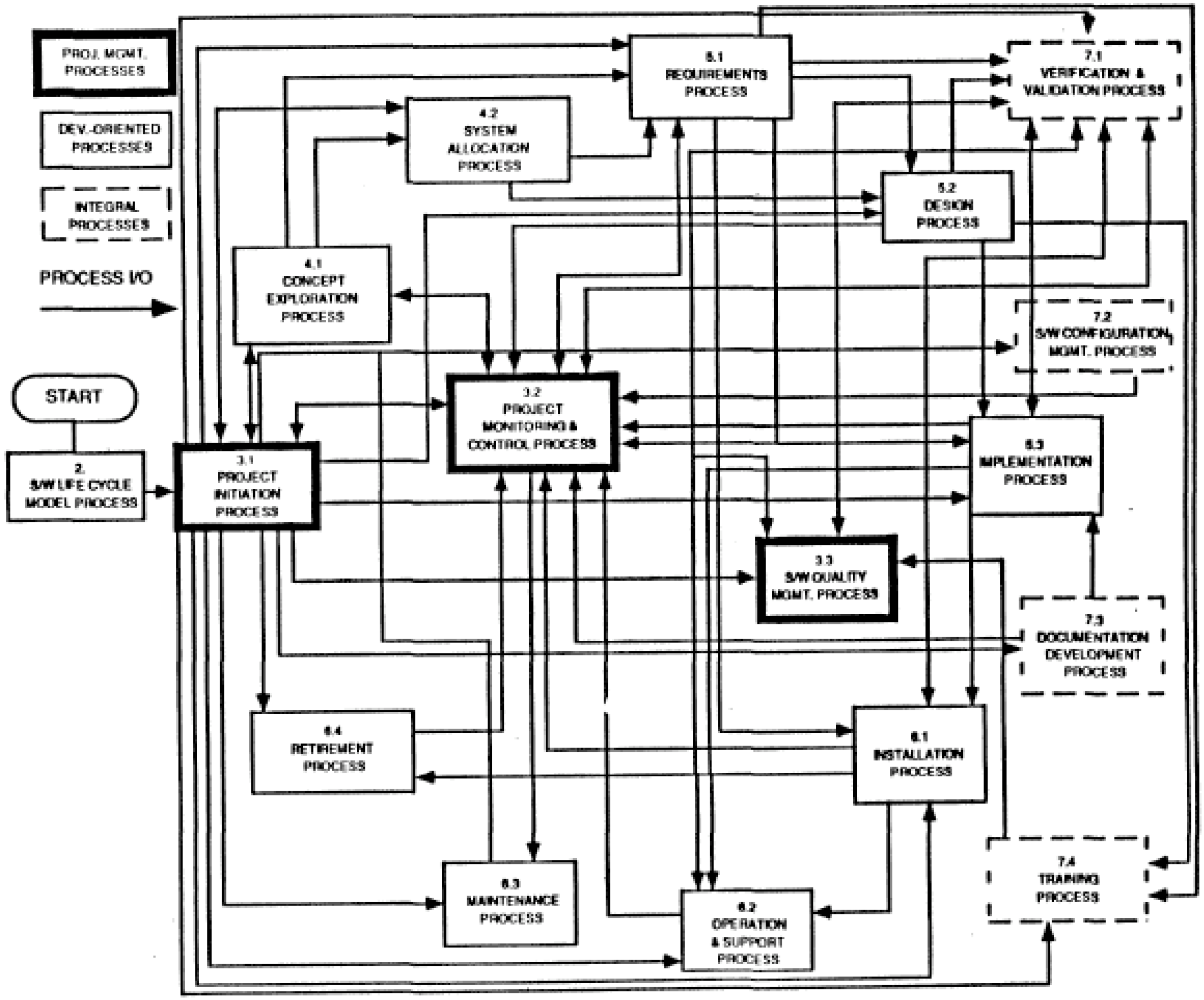
Odds and Ends (1)

- Registration for the Exercises
  - Started yesterday
  - Any problems?
- Deadline for registration
  - Friday, April 20 at 12:00
- First group meeting:
  - Monday, April 23 at 10:00

Odds and Ends (2)

- Reading for this Week:
  - Chapter 1 and 2, Bruegge&Dutoit, Object-Oriented Software Engineering
- **Software Engineering I Portal**
  - http://wwwbruegge.in.tum.de/twiki/bin/view/Lehrstuhl/SoftwareEngineeringSoSe2007
- **Lectures Slides:**
  - Will be posted after each lecture.

Overview for the Lecture



Overview for the Lecture

- Three ways to deal with complexity
  - Abstraction and Modeling
  - Decomposition
  - Hierarchy
- Introduction into the UML notation
- First pass on:
  - Use case diagrams
  - Class diagrams
  - Sequence diagrams
  - Statechart diagrams
  - Activity diagrams

Abstraction

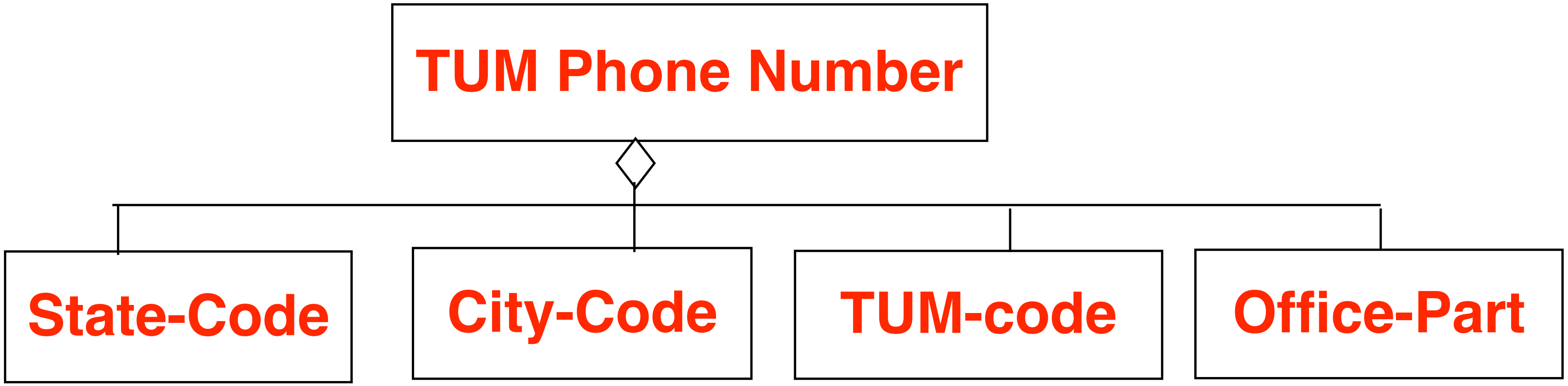
- Complex systems are hard to understand
  - The 7 +- 2 phenomena
    - Our short term memory cannot store more than 7+-2 pieces at the same time -> limitation of the brain
    - TUM Phone Number: 498928918204

Abstraction

- Complex systems are hard to understand
  - The 7 +- 2 phenomena
    - Our short term memory cannot store more than 7+-2 pieces at the same time -> limitation of the brain
    - TUM Phone Number: 498928918204
- Chunking:
    - Group collection of objects to reduce complexity
    - 4 chunks:
      - State-code, city-code, TUM-code, Office-Part

Abstraction

- Complex systems are hard to understand
  - The 7 +- 2 phenomena
    - Our short term memory cannot store more than 7+-2 pieces at the same time -> limitation of the brain
    - TUM Phone Number: 498928918204
- Chunking:
    - Group collection of objects to reduce complexity
    - State-code, city-code, TUM-code, Office-Part



Abstraction

- Abstraction allows us to ignore unessential details
- Two definitions for abstraction:
  - Abstraction is a *thought process* where ideas are distanced from objects
    - **Abstraction as activity**
  - Abstraction is the *resulting idea* of a thought process where an idea has been distanced from an object
    - **Abstraction as entity**
- Ideas can be expressed by models

Model

- A model is an abstraction of a system
  - A system that no longer exists
  - An existing system
  - A future system to be built.

We use Models to describe Software Systems

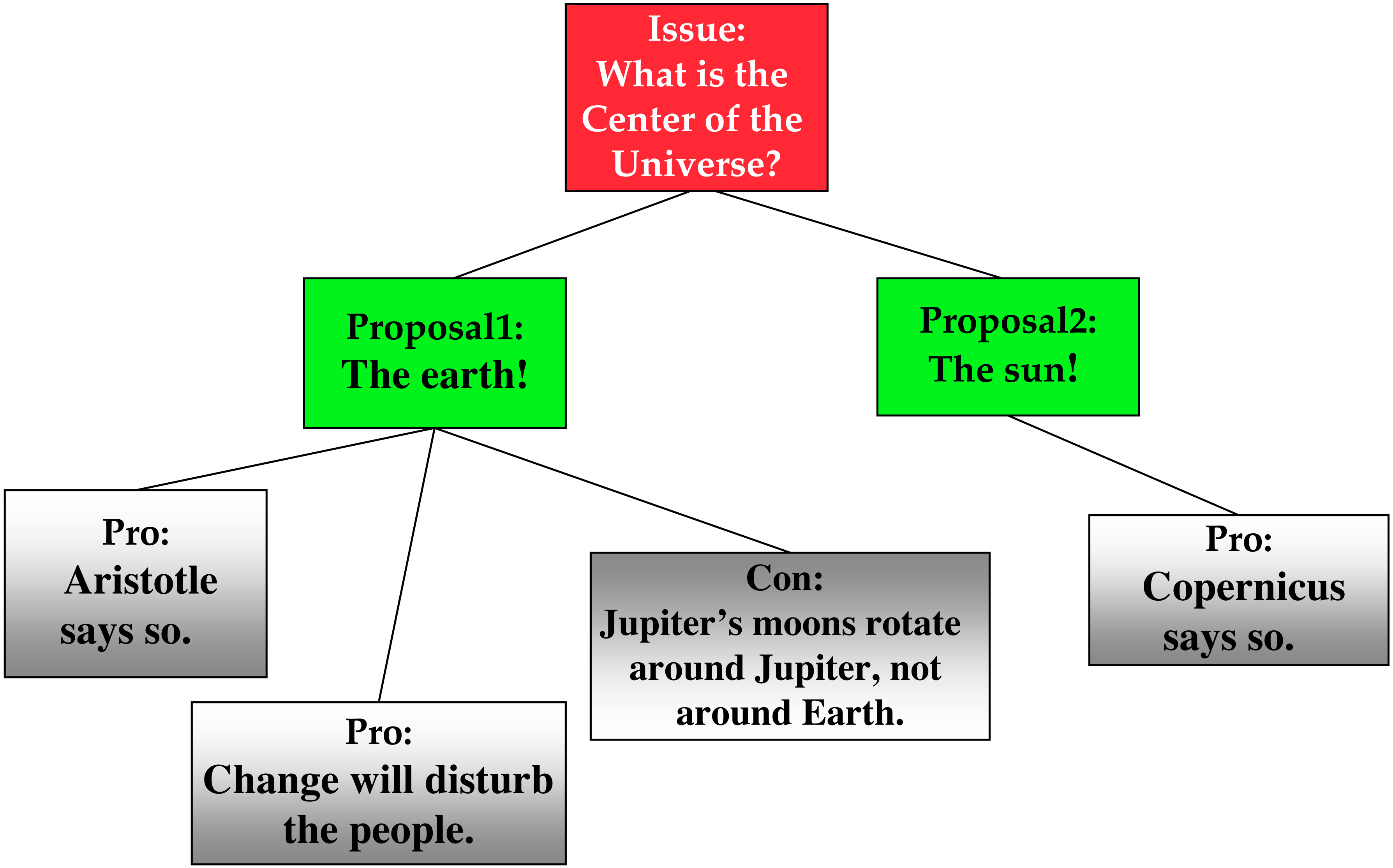
- Object model: What is the structure of the system?
- Functional model: What are the functions of the system?
- Dynamic model: How does the system react to external events?

