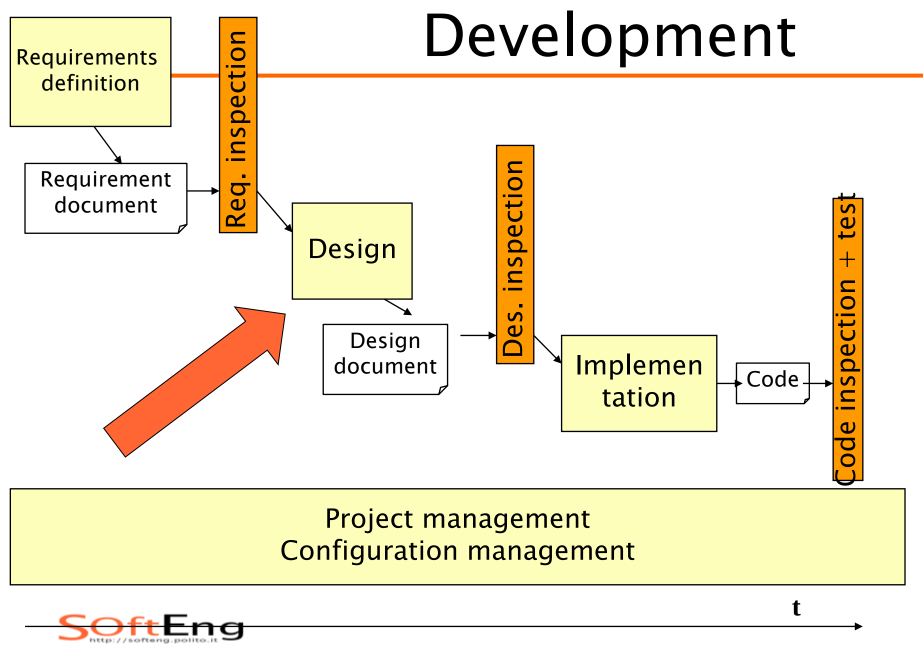
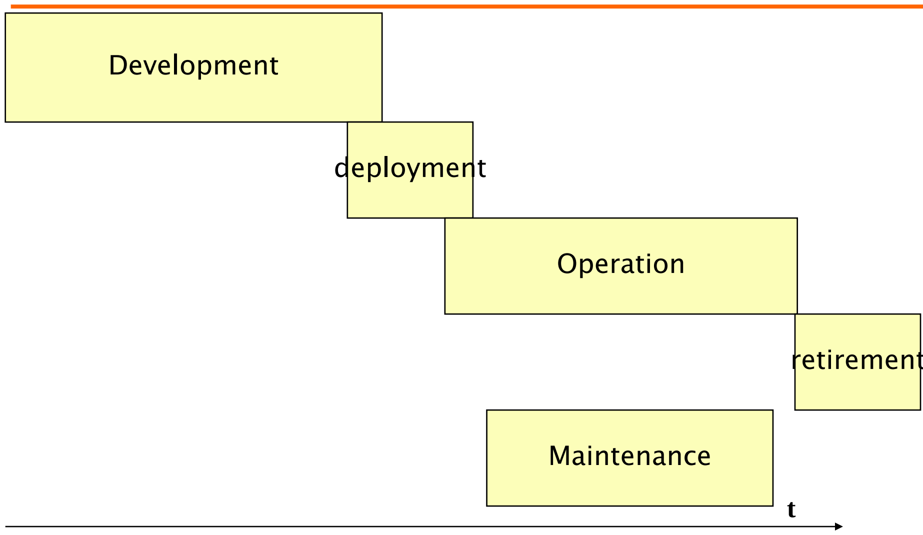
Architecture and Design

Development



Main Phases



Outline

- Process
- Properties
- Notations
- Patterns
  - Architectural patterns /styles
  - Design patterns

Architecture

- Requirements: **what** the system should do
- Architecture, design: **how** the system should be built
  - Architecture, design: same flavour but
    - Architecture: high level, decide major components and their control and communication framework
    - Design: lower level, decide internals of each component

Architecture, design, why

- Most defects come from requirements and design
- Essential to define, analyze and evaluate design choices *early*
- If no design is defined, but code is developed immediately, design choices are made implicitly and evaluated *late*
- Doing design allows to make design choices *explicit* , document and evaluate them

Requirements to design

- Given one set of requirements
- In general many different designs are possible (*design choices*)
  - Cfr. Requirement: mid sized car in price range 10 to 20k
  - Designs: hundreds of models on the market,
    - High level design choices
      - diesel or gas engine
      - front or rear or all wheel drive
    - Low level design choices
      - Color
      - With ABS, ESP, or not
- But not all designs are equal

Requirements to design

- A creative process
- Driven by skill and experience
- Experience formalized in semi formal guidelines
  - Architectural styles (patterns)
  - Design patterns

System – software design

- Design has 2 sides
  - System design
    - Decisions about computing nodes and their connections
    - For embedded systems it includes also decisions about components and connections in other technologies (electrical, electronic, mechanical..)
  - Software design
    - Decisions about software components and their connections, within a given system design

Process

Process

- Analysis
  - Architecture
  - High level design
  - Low level design
- Formalization
  - Text, diagrams (UML)
- Verification

Process

- Input
  - Requirement document
    (functional requirements
    non functional requirements)
- Output
  - Design document
    - Component + connections
    - Capable of satisfying functional + non functional requirements

- 1a Architecture

  (about the whole system)

  - Define high level components and their interactions
  - Select communication and coordination model
    - Processes, threads
    - Messages, (remote) procedure calls, broadcast, blackboard
  - Use architectural style(s) /pattern(s)

- 1b Design

  - High level (about many classes)
    - Define classes and their interactions
    - Use design patterns
  - Low level (about one class)

1B Design

- Definition of classes
  - From glossary: consider a class for each key entity in glossary
  - From context diagram:
    - Consider a class for each actor = physical device or subsystem
    - Define GUI for each actor = human actor
- Consider design patterns

2 Design

- Low level design
  - (inside a class or two)
  - For each attribute, define type, privacy
  - For each method, define return type, number and type of parameters, privacy
  - Define setters, getters (if needed)
  - For each method, choose algorithms (if needed)
  - For each relationship with other class, choose implementation
    - If 'one' relationship: reference or key
    - If 'many' relationship: array, map, list

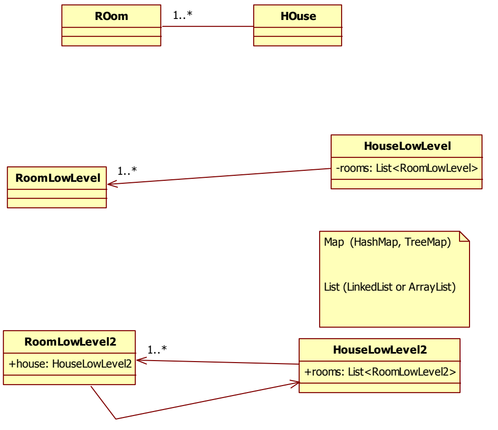
2 Design

- Low level design
  - (inside a class or two)
  - Decide persistency
    - No persistence
    - Yes persistence
      - Serialization (to file, to network)
      - To database

      - On all objects
      - On part of objects – (hybernate, ..)

Relationships- low level design

Relationships – 1-1*



Many many

Design choices – examples

	Internship management	Heating control system
Technical domain	Web application	Embedded system
Architectural choices	Client server Layered (database, appl logic, presentation) (repository)	Single computer Layered (sensors, appl logic, presentation)
Packages, classes (attributes, methods) relationships	Many reused from glossary, added some (app logic level and presentation layer)	Many reused from glossary, added some (app logic level and presentation layer)
Low level design (for attributes, methods, relationships)	Common choices for implementing relationships	

Properties

Properties of a design

- Functional properties
  - Does the design support the functional requirements?
    - Functional requirements (requirements document)
      vs.
    - functional properties (design)
- Non functional properties
  - Does the design support the non functional requirements?
    - Non functional requirements (requirements document)
      vs.
    - Non functional properties (design)

Non functional properties

- Reliability
- Efficiency/performance
- Usability
- Maintainability
- Portability
- Safety
- Security

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Non functional properties

- More specific to design
  - Testability
    - Observability
    - controllability
  - Monitorability
  - Interoperability
  - Scalability
  - Deployability
  - Mobility

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Non functional properties

- Complexity
  - Number of components
  - Number of interactions
  - KISS: keep it simple, stupid
- Coupling (or decoupling)
  - Degree of dependence between two components
- Cohesion
  - Degree of consistence of functions of a component

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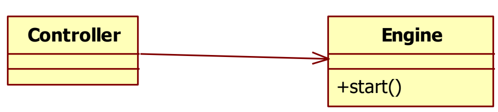
Coupling

Walls vs plumbing system

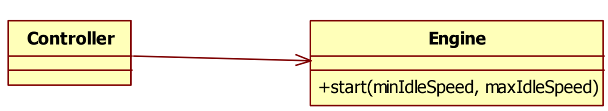
Coupling

- Controller vs engine
  - lowest



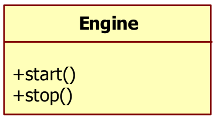
  - intermediate

  - highest

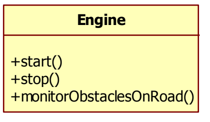


Cohesion

- Higher



- lower



Non functional properties

- Cost
- Schedule
- Staff skills

Properties – what to do

- Performance
  - Localise critical operations and minimise communications. Use large rather than fine-grain components.
- Security
  - Use a layered architecture with critical assets in the inner layers.
- Safety
  - Localise safety-critical features in a small number of sub-systems.
- Availability
  - Include redundant components and mechanisms for fault tolerance.
- Maintainability
  - Use fine-grain, replaceable components.