- System Model: Object model + functional model + dynamic model

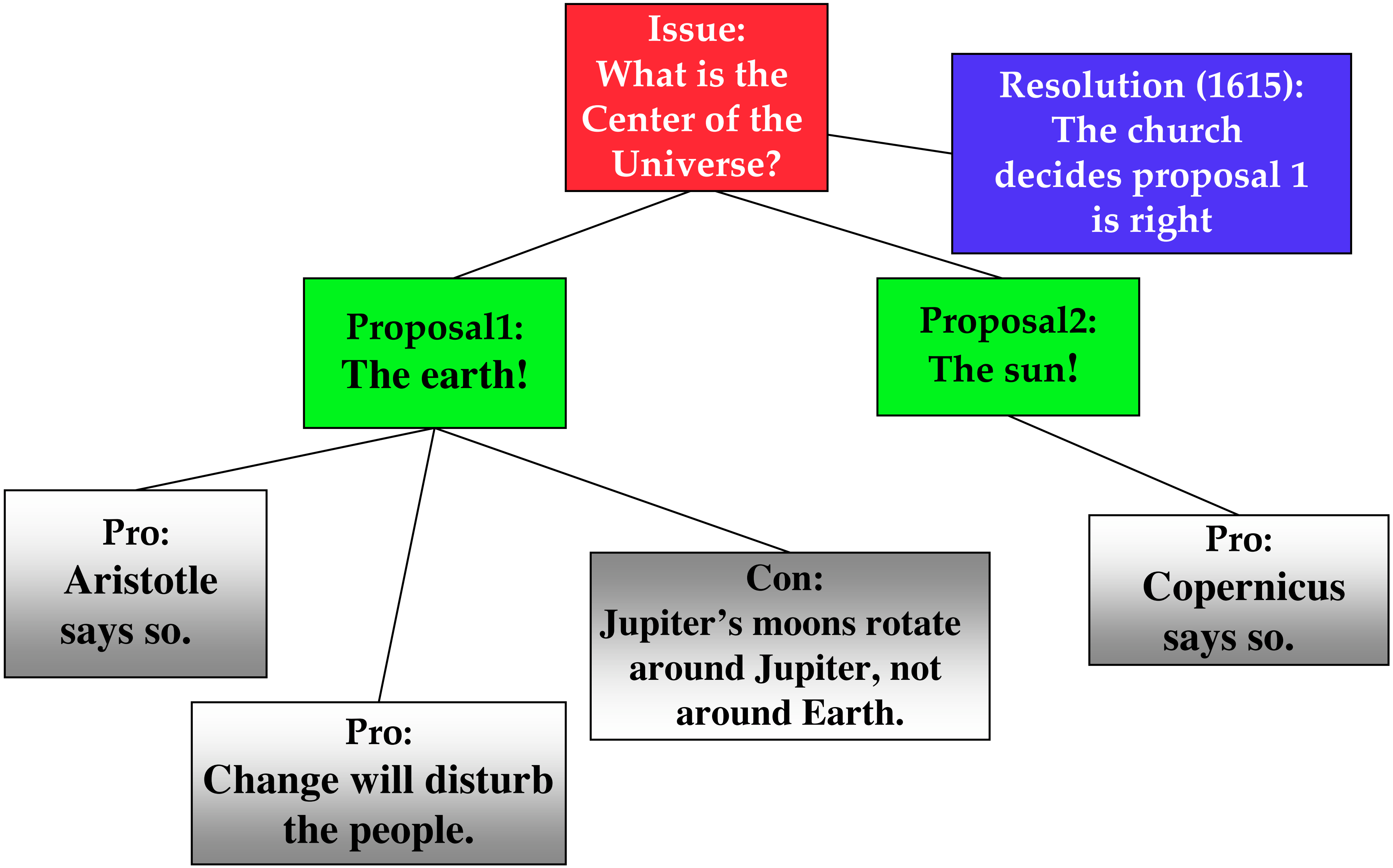
Other models used to describe Software System Development

- Task Model:
  - PERT Chart: What are the dependencies between tasks?
  - Schedule: How can this be done within the time limit?
  - Organization Chart: What are the roles in the project?
- Issues Model:
  - What are the open and closed issues?
    - What blocks me from continuing?
  - What constraints were imposed by the client?
  - What resolutions were made?
    - These lead to action items

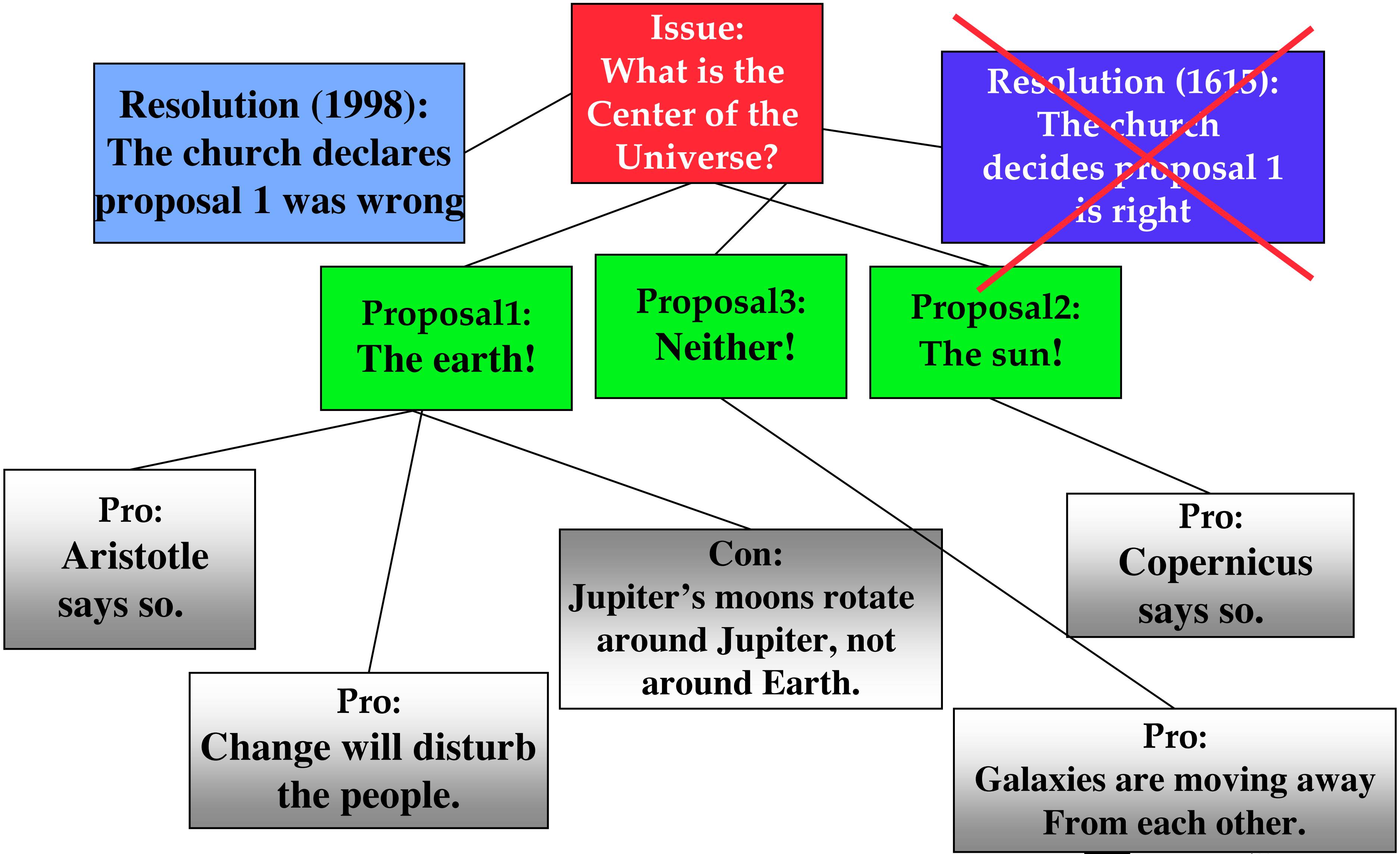
Issue-Modeling



Issue-Modeling



Issue-Modeling



2. Technique to deal with Complexity: Decomposition

- A technique used to master complexity ("divide and conquer")
- Two major types of decomposition
  - Functional decomposition
  - Object-oriented decomposition
- Functional decomposition
  - The system is decomposed into modules
  - Each module is a major function in the application domain
  - Modules can be decomposed into smaller modules.