Properties

- Using large-grain components improves performance but reduces maintainability.
- Introducing redundant data improves availability but makes security more difficult.
- Localising safety-related features usually means more communication so degraded performance

Properties, trade offs

- Not all properties can be satisfied
- Design is also about deciding tradeoffs
  - Ex security (add layers) vs. speed (avoid layers)
  - Ex. changeability (add abstraction layer to insulate from hardware change) vs. speed (avoid layers)
- Possibly, trade offs are decided at requirement time
  - Ex: requirement: security prevails on speed

Notations for formalization of architecture

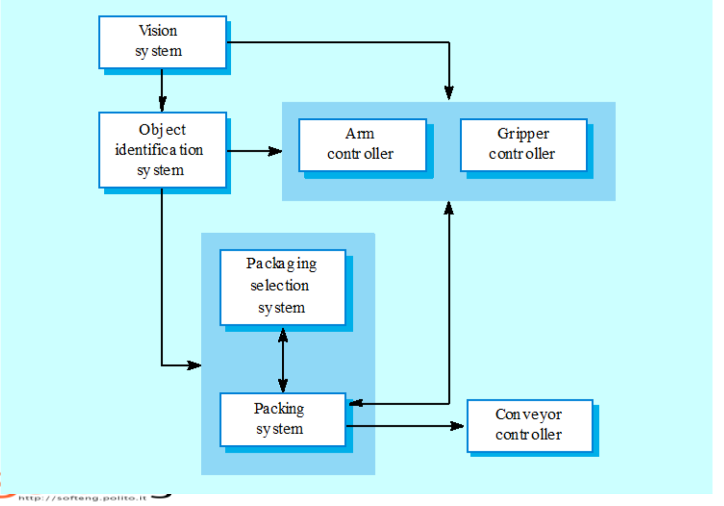
Formalizing the architecture

- Informal
  - box and lines
- Semiformal
  - UML diagrams
    - Structural views
      - Component, package diagrams
      - Class diagrams
      - Deployment diagram
    - Dynamic views
      - Sequence diagrams
      - State charts
- Formal ADL (Architecture description languages)
  - Many, ex C2 (component Connector)

Box and line diagrams

- Very abstract - they do not show the nature of component relationships nor the externally visible properties of the sub-systems.
- However, useful for communication with stakeholders and for project planning.

Packing robot control system



UML diagrams

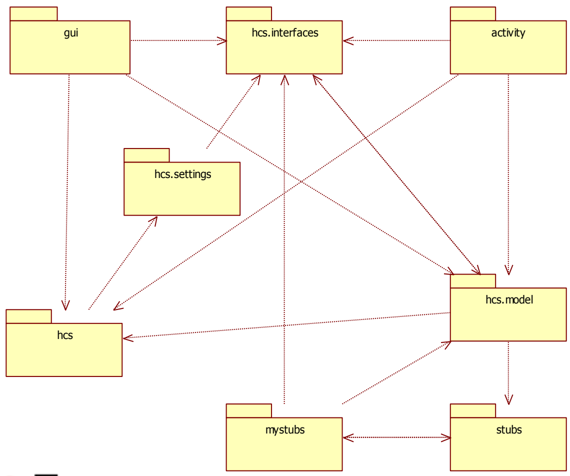
- Structural view
  - Component or package diagram for high level view
  - Class diagram (inside each package or component)
  - Class description (for each class)

Heating control system

- (see requirement document and design document)
- Choices – high level
  - One CPU, one process (no distribution, no concurrency)
  - Communication and control: procedure call
  - Layered style (at least partially)
- Choices – low level
  - Observer pattern

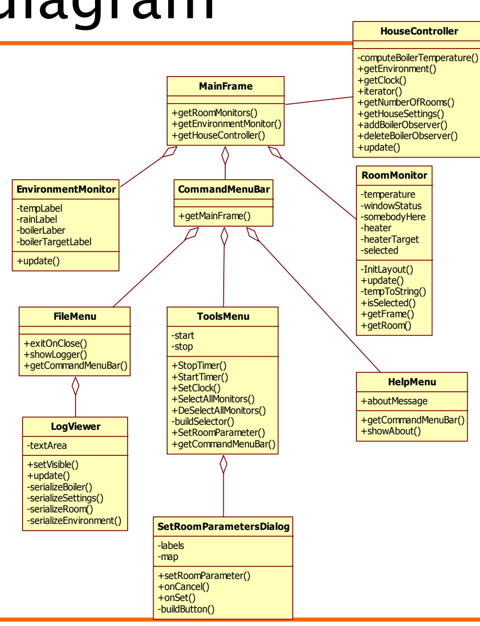
UML – structural

UML – package diagram



UML – class diagram

- Package GUI



Class (HouseController)

- The main class in the heating control system, it integrates the logical model of the various parts of the house and performs the high-level activities.
- computeBoilerTemperature()
  - Computes the desired water temperature in the boiler
- getEnvironment()
  - Navigates to the logical model of the environment
- getClock()
  - Navigates to the Clock
- iterator()
  - Returns an iterator to the contained Rooms
- getNumberOfRooms()
  - Returns the number of rooms
- getHouseSettings()
  - Navigates to the current global settings
- update()
  - Computes the next logical state of the system
- addBoilerObserver()
  - Adds an observer to the Boiler
- deleteBoilerObserver()
  - Removes an object from the list of Boiler observers

Structure and hierarchy

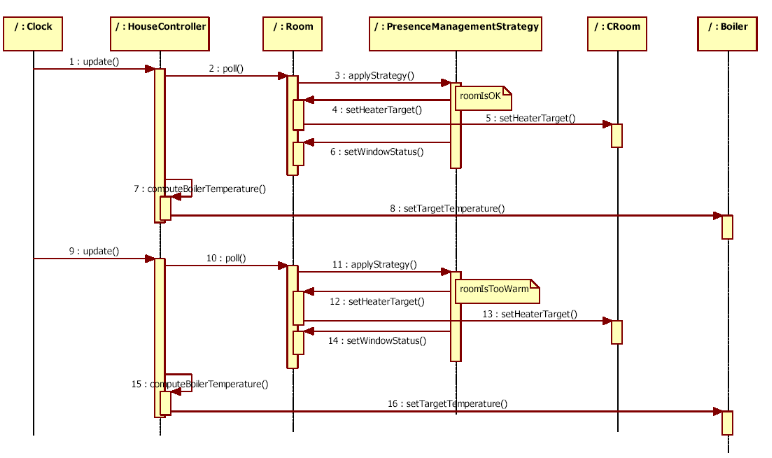
- UML helps in presenting structure in an organized (hierarchical) way
  - Packages in system
  - Classes in package
  - Attributes and methods in class
- Presentation is sequential, but the definition of such a structure requires several iterations

UML – dynamic

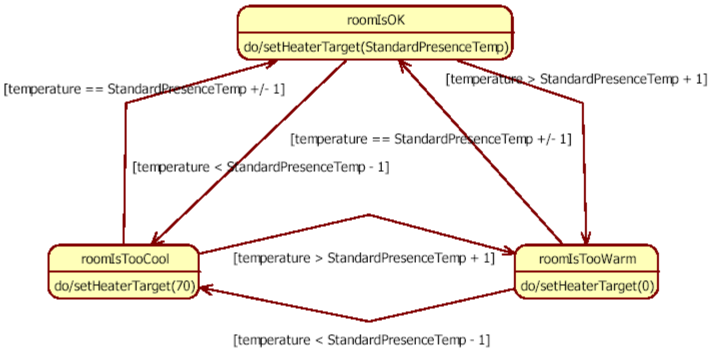
- State charts
- Sequence diagrams

Sequence

Sequence diagram for scenario 11:



State chart



Patterns

Patterns

- Reusable solutions
- To recurring problems
- In a defined context

- Cfr also dominant design in technology management area

History

- Initially proposed by Christopher Alexander
- He described patterns for architecture (of buildings)
  - *The pattern is, in short, at the same time a thing, which happens in the world, and the rule which tells us how to create that thing and when we create it. It is both a process and a thing …*

Design patterns

- Known, working ways of solving a problem

Types of Pattern

- Architectural Patterns (or styles)
  - Address system wide structures
- Design Patterns
  - Leverage higher level mechanisms
- Idioms
  - Leverage language specific features

Architectural Patterns / Styles

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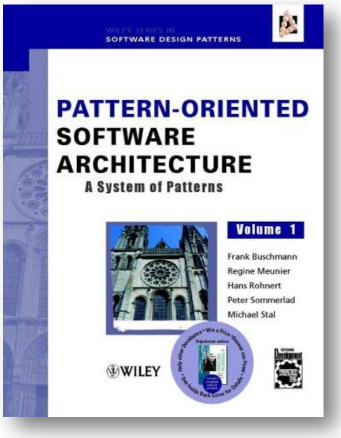
Architectural patterns



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Architectural Patterns

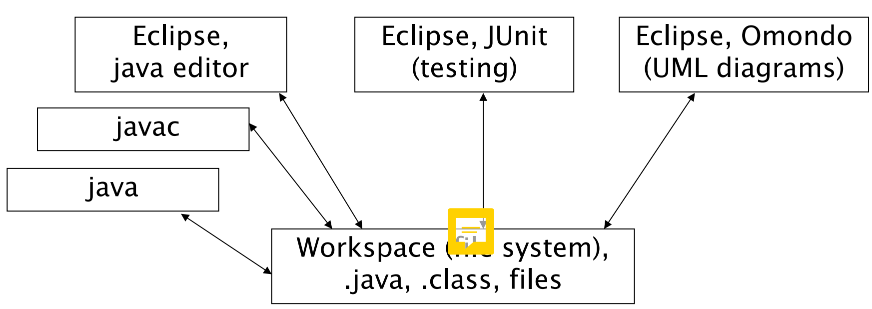
- Layers
- Pipes and filters
- Repository
- Client server
- Broker
- MVC
- Microkernel

- A real system is usually influenced by many architectural patterns / styles

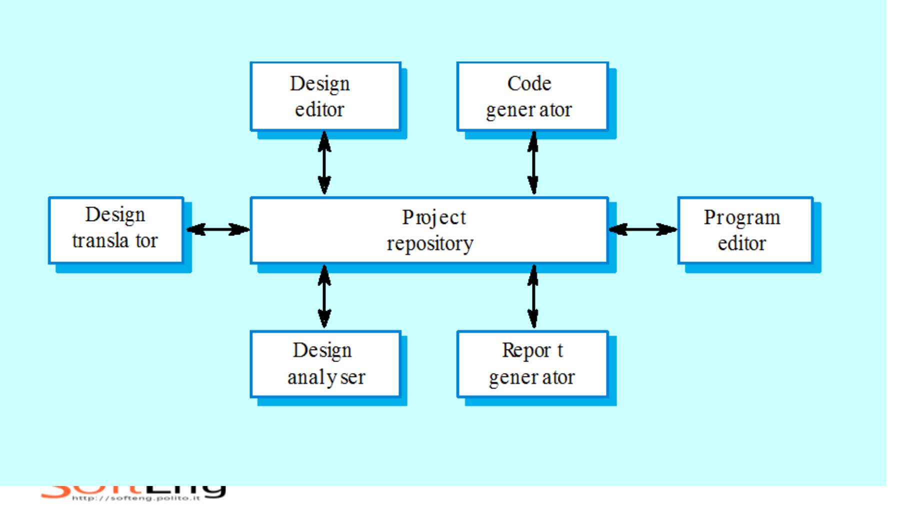
The repository style

- Sub-systems must exchange data. This may be done in two ways:
  - Shared data is held in a central database or repository and may be accessed by all sub-systems;
  - Each sub-system maintains its own database and passes data explicitly to other sub-systems.
- When large amounts of data are to be shared, the repository model of sharing is most commonly used.

Eclipse and plugins



CASE toolset architecture



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Repository style characteristics

- Advantages
  - Efficient way to share large amounts of data;
  - Sub-systems need not be concerned with how data is produced
  - Centralised management e.g. backup, security
  - Sharing model is published as the repository schema.
- Disadvantages
  - Sub-systems must agree on a repository data model. Inevitably a compromise;
  - Data evolution is difficult and expensive;
  - No scope for specific management policies;
  - Difficult to distribute efficiently.

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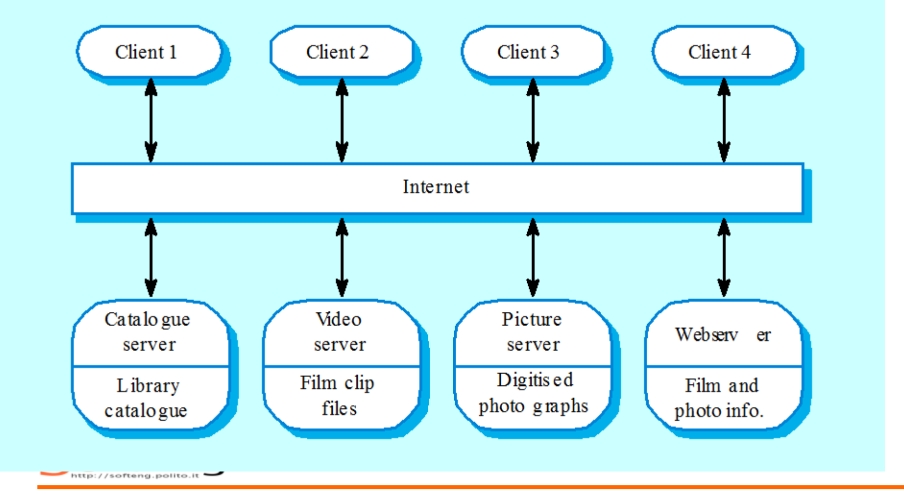
Client-server model

- Distributed system model which shows how data and processing is distributed across a range of components.
- Set of stand-alone servers which provide specific services such as printing, data management, etc.
- Set of clients which call on these services.
- Network which allows clients to access servers.

Film and picture library



Client-server characteristics

- Advantages
  - Distribution of data is straightforward;
  - Makes effective use of networked systems. May require cheaper hardware;
  - Easy to add new servers or upgrade existing servers.
- Disadvantages
  - No shared data model so sub-systems use different data organisation. Data interchange may be inefficient;
  - Redundant management in each server;
  - No central register of names and services - it may be hard to find out what servers and services are available.

Abstract machine (layered) model

- Used to model the interfacing of sub-systems.
- Organises the system into a set of layers (or abstract machines) each of which provide a set of services.
- Constraint: layer uses only services from adjacent layer
- Advantages
  - In design: each layer is about a problem (separation of concerns)
  - In evolution: when a layer interface changes, only the adjacent layer is affected.
- Problems
  - Sometimes artificial to structure systems in this way.

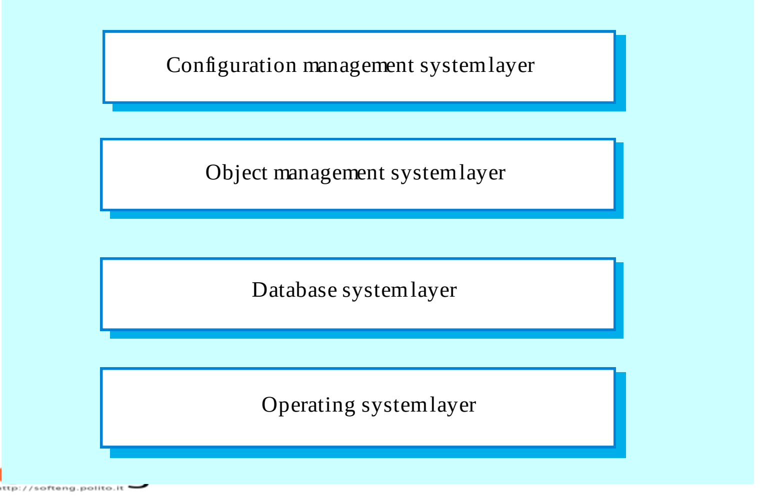
ISO Osi model

7 application
6 presentation
5 session
4 transport
3 network
2 data link
1 physical

3 tier architecture

Presentation	Presentation
Application logic	Application logic
Data (drivers)	Data (DBMS)

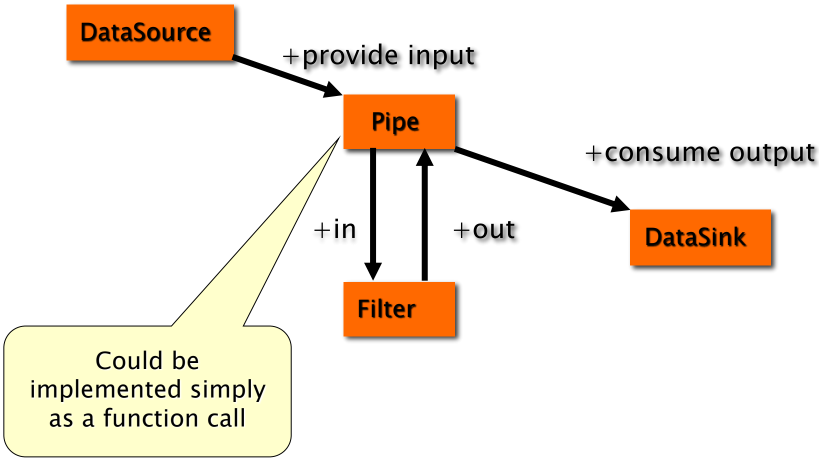
Version management system



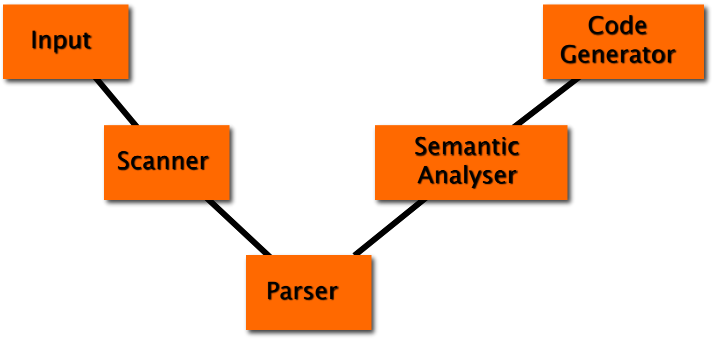
Pipes & Filters

- Context
  - We need to process data streams according to several steps
- Problem
  - Must be possible recombining steps
  - Non-adjacent steps do not share info
  - The user storing data after each step may result into errors and garbage

Pipes & Filters

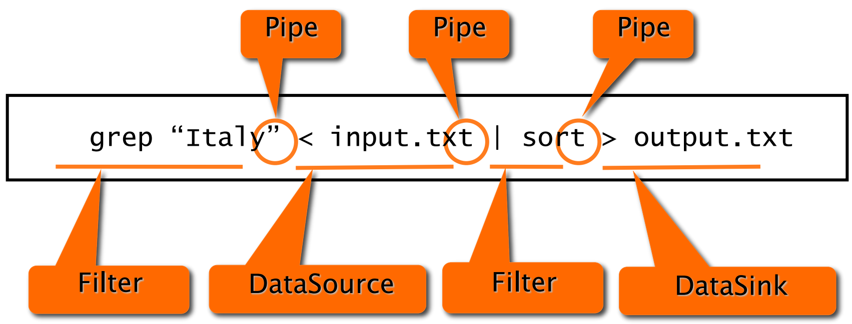


Pipes & Filters Example

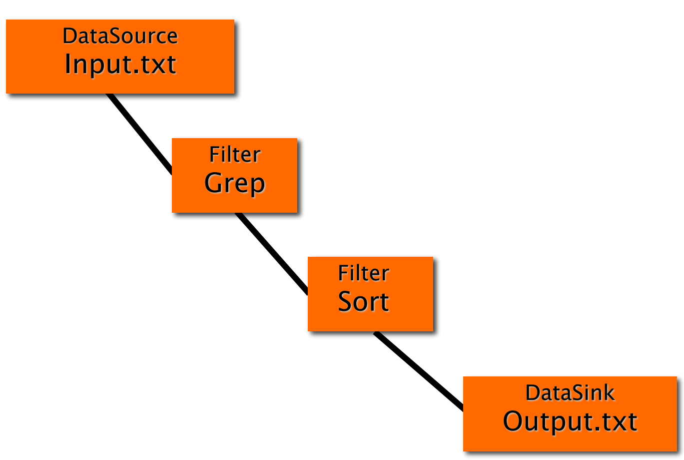


Pipes & Filter Example

Unix shell commands



Pipes & Filter Example



Pipes & Filter Example

Input.txt

```
Rome, Italy
Milan, Italy
Turin, Italy
Paris, France
Marseille, France
Brussels, Belgium
Munich, Germany
Berlin, Germany
```