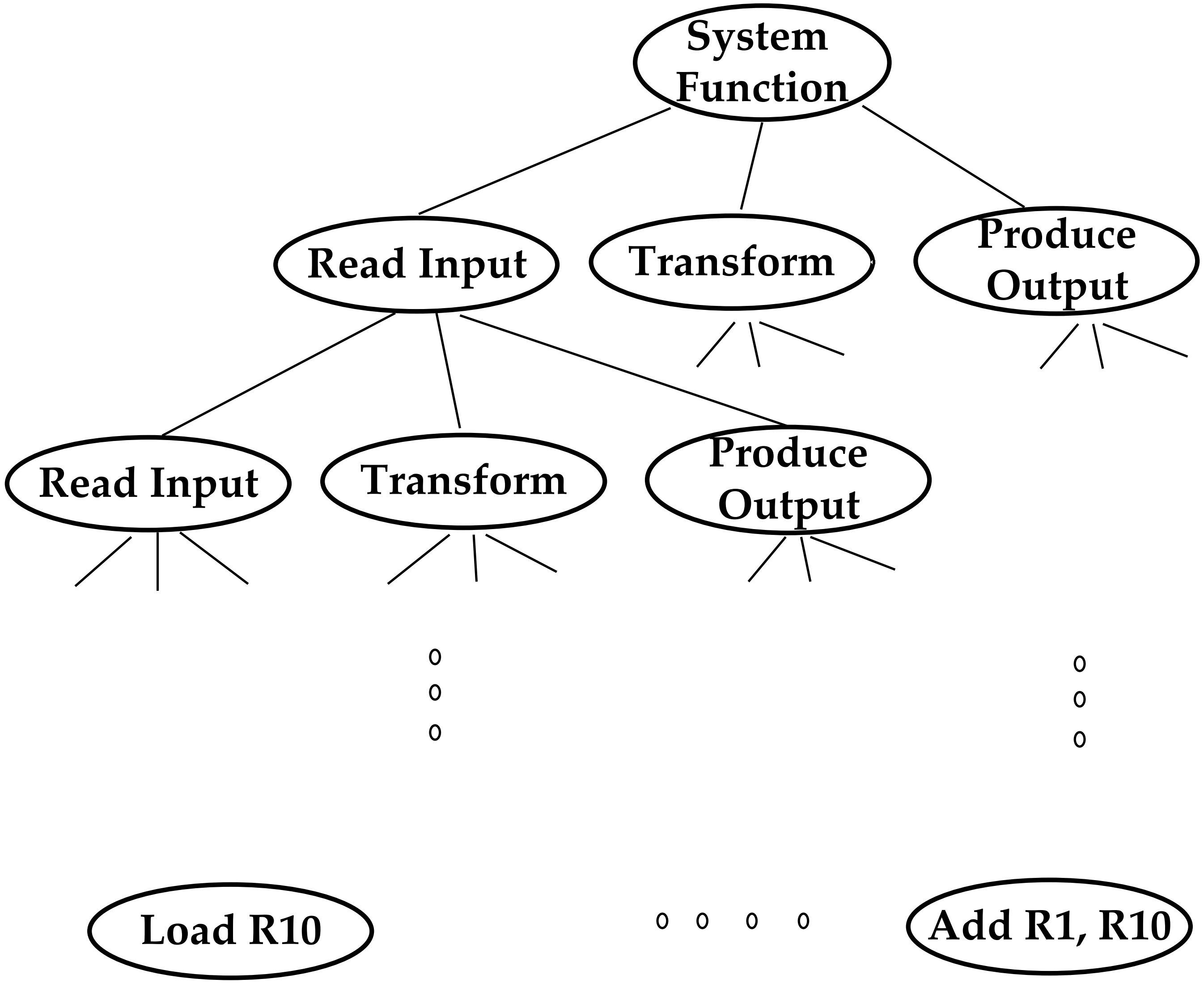
Decomposition (cont'd)

- Object-oriented decomposition
  - The system is decomposed into classes ("objects")
  - Each class is a major entity in the application domain
  - Classes can be decomposed into smaller classes

- Object-oriented vs. functional decomposition

Which decomposition is the right one?

Functional Decomposition



Top Level functions

Level 1 functions

Level 2 functions

Machine instructions

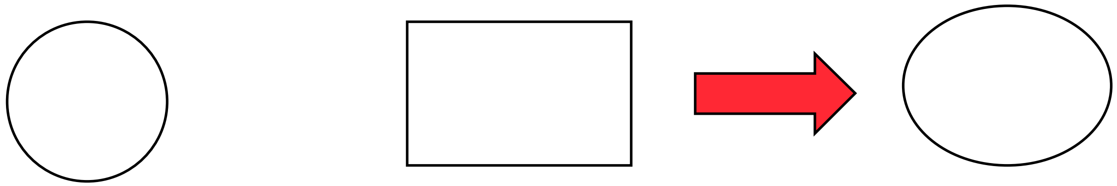
Functional Decomposition

- The functionality is spread all over the system
- Maintainer must understand the whole system to make a single change to the system
- Consequence:
  - Source code is hard to understand
  - Source code is complex and impossible to maintain
  - User interface is often awkward and non-intuitive.

Functional Decomposition

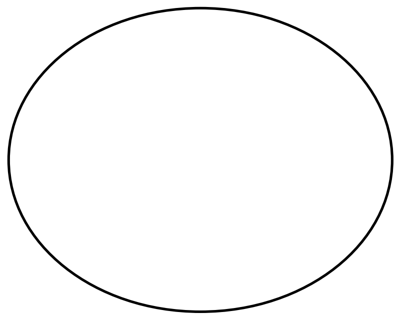
- The functionality is spread all over the system
- Maintainer must understand the whole system to make a single change to the system
- Consequence:
  - Source code is hard to understand
  - Source code is complex and impossible to maintain
  - User interface is often awkward and non-intuitive

- Example: Microsoft Powerpoint's Autoshapes
  - How do I change a square into a circle?

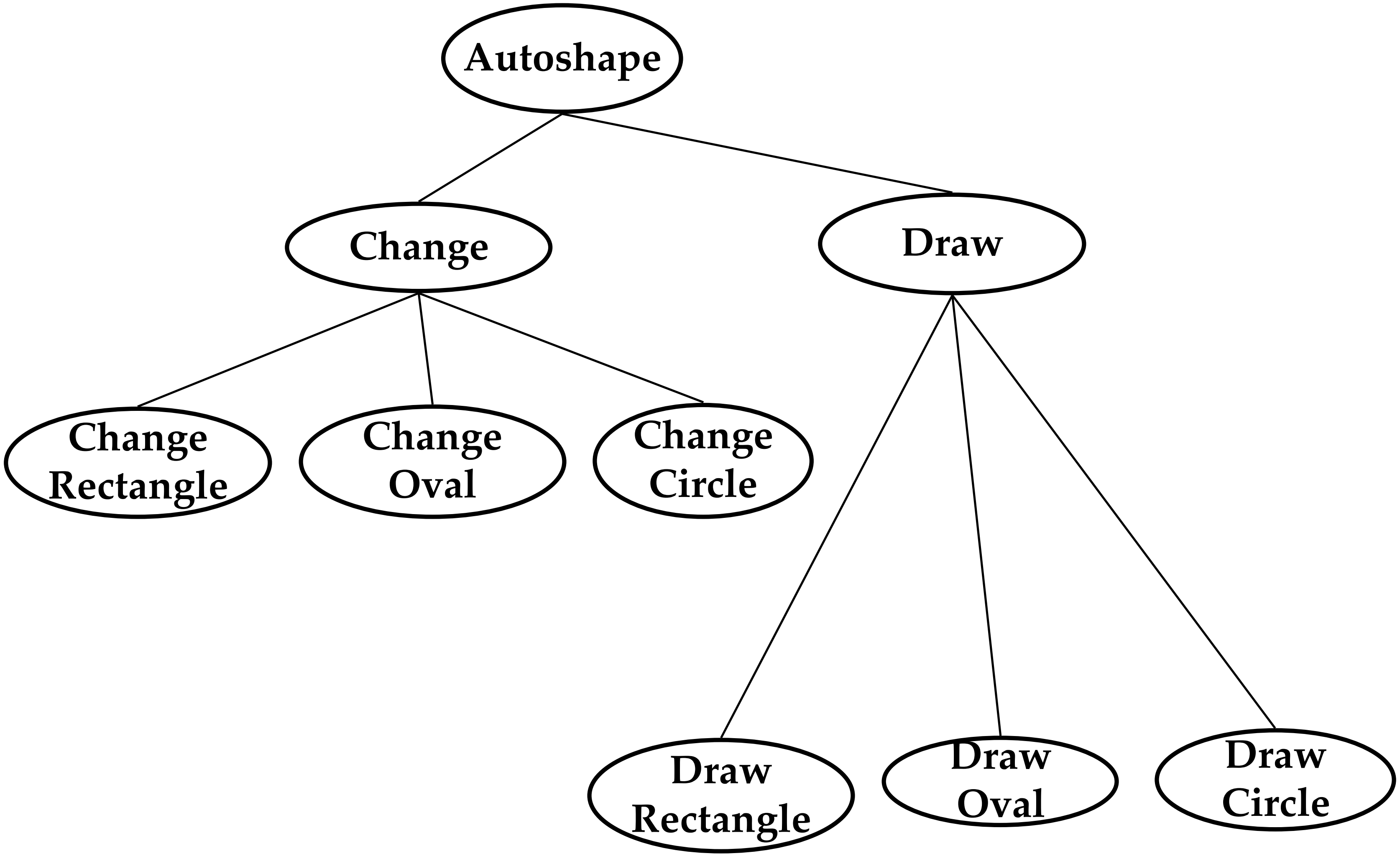


?