Pipes & Filter Example

grep “Italy” < Input.txt

```
Rome, Italy
Milan, Italy
Turin, Italy
Paris, France
Marseille, France
Brussels, Belgium
Munich, Germany
Berlin, Germany
```

Pipes & Filter Example

| sort > output.txt

```
Rome, Italy
Milan, Italy
Turin, Italy
```

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Pipes & Filter Example

Output.txt

```
Milan, Italy
Rome, Italy
Turin, Italy
```

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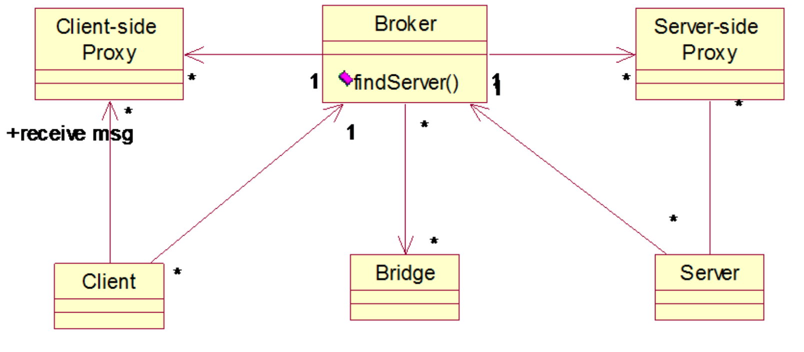
Broker

- Context
  - Environment with distributed and possibly heterogeneous components
- Problem
  - Components should be able to access others
    - Remotely
    - Location independently
  - Components can be changed at run-time
  - Users should not see too many details

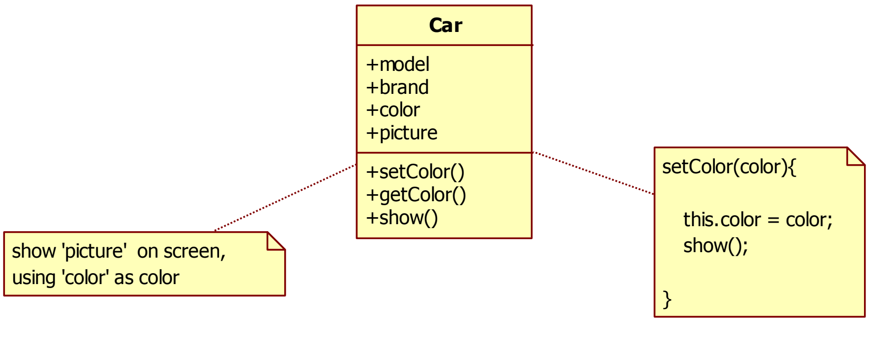
Broker



MVC – Problem

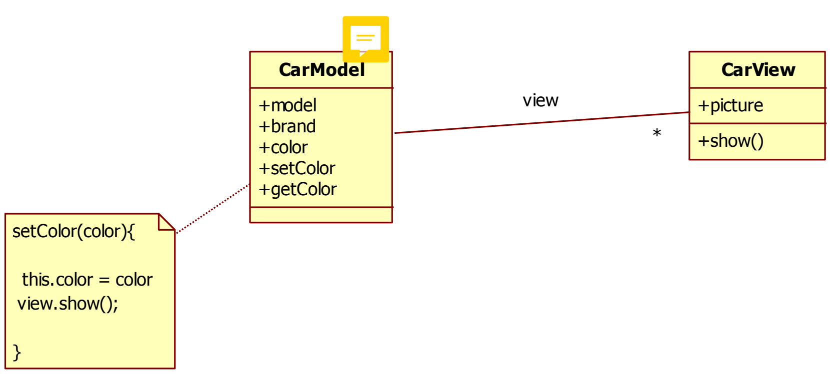
- Show data to user, manage changes to data
  - Option1: one class
  - Option2: MVC pattern

Option1

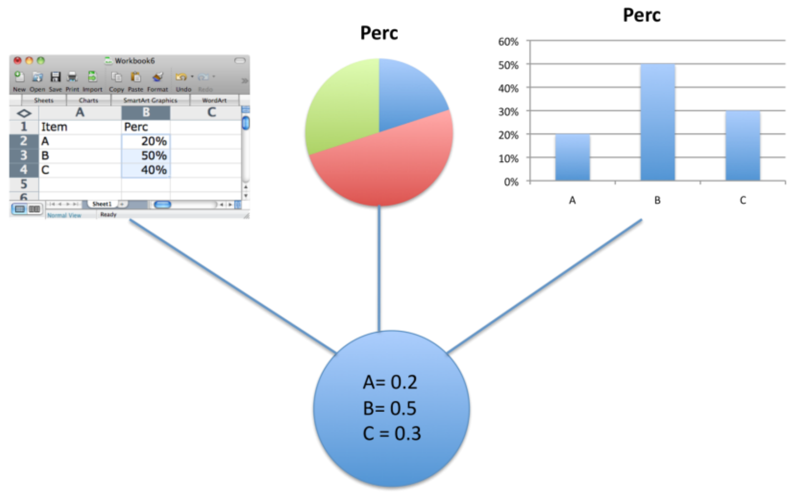


Option1

- Pro
  - Easy
- Con
  - What if two (three..) pictures?



Another case



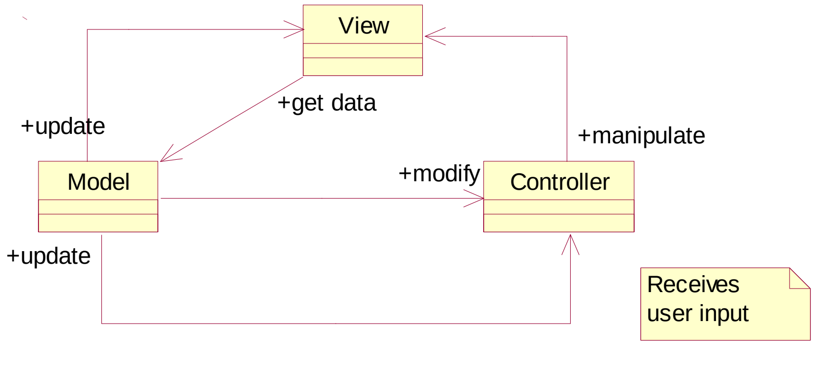
MVC

- Context
  - Interactive applications with flexible HCI
- Problem
  - The same information is presented in different ways/windows
  - Windows must present consistent data
  - Data changes
- Goal (product property)
  - Maintainability, portability

MVC

- Model
  - Responsible to manage state (interfaces with DB or file system)
- View
  - Responsible to render on UI
- Controller
  - Responsible to handle events from UI

MVC



- Pros
  - Separation of responsibilities
    - Many different views possible
    - Model and view can evolve independently (maintainability)
- Cons
  - More complexity (less performance)

Execution flow

- There is no predefined order of execution
  - Operation are performed in response to external events (e.g. mouse click)
  - Event handling is serialized
  - To execute operations in parallel threads must be used
  - Method main in GUIs has the only goal of instantiating the graphical elements

MVC implementations

- Given the high level idea
- Different implementations happen in different environments
  - Java
  - C#
  - Android
  - IoS

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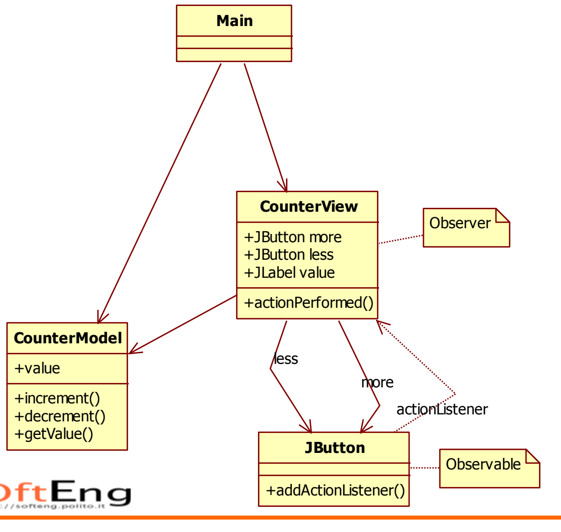
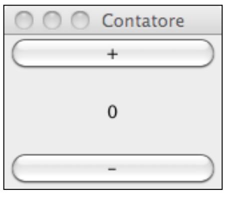
MVC in Java (MV)