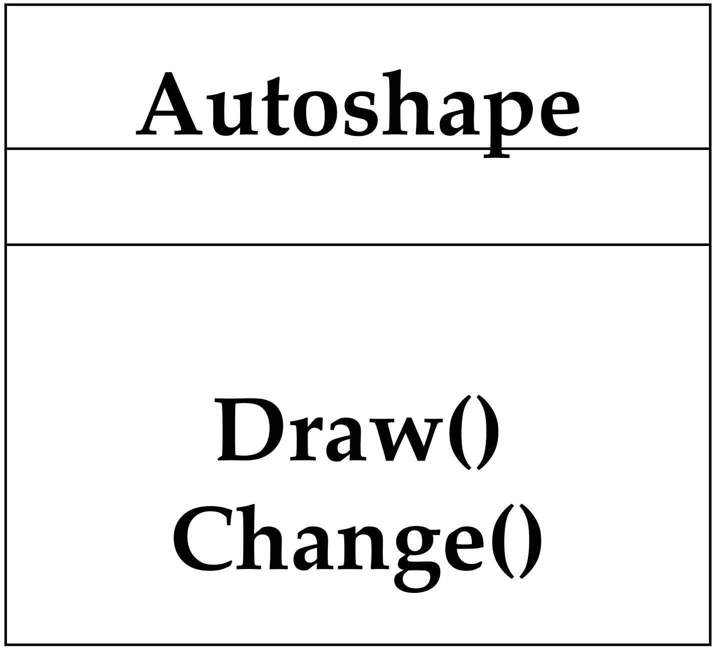
Changing a Square into a Circle



Functional Decomposition: Autoshape

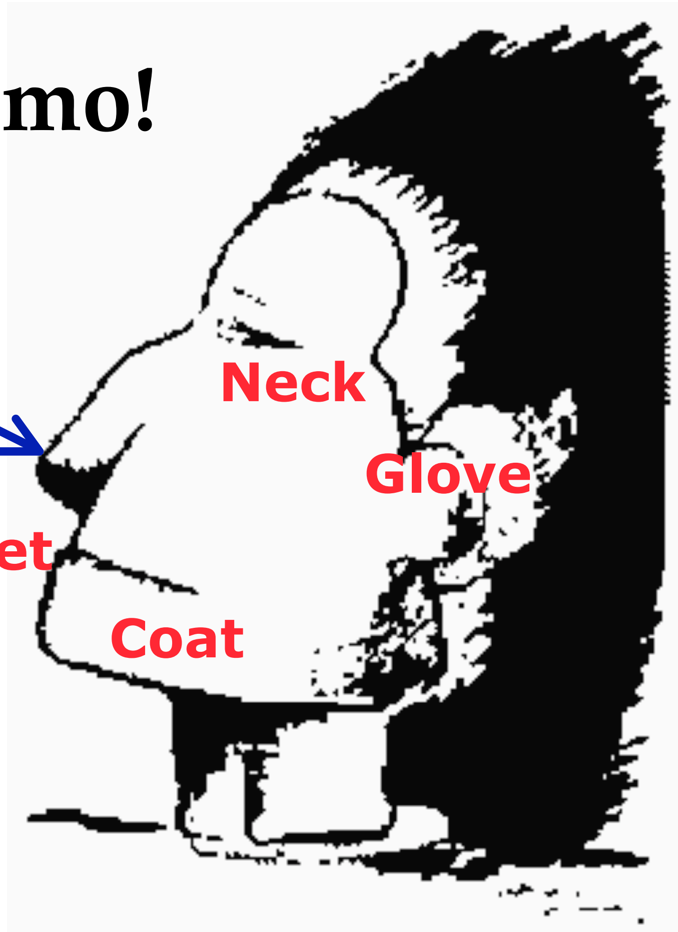


Object-Oriented View

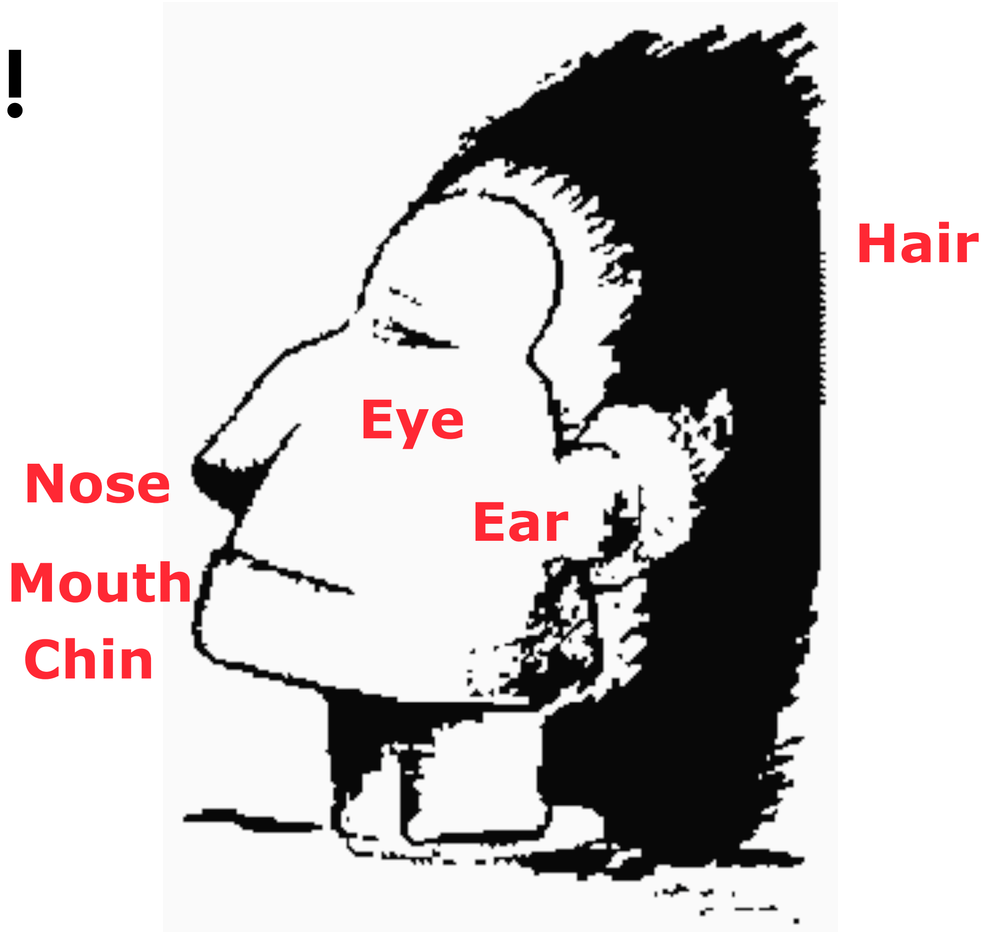


What is This?

An Eskimo!

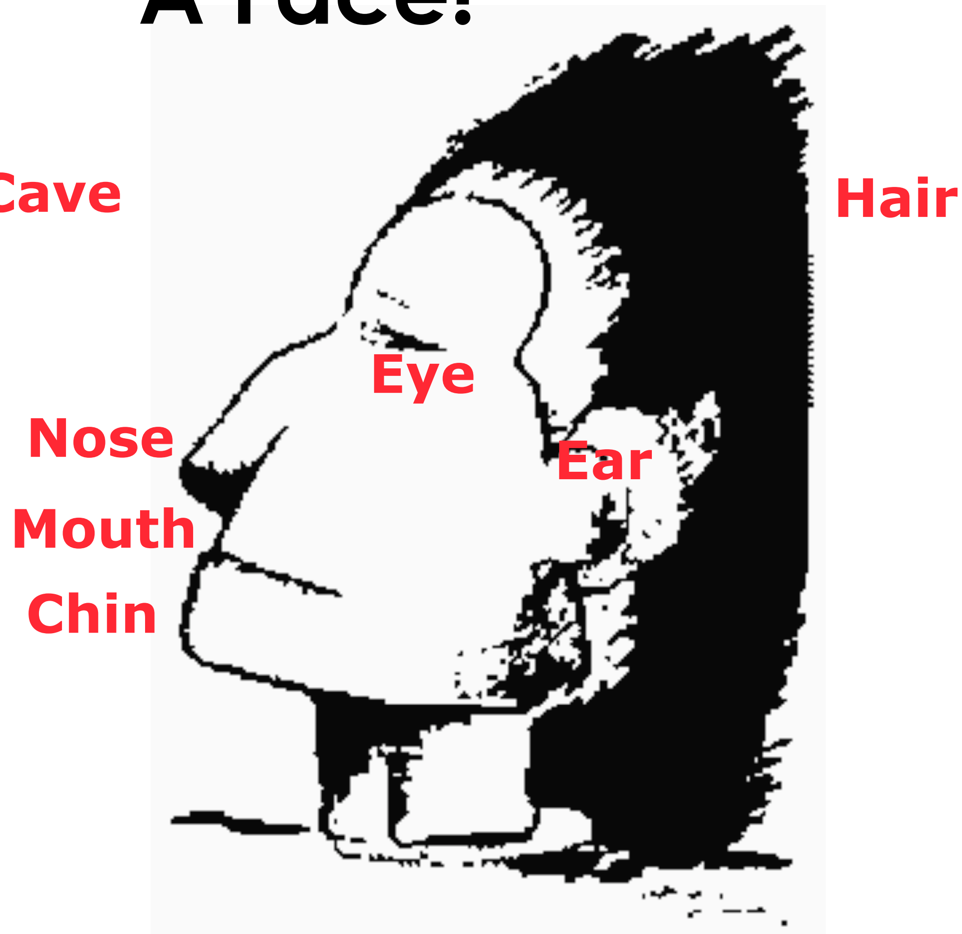


A Face!



An Eskimo!

A Face!