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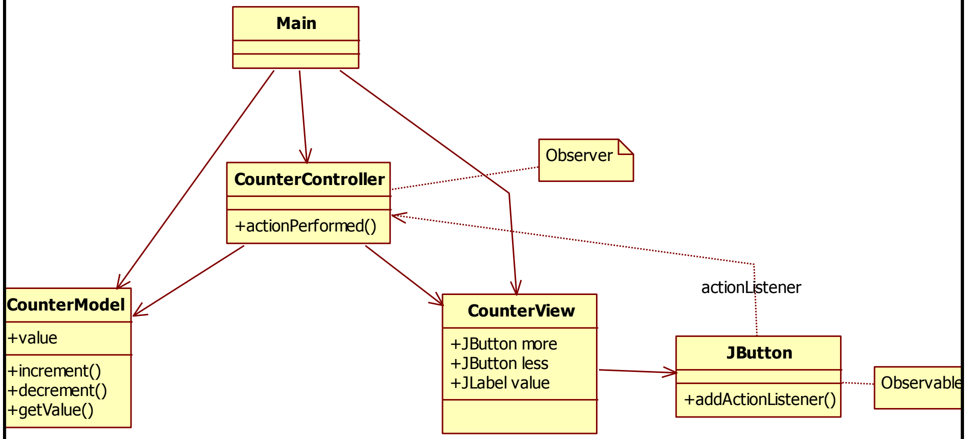
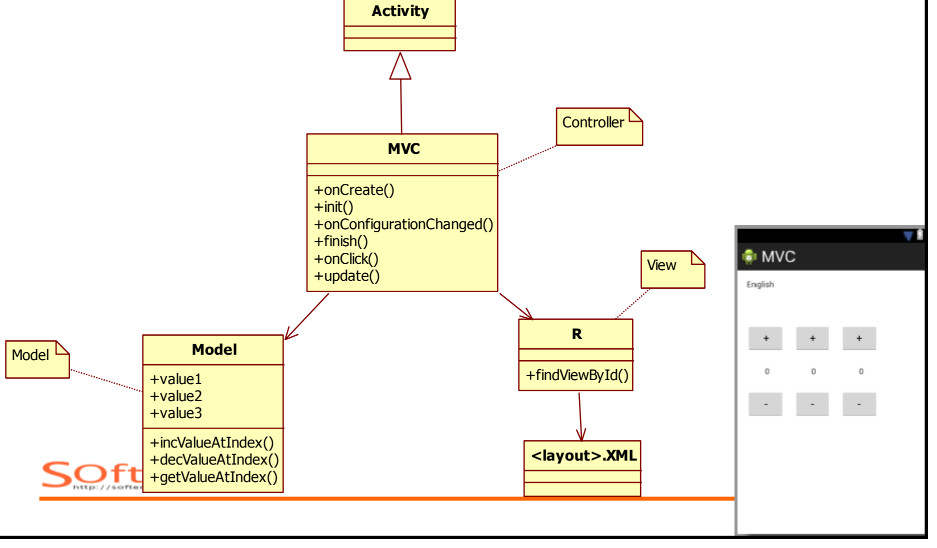
```java
class CounterView implements ActionListener {
    private CounterModel model;
    private JLabel valueLabel;
    private JButton more;
    private JButton less;

    public CounterView(CounterModel m, JPanel panel) {
    model = m;

    int value = model.getValue();
    panel.add(new JLabel("counter"));
    panel.add(valueLabel= new JLabel(Integer.toString(value)));
    more = new JButton("more");
    less = new JButton("less");
    panel.add(more);
    panel.add(less);
    more.addActionListener(this);
    less.addActionListener(this);
    }

    public void update(){
    valueLabel.setText(Integer.toString(model.getValue()));
    }

    public void actionPerformed(ActionEvent arg0) {
      Object o = arg0.getSource();
      if (o== more) model.increment();
      if (o == less) model.decrement();
      update();
    }

    }
```

```java
public class CounterModel {

  private int value;
  public void increment(){ value++;}
  public void decrement(){ value--;}
  public int getValue(){ return value;}


}
public class MainMV {

public static void main(String[] args) {


JFrame frame = new JFrame();
JPanel panel = new JPanel();
panel.add(new JLabel("here"));
frame.setContentPane(panel);
frame.setSize(300,100);
frame.setVisible(true);
frame.repaint();

CounterModel m = new CounterModel();
CounterView v = new CounterView(m, panel);
}
```

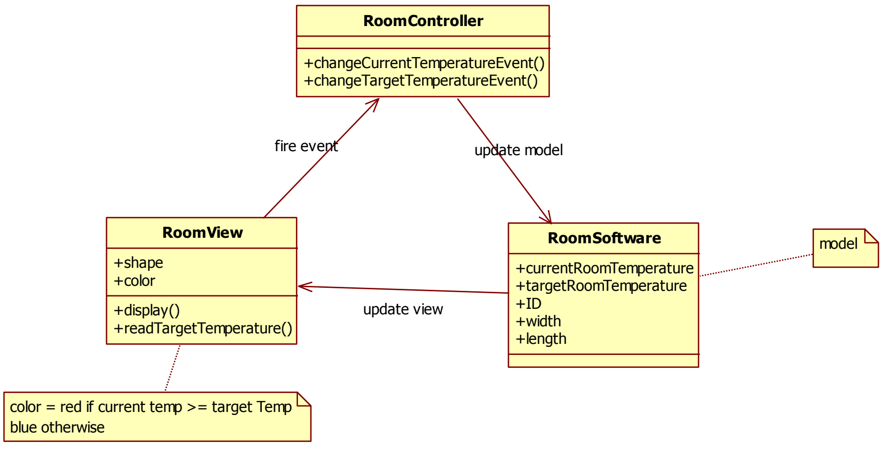
MVC in Java (MVC)



MVC in Android



In heating control system



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Microkernel

- Context
  - Several APIs insisting on a common core
- Problem
  - HW and SW evolve continuously and independently
  - The platform should be:
    - Portable
    - Extendable

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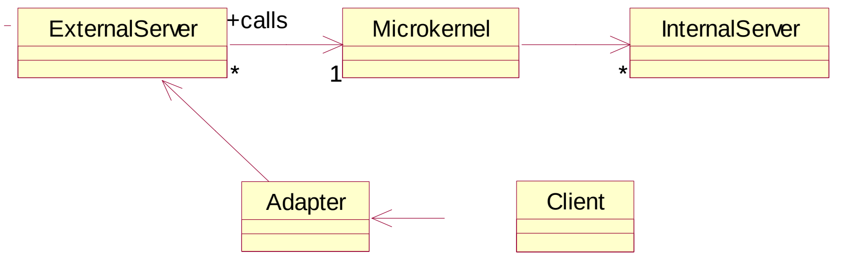
Microkernel



Summary

- Architectural patterns deal with overall system structure
- They provide a unique metaphor for the system (e.g. pipe and filters)
- They address specific domains (e.g. distribution or interaction) and system evolvability

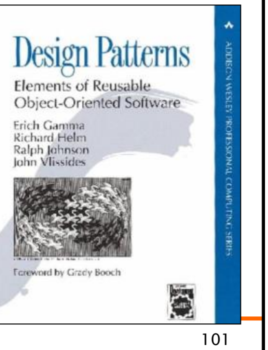
Design patterns

Design Patterns (GoF)

- Describe the structure of components
- Most widespread category of pattern
- First category of patterns proposed for software development

Design Patterns (GoF)

- Creational
  - E.g. Abstract Factory, Singleton
- Structural
  - E.g. Façade, Composite
- Behavioral
  - *Class:* e.g. Template Method
  - *Object:* e.g. Observer



Design patterns

- Description of communicating objects and classes that are customized to solve a general design problem in a particular context
- A design pattern names, abstracts, and identifies the key aspects of a common design structure that make it useful for creating a reusable object-oriented design

Description

- Name and classification
- Intent
  - Also known as
- Motivation
- Applicability
- Structure
- Participants
- Collaborations

Description

- Consequences
- Implementation
- Sample code
- Known uses
- Related patterns

Classification

- Purpose
  - Creational
  - Structural
  - Behavioral
- Scope
  - Class
  - Object

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Classification

Scope		Purpose		
		Creational	Structural	Behavioral
	Class	1	1	2
	Object	4	6	10

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Pattern selection

- Consider how patterns solve problems
- Scan intent sections
- Study how pattern interrelate
- Study patterns of like purpose
- Examine a cause of redesign
- Consider what should be variable in your design

Using a pattern

- Read through the pattern
- Go back and study
  - Structure
  - Participants
  - Collaborations
- Look at the sample code

Using a pattern

- Choose names for participants
  - Meaningful in the application context
- Define the classes
- Choose operation names
  - Application specific
- Implement operations

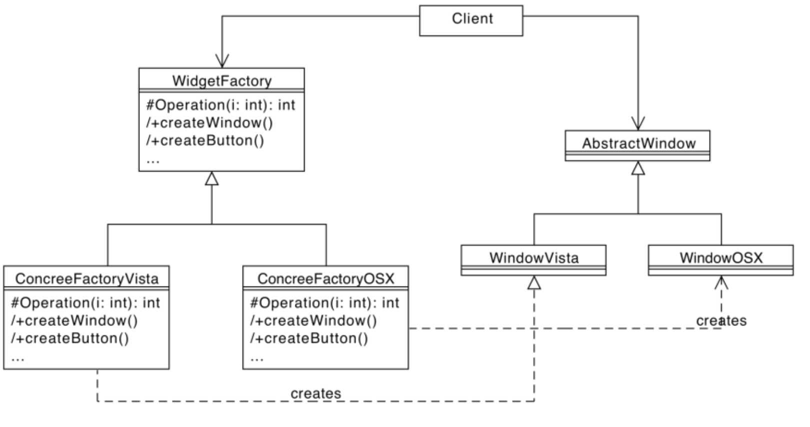
Creational patterns

- Factory Method
- Abstract Factory
- Builder
- Prototype
- Singleton

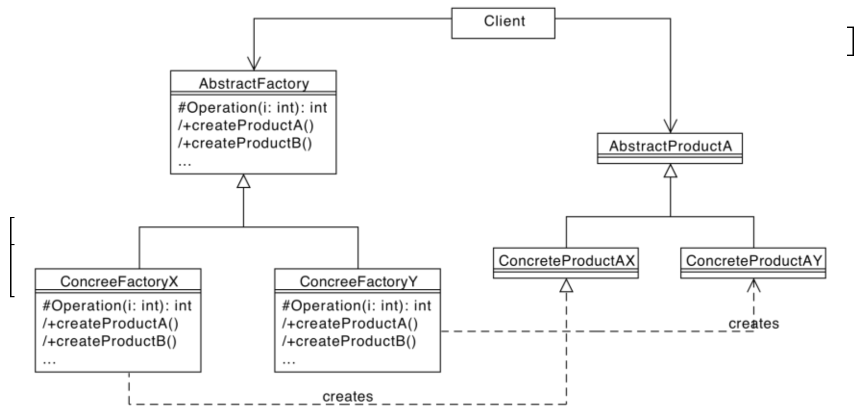
Abstract Factory

- Context
  - A family of related classes can have different implementation details
- Problem
  - The client should not know anything about which variant they are using / creating

Abstract Factory Example



Abstract Factory



Singleton

- Context:
  - A class represents a concept that requires a single instance
- Problem:
  - Clients could use this class in an inappropriate way

Singleton

- Count how many objects in my program
- Class ObjectCounter {
- static boolean new = false;

  ObjectCounter () { if new == false then }

  static counter = 0; new = true}

  else donothing

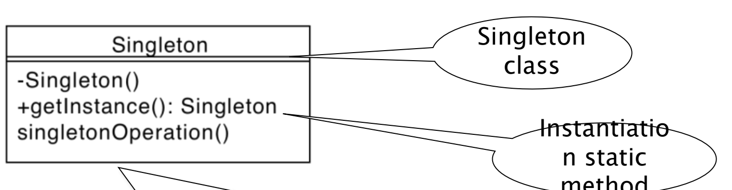
  add() {counter++;}

  sub() {counter--;} }

Client: ObjectCounter oc = new ObjectCounter();

.... Oc.add(); ... Oc.sub

Singleton




```
private Singleton() { }
private static Singleton instance;
public static Singleton getInstance(){
    if(instance==null)
        instance = new Singleton();
    return instance;
}
```

Structural patterns

- Structural patterns are concerned with how classes and objects are composed to form larger structures.