Class Identification

- **Basic assumptions:**
  - We can find the *classes for a new software system:* Greenfield Engineering
  - We can identify the *classes in an existing system*: Reengineering
  - We can create a *class-based interface to an existing system:* Interface Engineering

Class Identification (cont'd)

- **Why can we do this?**
  - Philosophy, science, experimental evidence
- **What are the limitations?**
  - Depending on the purpose of the system, different objects might be found
- **Crucial**

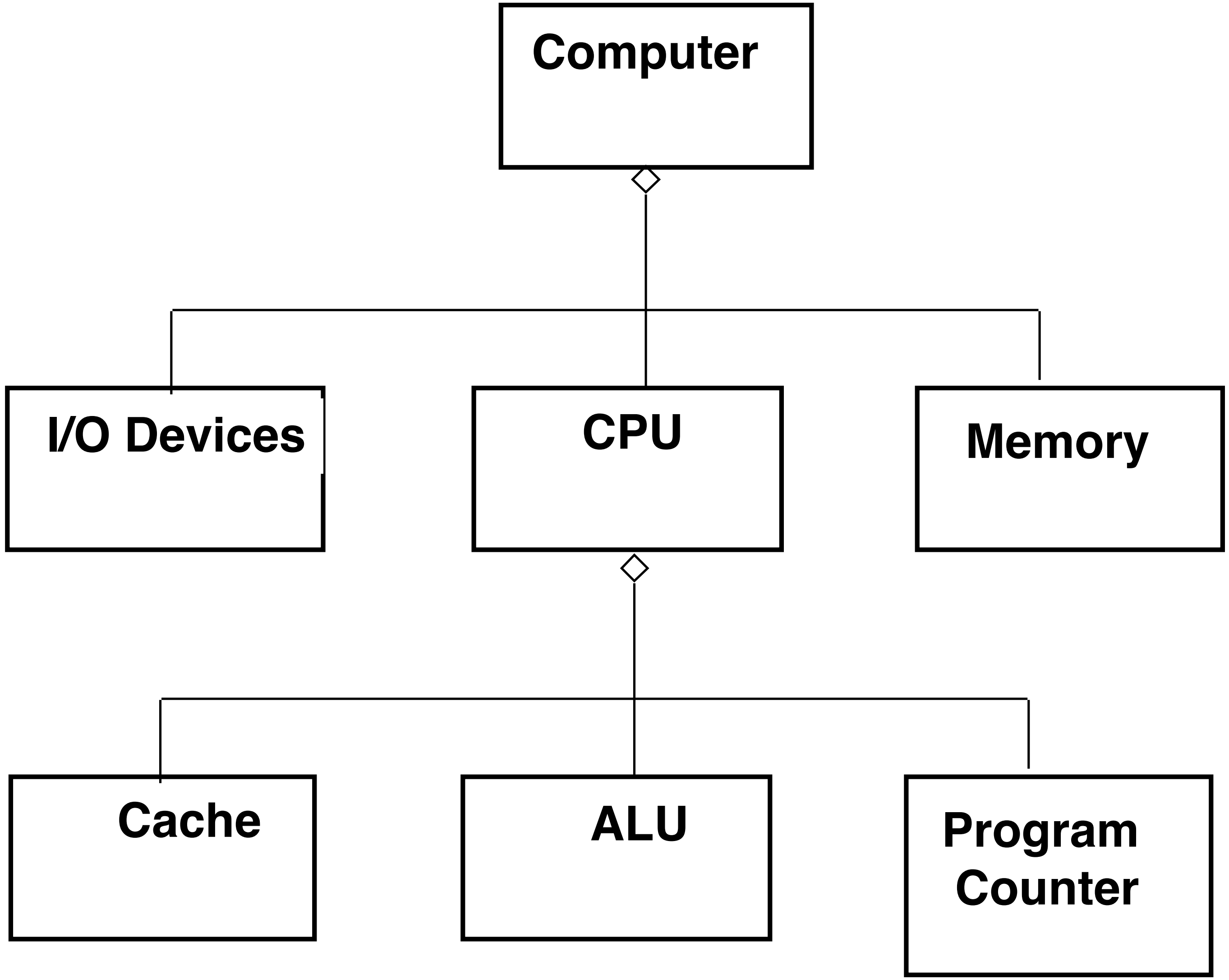
  Identify the purpose of a system

3. Hierarchy

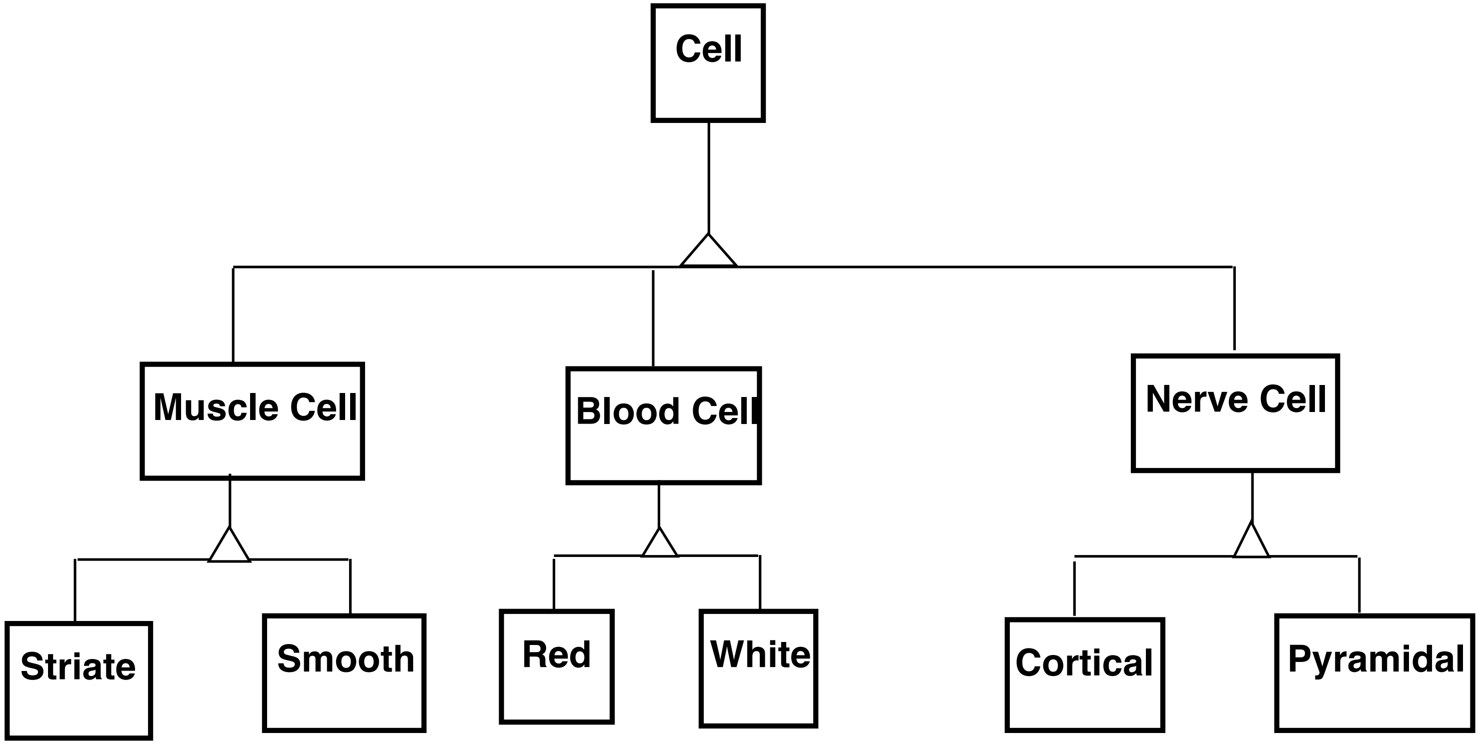
- So far we got abstractions
  - This leads us to classes and objects
  - “Chunks”

- Another way to deal with complexity is to provide relationships between these chunks
- One of the most important relationships is hierarchy
- 2 special hierarchies
  - "Part-of" hierarchy
  - "Is-kind-of" hierarchy

Part-of Hierarchy (Aggregation)



Is-Kind-of Hierarchy (Taxonomy)



Where are we now?

- Three ways to deal with complexity:
  - Abstraction, Decomposition, Hierarchy
- Object-oriented decomposition is good
  - Unfortunately, depending on the purpose of the system, different objects can be found
- How can we do it right?
  - Start with a description of the functionality of a system
  - Then proceed to a description of its structure
- Ordering of development activities
  - Software lifecycle

Models must be falsifiable

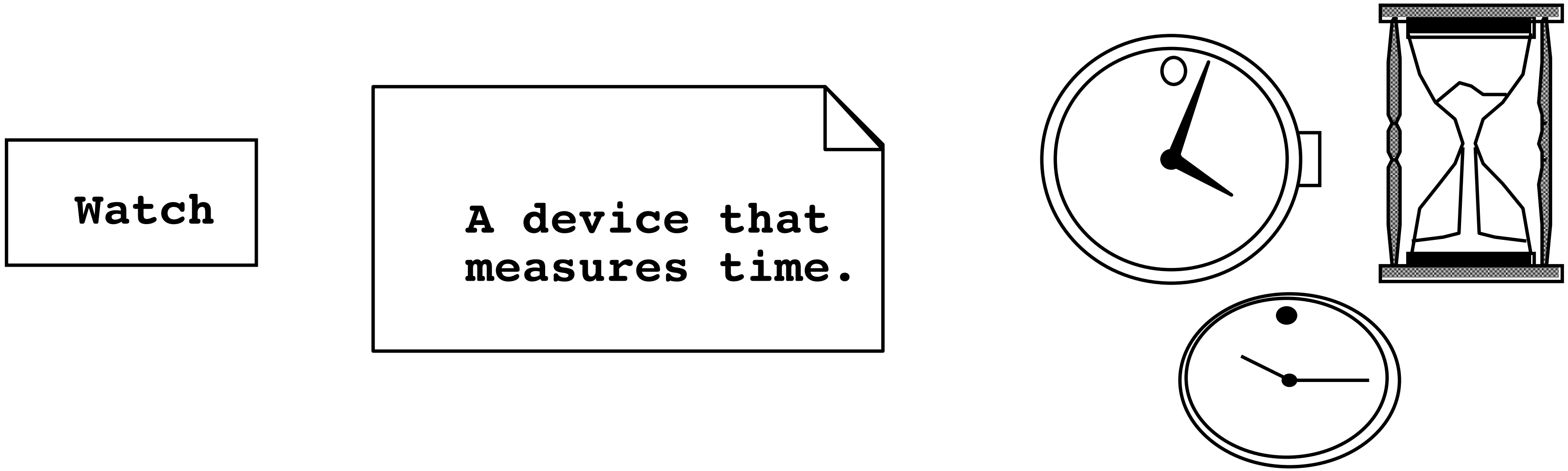
- Karl Popper (“Objective Knowledge):
  - There is no absolute truth when trying to understand reality
  - One can only build theories, that are “true” until somebody finds a counter example
- Falsification: The act of disproving a theory or hypothesis
- The truth of a theory is never certain. We must 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 April 18 at 9:35, 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**



Definition Abstraction:

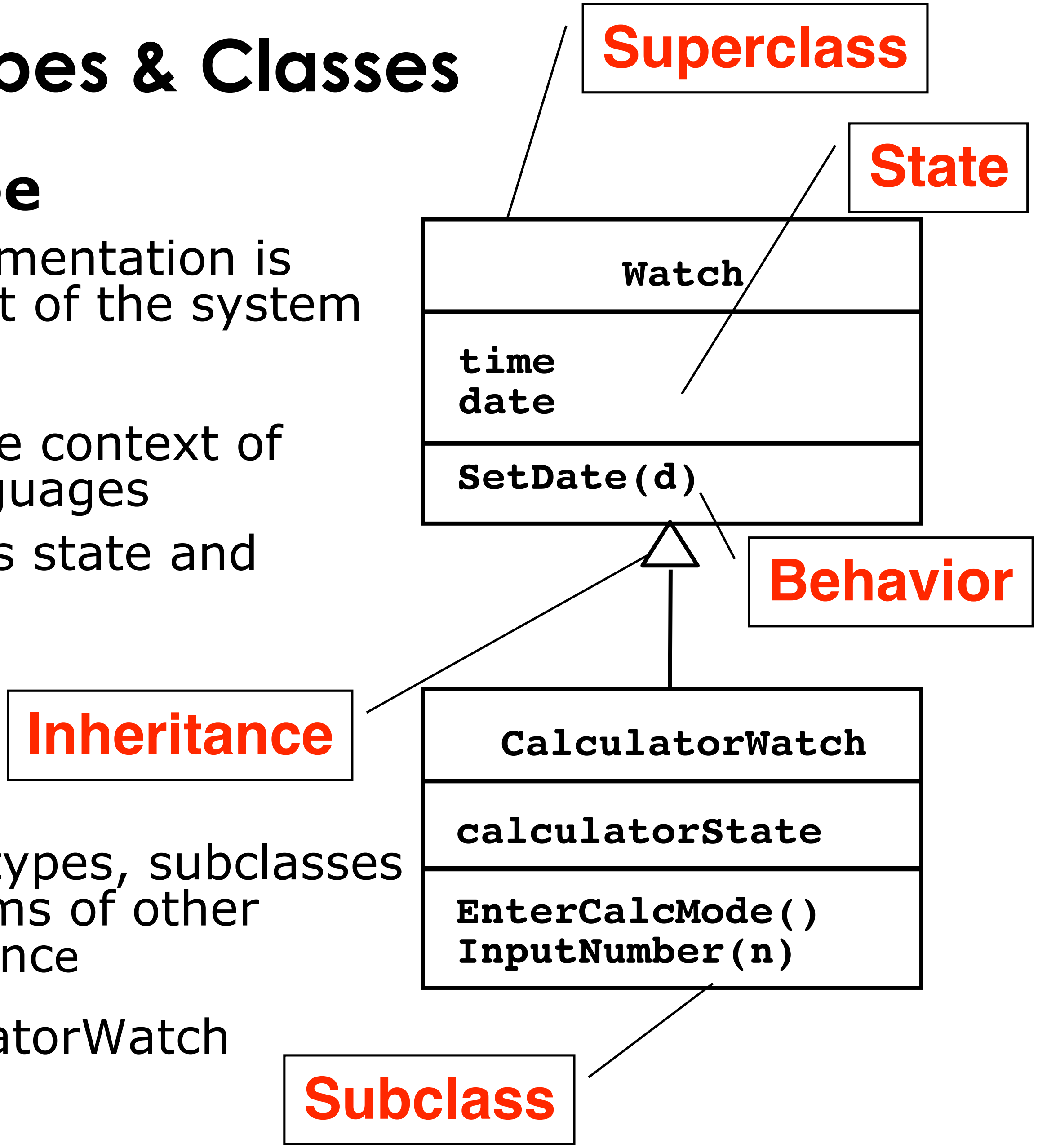
- Classification of phenomena into concepts

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.

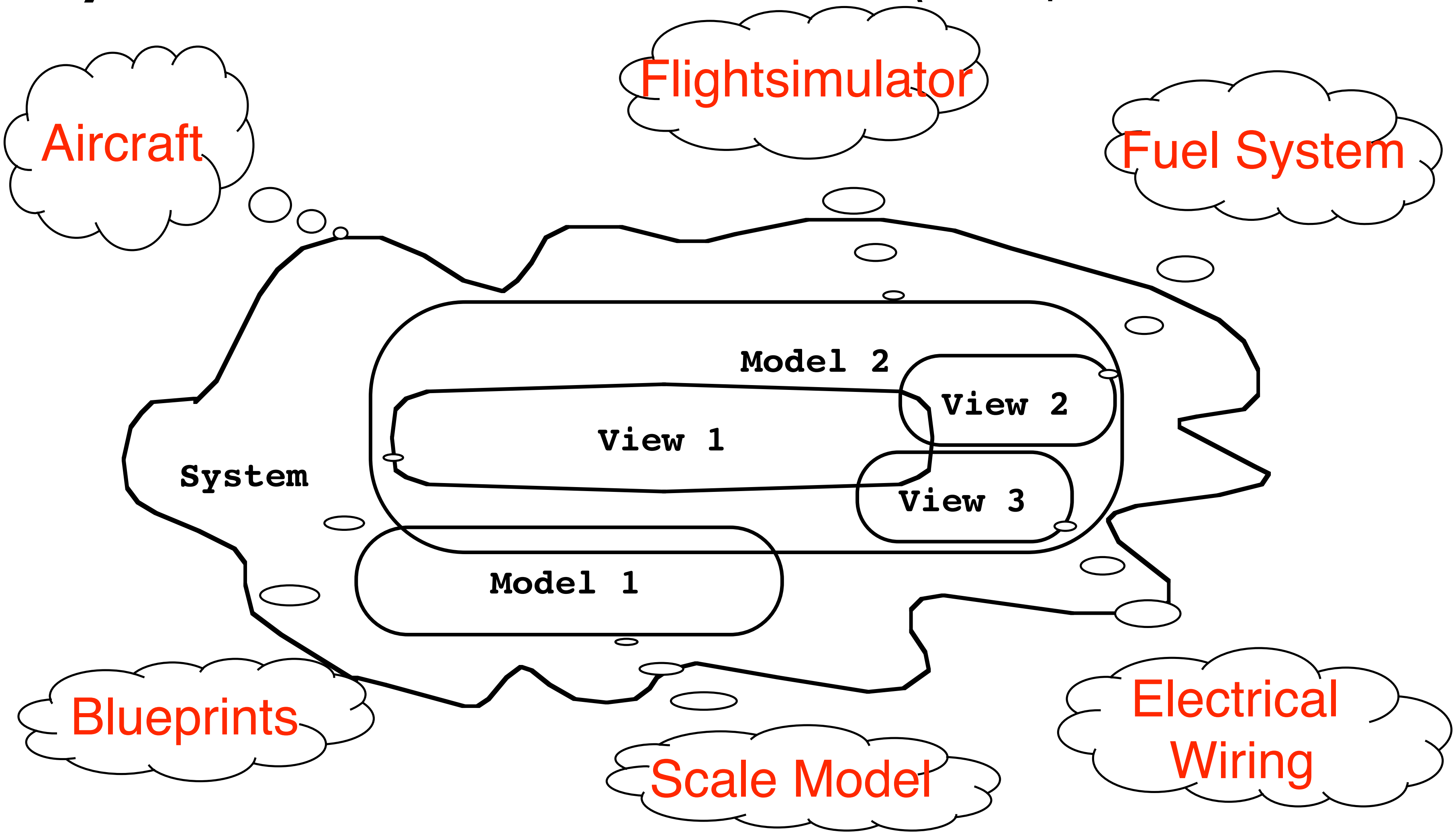
Systems, Models and Views

- 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

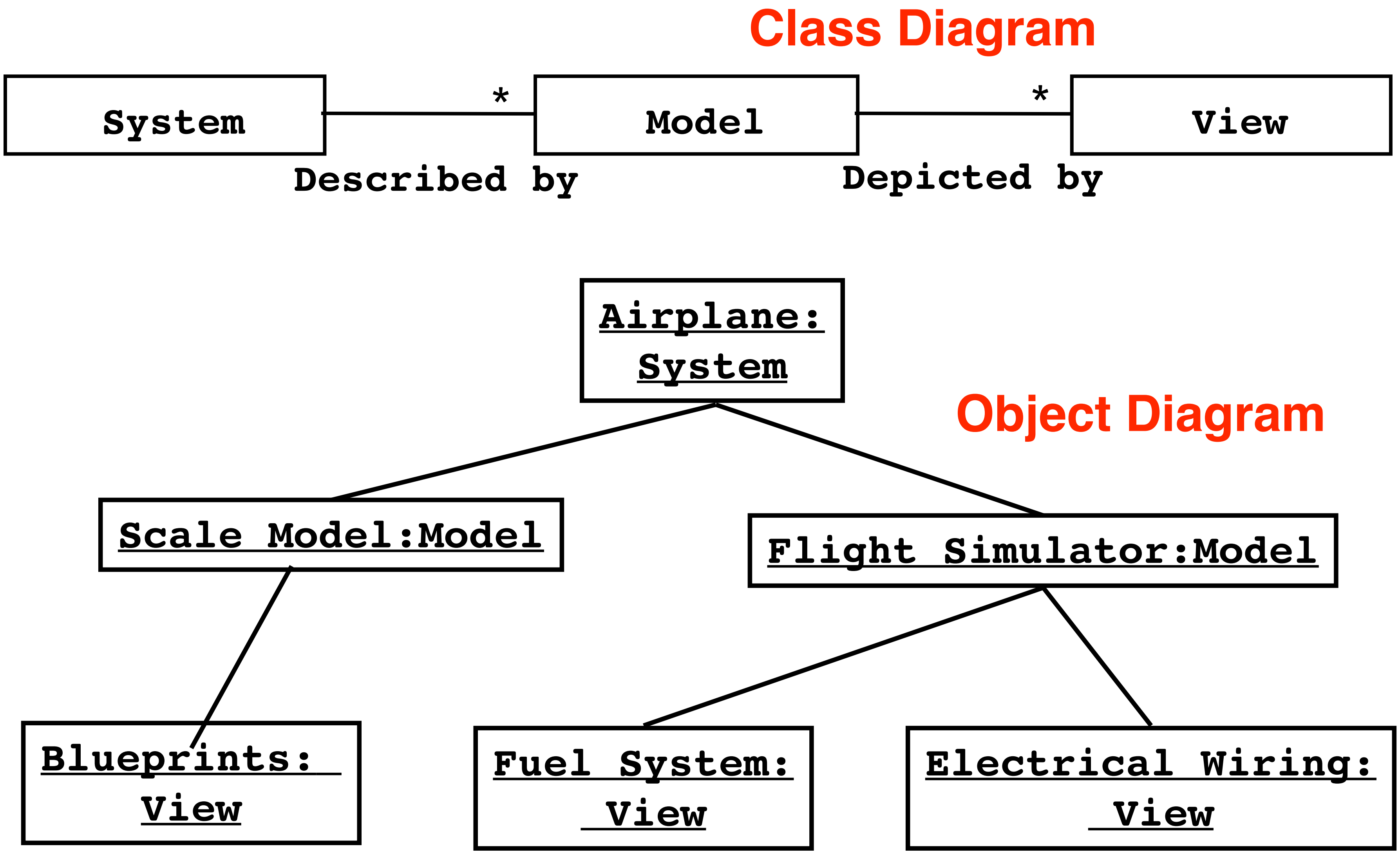
Models:	**Views:**
Flight simulator	Blueprint of
Scale model	Electrical wi
	Fuel system
	Sound wave created by airplane

Systems, Models and Views (“Napkin” Notation)



Views and models of a complex system usually overlap

Systems, Models and Views (UML Notation)



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):

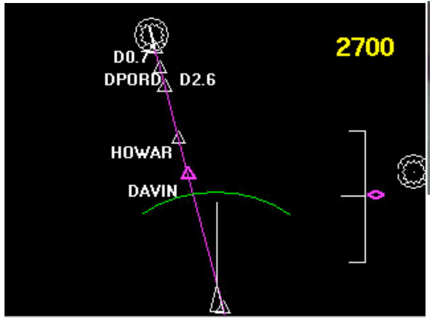
```
public class StockExchange {
    public m_Company = new Vector();
 };
public class Company  {
 public int m_tickerSymbol;
 public Vector m_StockExchange = new Vector();
};
```

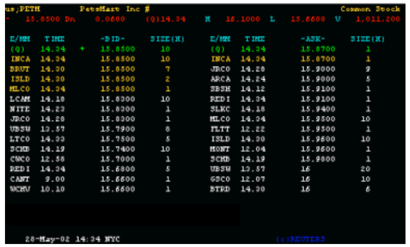
Application vs Solution Domain

- 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

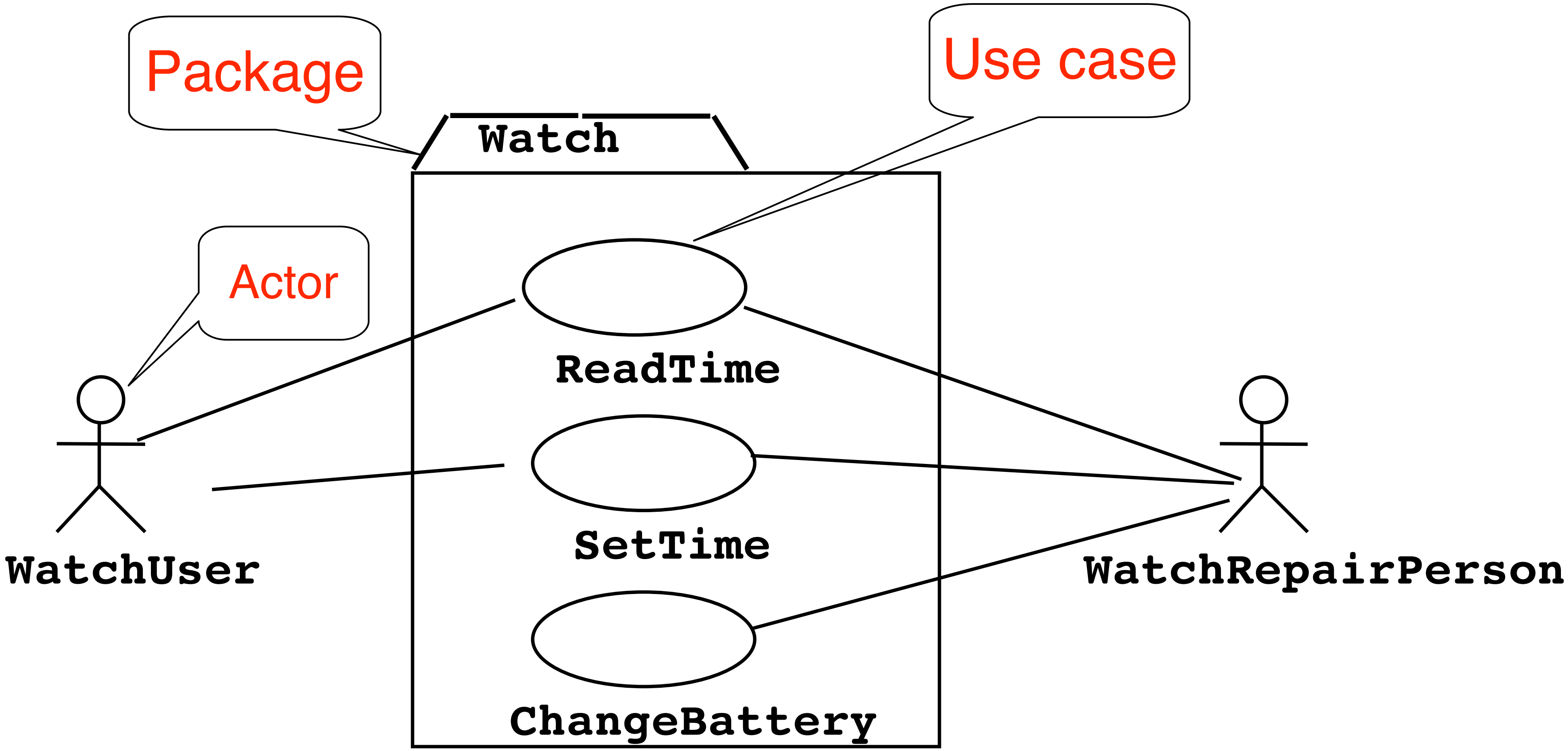
UML First Pass

- 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

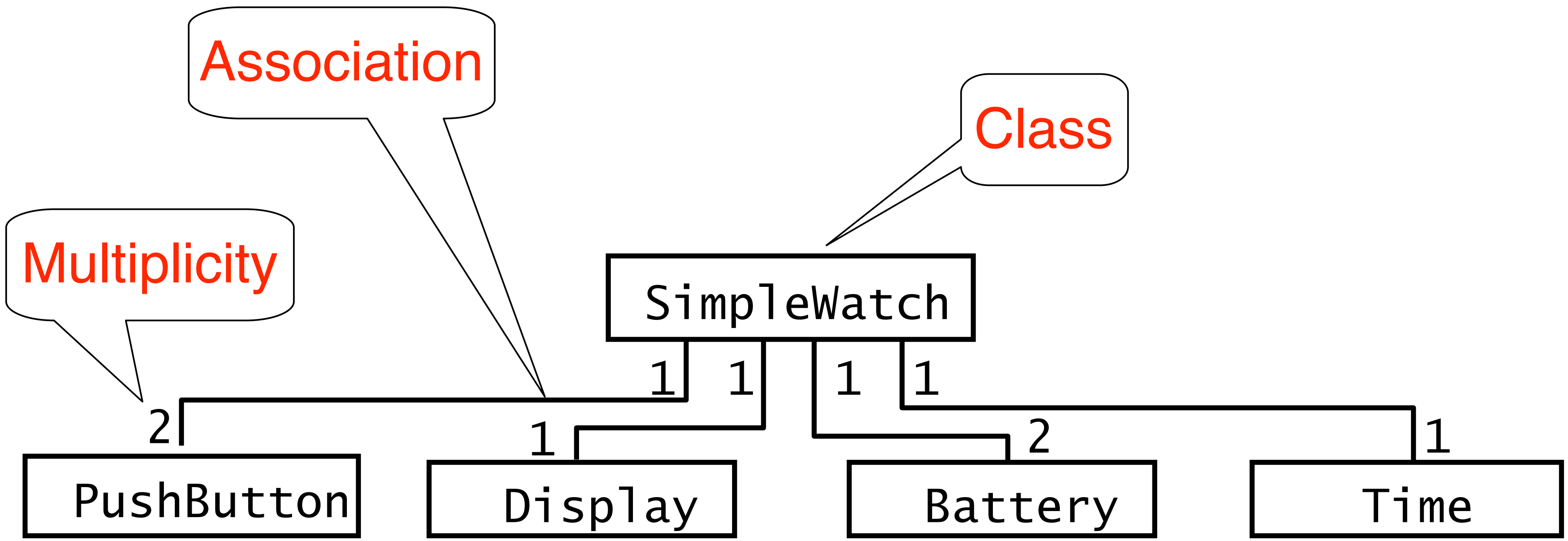
- All UML Diagrams denote graphs of nodes and edges
  - Nodes are entities and drawn as rectangles or ovals
  - Rectangles denote classes or instances
  - Ovals denote functions
- Names of Classes are not underlined
  - `SimpleWatch`
  - `Firefighter`
- Names of Instances are underlined
  - <u>`myWatch:SimpleWatch`</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