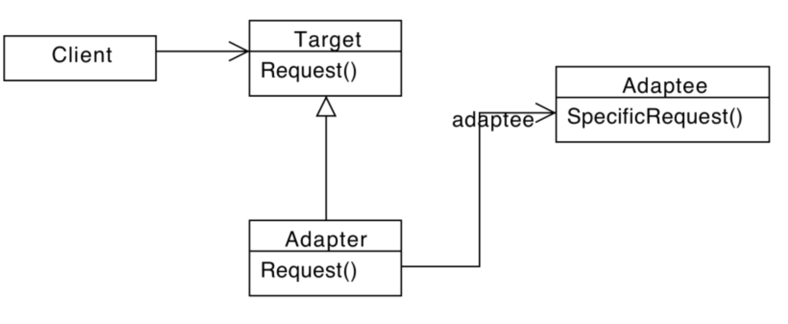
GoF structural patterns

- Adapter
- Bridge
- Composite
- Decorator
- Facade
- Flyweight
- Proxy

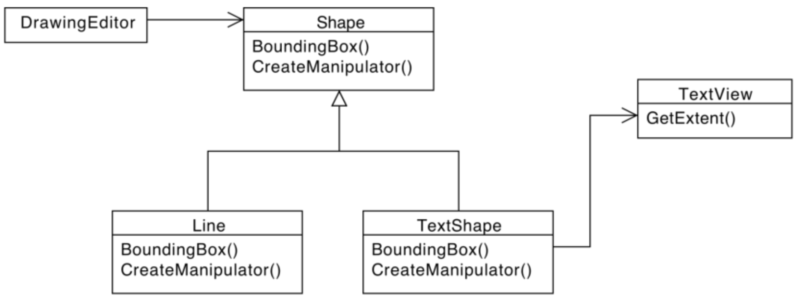
Adapter

- Context:
  - A class provides the required features but its interface is not the one required
- Problem:
  - How is it possible to integrate the class without modifying it
    - Its source code could be not available
    - It is already used as it is somewhere else

Adapter



Adapter example



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Java Listener Adapter

- In Java GUI events are handled by Listeners
- Listener classes need to implement Listener interfaces
  - Include several methods
  - They all should be implemented

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Java Listener Adapter

```
class MyListener{
public void KeyPressed(..){}
public void KeyReleased(..){
// … handle event
}
public void KeyTyped(..){} }
```

```
class MyListener{
public void KeyReleased(..){
// … handle event
}
}
```

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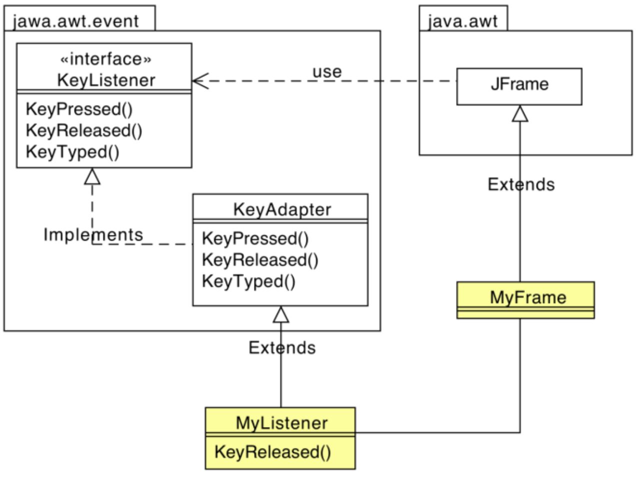
Java Listener Adapter



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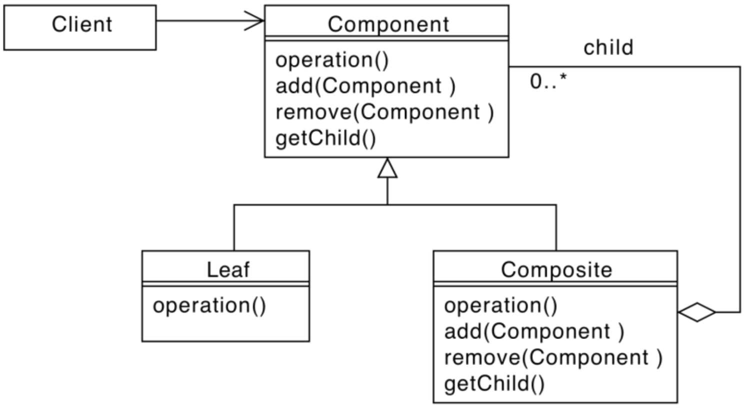
Structural Class Patterns

- Adapter pattern
  - Inheritance plays a fundamental role
  - Only example of structural class pattern

Composite

- Context:
  - You need to represent part-whole hierarchies of objects
- Problem
  - Clients are complex
  - Difference between composition objects and individual objects.

Composite

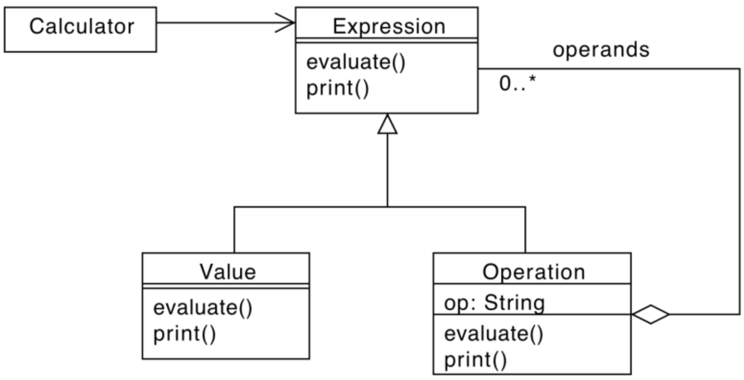


Composite Example

- Arithmetic expressions representation
  - Operators
  - Operands

  - A+ B * (A + B)
- Evaluation of expressions

Composite Example



Composite Example

```
abstract class Expression {
public abstract int evaluate();
public abstract String print();
}
```

Composite Example

```
class Value {
private int value;

public Value(int v){
value = v;
}
public int evaluate(){
    return value;
}
public String print(){
return new String(value);
}
}
```

Composite Example

```
class Operation {
private char op; // +, -, *, /
private Expression left, right

public Operation(char op,
  Expression l, Expression r){
this.op = op;
left = l;
right= r;
}
…
```

Composite Example

```
class Operation {
…
public evaluate(){
switch(op){
case '+': return
        left.evaluate() +
            right.evaluate();
        break;
…
}
}
…
```

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Composite Example

```
class Operation {
…
public print(){
return left.print() + op +
        right.print();
}
}
```

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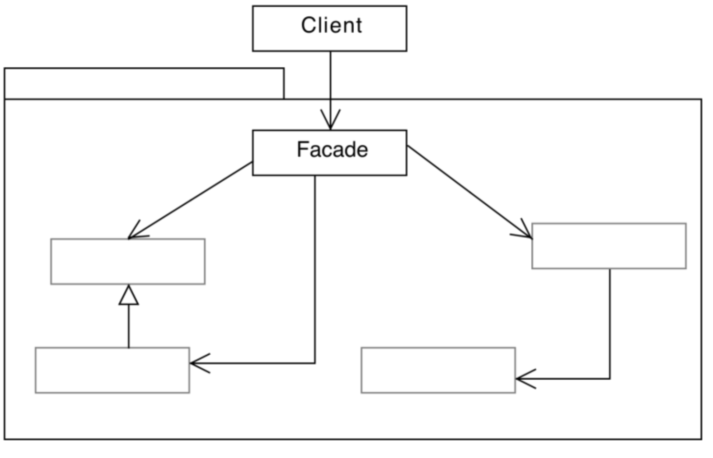
Facade

- Context
  - A functionality is provided by a complex group of classes (interfaces, associations, etc.)
- Problem
  - How is it possible to use the classes without being exposed to the details

Façade



- Package

Pub Class A { pub void method1()}

Pub Class B { pub void method2()}

Pub Class C { void method3()}

- Client

A.method1(); b.method2() C.method3()

- Package

Public Class Facade {

void method1(A.metho

void method2(B.methoc

void method3(C.methoc

}

- Client

Facade.method1(); Facade.method2() Facade.method3()

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Behavioral patterns

- Behavioral patterns are concerned with algorithms and the assignment of responsibilities between objects.
- Not just patterns of objects or classes but also the patterns of communication.
  - Complex control flow that's difficult to follow at run-time.
  - Shift focus away from flow of control to let concentrate just on the way objects are interconnected.

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GoF behavioral patterns

- Object-level
  - Chain of Responsibility
  - Command
  - Iterator
  - Mediator
  - Memento
  - Observer
  - State
  - Strategy
  - Visitor
- Class-level
  - Template Method
  - Interpreter

Mechanisms

- Encapsulating variation
- Objects as arguments
- Information circulation policies
- Sender and Receiver decoupling

Encapsulating Variation

- A varying aspect of a program
- Captured by an object
  - Other delegate operations to the “variant” object

Argument Objects

- Often an object is passed as argument
  - Hides complexity from clients
  - Concentrate the “active” code in one class

Information circulation

- Responsibility of how to circulate information may be:
  - Distributed among different parties.
  - Encapsulated in a single object.

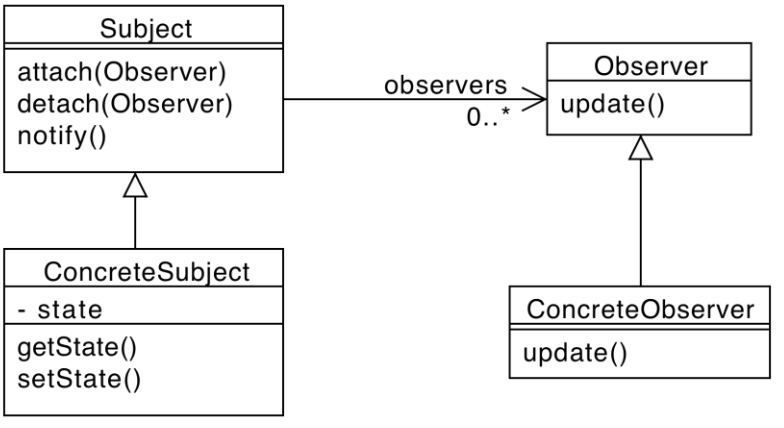
Communication decoupling

- Decoupling senders and receivers is a key to:
  - Reduce coupling
  - Improve reusability
  - Enforce layering and structure

Observer

- Context:
  - The change in one object may influence one or more other objects
- Problem
  - High coupling
  - Number and type of objects to be notified may not be known in advance

Observer



Observer – Consequences

+Abstract coupling between Subject and Observer

+Support for broadcast communication

-Unanticipated updates

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Java Observer-Observable

```
class Observable{
void addObserver(..){}
void deleteObserver(..){}
void deleteObservers(){}
int countObservers() {}
void setChanged() {}
void clearChanged() {}
boolean hasChanged() {}
void notifyObservers() {}
void notifyObservers(..) {}
}
```

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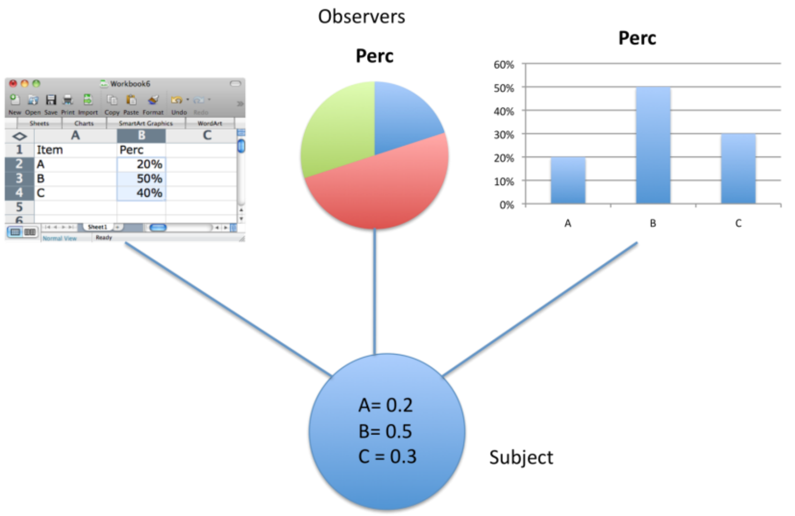
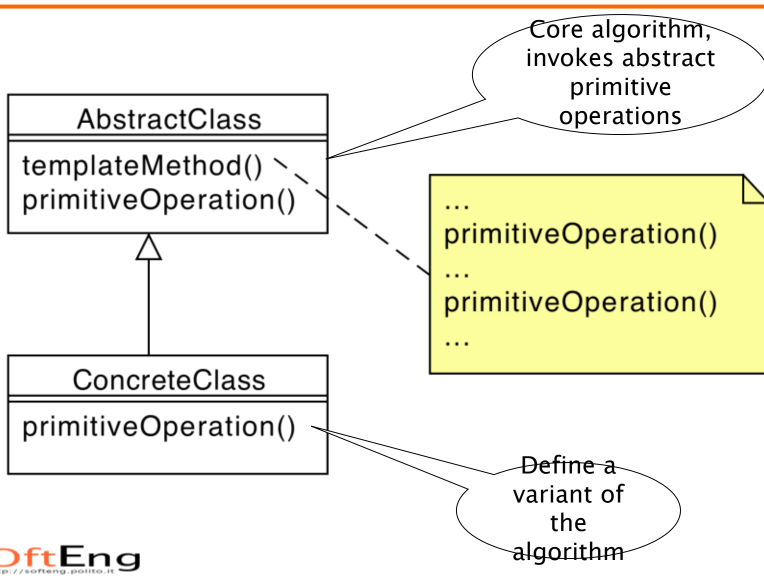
Observer Example



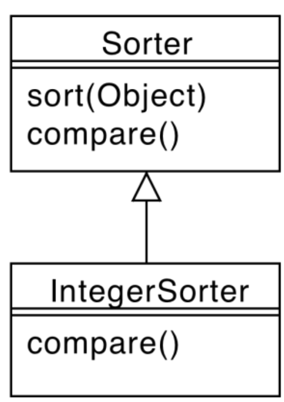
Template Method

- Context:
  - An algorithm/behavior has a stable core and several variation at given points
- Problem
  - You have to implement/maintain several almost identical pieces of code

Template Method



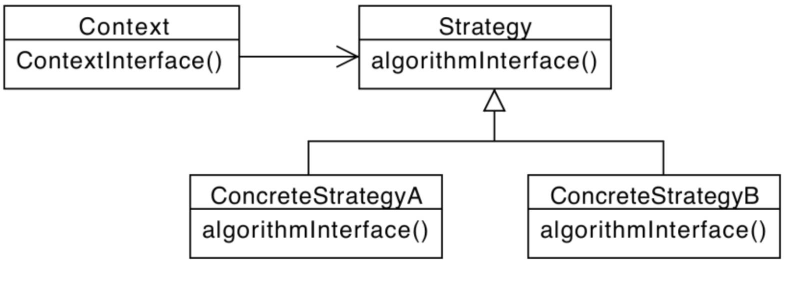
Template Method Example



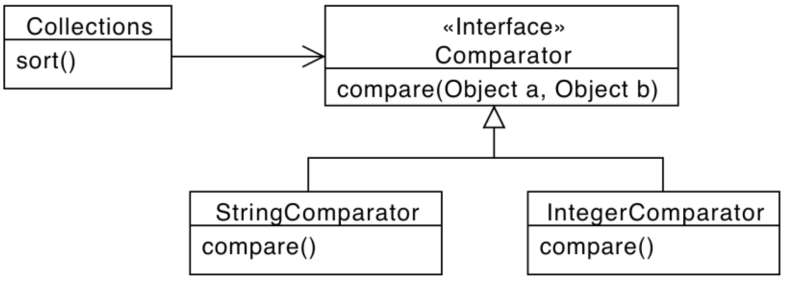
Strategy

- Context
  - Many classes or algorithms have a stable core and several behavioral variations
- Problem
  - Several different implementations are needed.
  - Multiple conditional constructs tangle the code.

Strategy



Strategy Example



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Consequences

+ Avoid conditional statements
+ Algorithms may be organized in families
+ Choice of implementations
+ Run-time binding
- Clients must be aware of different strategies
- Communication overhead
- Increased number of objects

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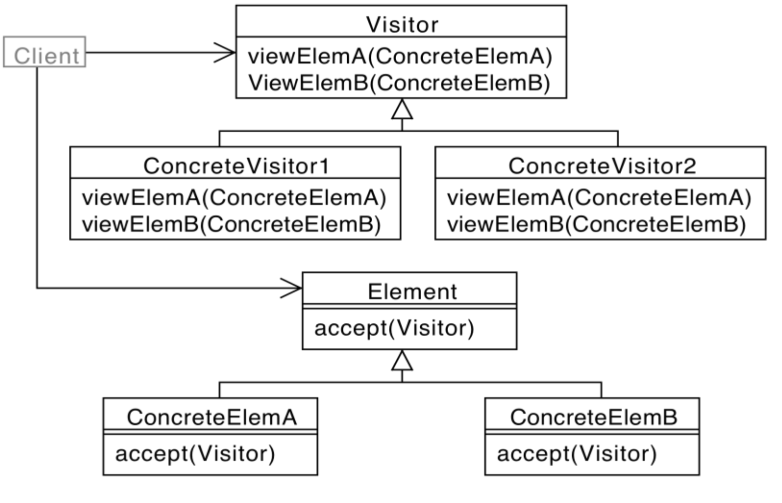
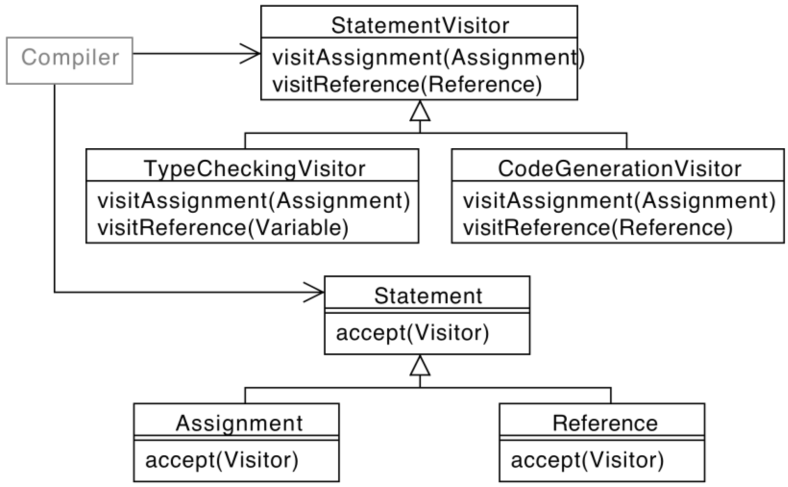
Visitor

- Context
  - An object structure contains many classes with differing interfaces.
  - Many different operations need to be performed on the objects
- Problem
  - The operations on the objects depend on their concrete classes
  - Classes could be polluted with several operations

Visitor



Visitor Example



Consequences

+ Adding new operations is very easy
+ Behavior is partitioned
+ Can visit class hierarchies
+ State can be accumulated

– Difficult to add new concrete elements
– Break of encapsulation

Java Idioms

- Often used in Java programs and libraries:
  - Default interface adapter
    - Variant of Adapter
  - Enumeration class
    - Variant of flyweight

Enumeration Class

- Context
  - Often some variable are inherently of an enumerative type. E.g. states
  - The typical solution is to use an integer type with some constants
- Problem
  - How to enforce the use of the allowed values only
  - How to print the string values?