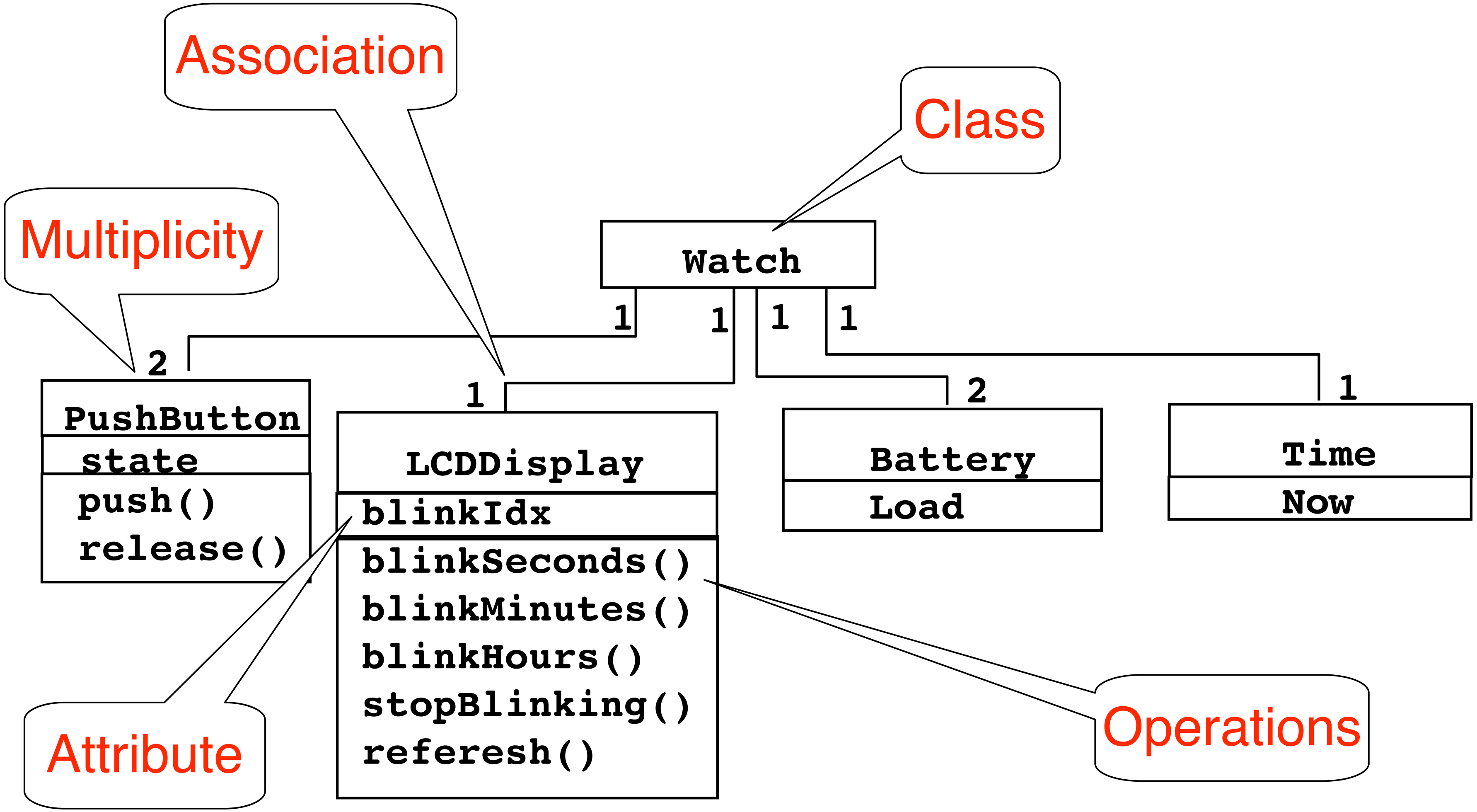
UML first pass: Class diagrams



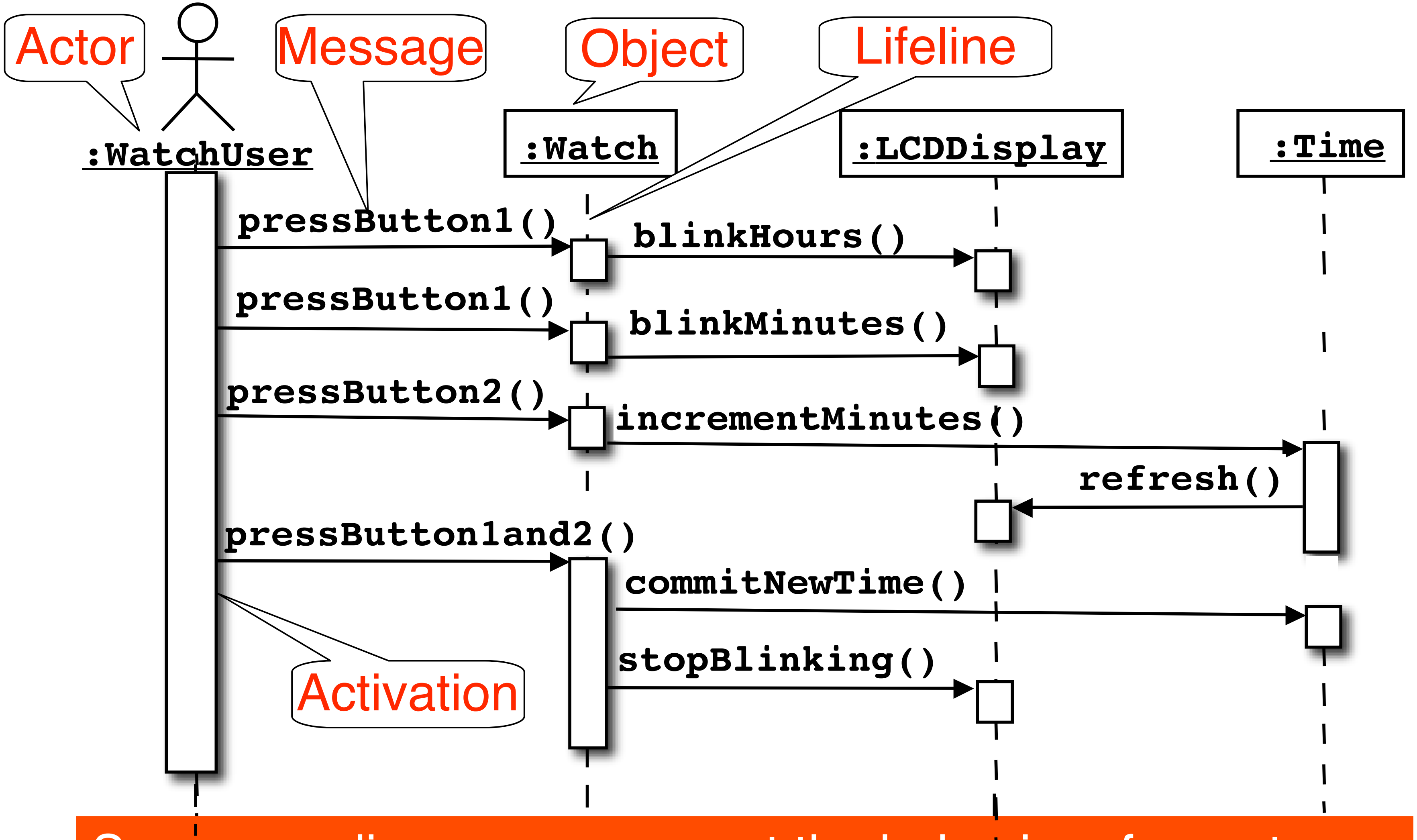
Class diagrams represent the structure of the system

UML first pass: Class diagrams

Class diagrams represent the structure of the system

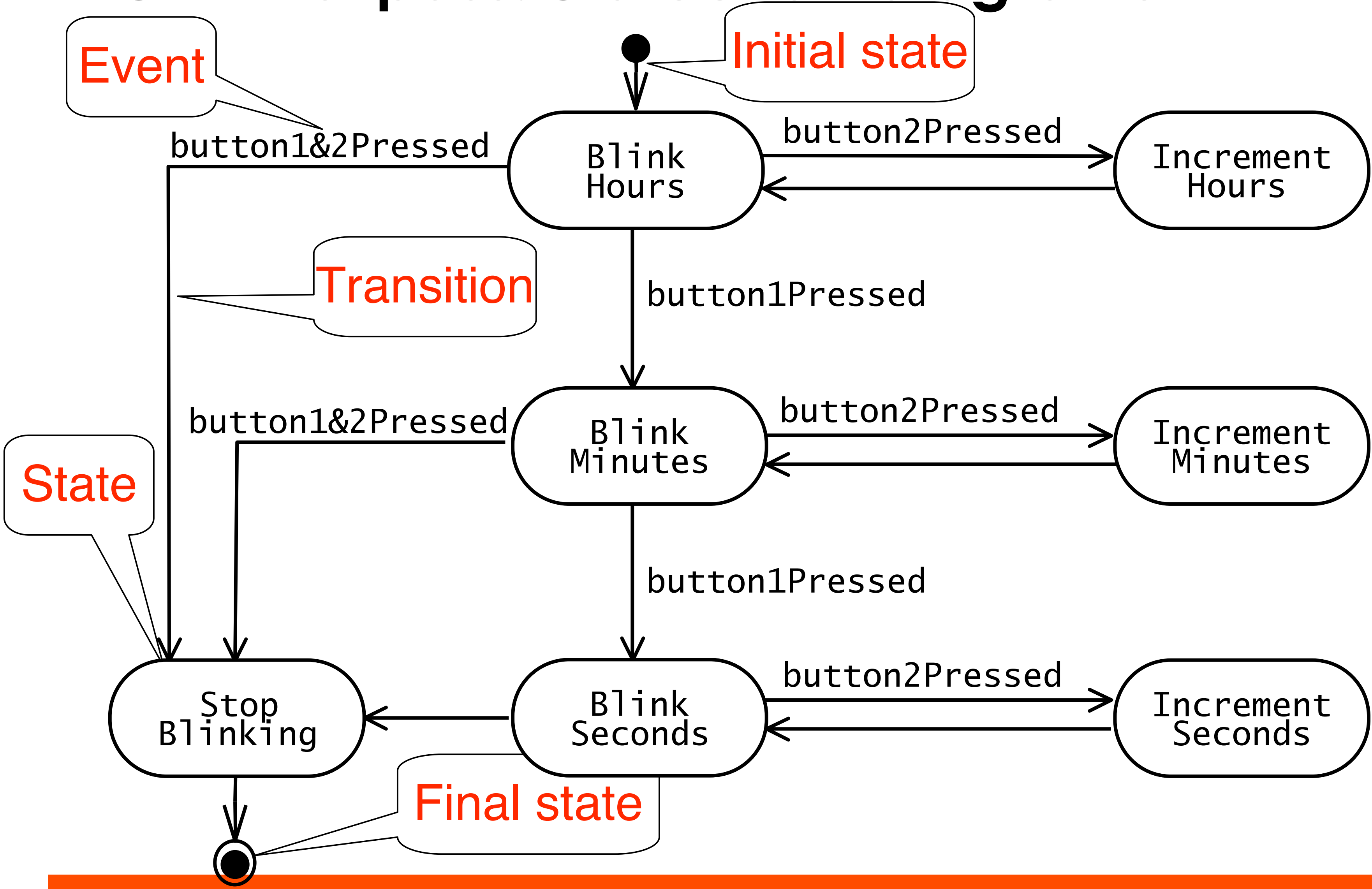


UML first pass: Sequence diagram



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, …