Enumeration Class

- Enumeration E = { V1, V2, … }

Repeat for every value in enumeration

```
class E {
  int value;
  public static int _V1=1;
  public static String V1_NAME = “V1”;
  public static E V1=new E(_V1,V1_NAME);
  private E(int id, String name){ }
  public String toString(){ }
}
```


Enumerator Class Example

- Visibility {private, public, package}

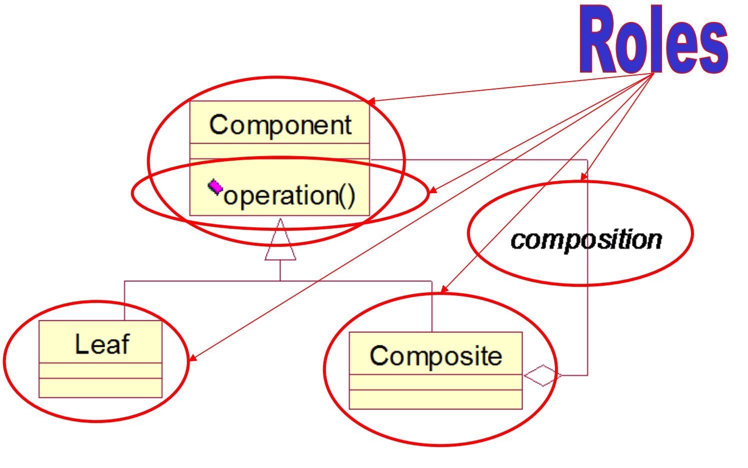
```
Visibility a = Visibility.PUBLIC;
Visibility b = Visibility.PRIVATE;
if( a != b ){
  System.out.println(a + “ != “ + b);
}
Visibility c = new Visibility(1,”friend”);
```

Constructor not visible

Analysis with Patterns

- Process:
  - Find out what patterns are used
  - Find out what the role assignments are
  - Find out how functionalities are implemented by means of patterns
  - …use this knowledge

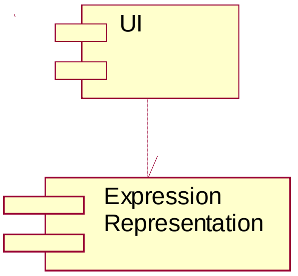
Example



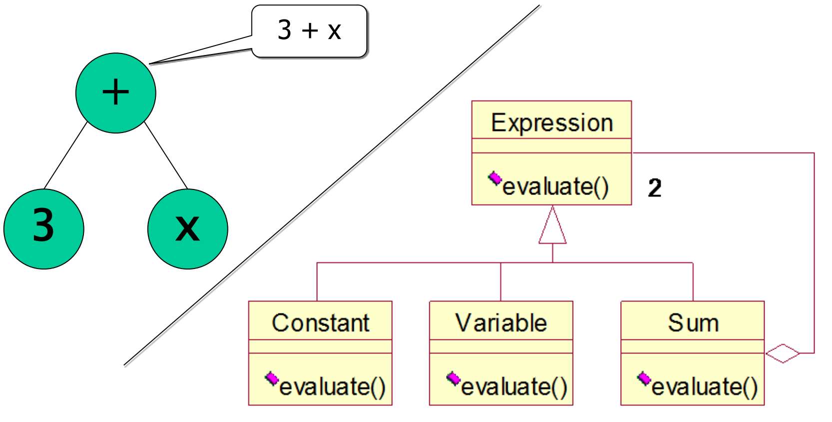
Example

- A program that handles symbolic algebraic expression manipulation
- Functionality:
  - Definition of expressions
  - Evaluation of expressions

Example – Architecture



Expression Representation



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Expression Definition

```
Constant three=new Constant(3);
Variable x = new Variable("x");
Expression e = new Sum(three,x);
//…
float result = e.evaluate();
//…
```

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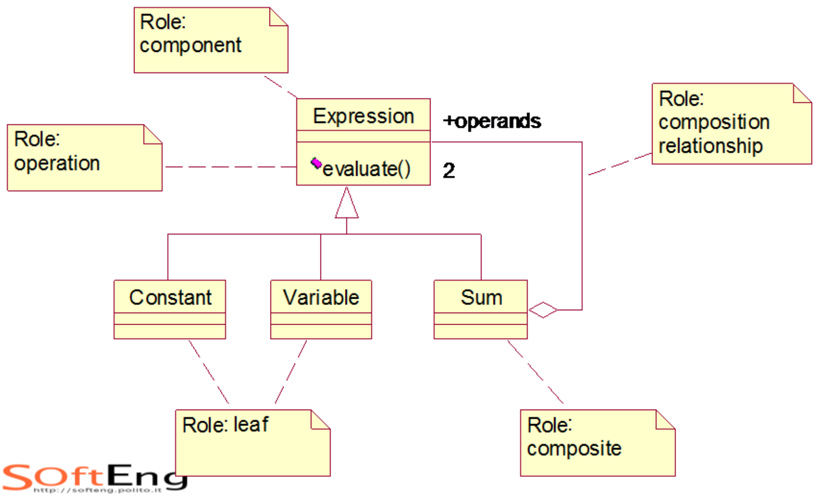
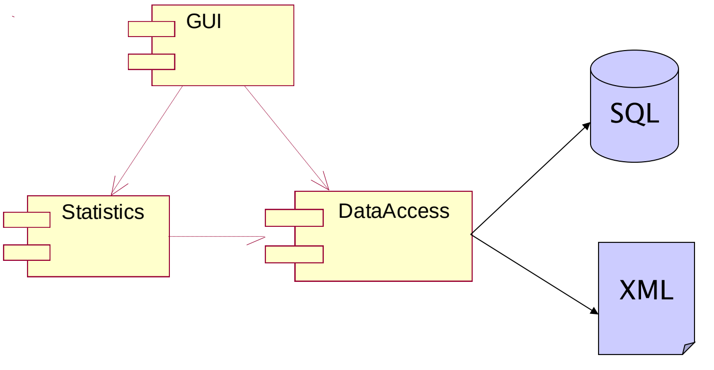
Roles Assignments



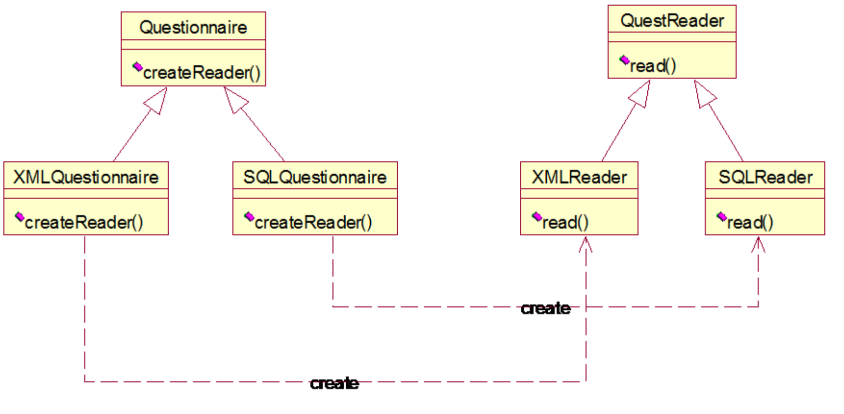
Exercise

- A program that calculates statistics for questionnaire replies.
- Data can be either in:
  - An XML file
  - A relational database
- All the statistics manipulations are independent from the medium

Exercise – Architecture



Exercise – Data Access



Exercise – Questionnaire

```
public abstract class Questionnaire{
  private static Questionnaire single;
  public static Questionnaire getQuestionnaire(){
    if(single!=null) return single;
    single = new something();
    return single;
  }
  public QuestReader createReader();
}
```

```
Questionnaire q =
    Questionnaire.getQuestionnaire();
QuestReader qread = q.createReader();
//…
q.read();
```


Exercise

- What patterns are used in this example?
- What are the role assignments?
- What purpose do(es) the pattern(s) serve?

Verification

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Verification

- Functional requirements
  - Traceability matrix
  - Scenarios executed on architecture
  - Inspection
- Non functional requirements
  - Performance
    - Scenarios enriched with time model
  - (Inspection)

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Traceability matrix

	AwayManagementStrategy	Boiler	CRoom	DefaultHouseSettings	Env	Environment	HouseController	InvalidTimeException	PhysBoiler	PresenceManagementStrategy	Room	RoomManagementStrategy	RoomSettings	SetRoomParametersActivity	SetRoomParametersDialog	XMLSettings
Temp-UR-F1											X		X	X	X	X
Temp-UR-F2											X		X	X	X	X
Temp-UR-F3											X		X	X	X	X
Temp-UR-F4											X		X	X	X	X
Temp-UR-F5											X		X	X	X	X
Temp-UR-F6		X	X		X	X	X		X	X	X	X				
Temp-UR-F7	X	X	X		X	X	X		X		X	X				
Temp-UR-F8		X	X		X	X	X		X	X	X	X				
Temp-UR-F9		X	X		X	X	X		X	X	X	X				
Temp-UR-F10	X	X	X		X	X	X		X		X	X				
Temp-UR-F11								X							X	
Temp-UR-F12				X									X	X		
Temp-UR-F13	X	X	X		X	X	X		X		X	X				
Temp-UR-F14	X		X		X	X	X			X	X	X				
Temp-UR-F15			X		X	X	X			X	X	X				
Temp-UR-F16	X									X						
Temp-UR-F17			X	X			X				X					X
Temp-UR-F18		X					X		X							
UR-Inv 1	X	X	X		X	X	X		X		X	X				
UR-Inv 2		X	X		X	X	X		X	X	X	X				

Traceability matrix

- Each functional requirement (from requirements document) must be supported by at least one function in one class in the software design
  - The more complex the requirement, the more member functions needed

Scenarios

- Each scenario (from requirements document) must be feasible
  - It is possible to define a sequence of calls to member functions of classes in the software design that matches the scenario

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Key points

- Architecture
  - defining high level components and their control, communication model
  - Tools: UML or ADL models, structural and dynamic
  - Styles: Layered, client server (2 tier, 3 tier), peer to peer, shared repository
- Design
  - Define internals of components
  - Tools: UML models
  - Design patterns

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Key points

- Verification
  - inspections
    - Architecture can satisfy functional properties (as defined in requirements doc)?
      - Traceability matrixes
      - Scenario execution
    - Architecture can satisfy non functional requirements?
      - Enriched scenarios
  - build prototype

Bicycles ..

Draisine

- 1820
- Front wheel steering
- Foot powered

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Velocipede

- 1860
- Front wheel steering
- Crank pedal on

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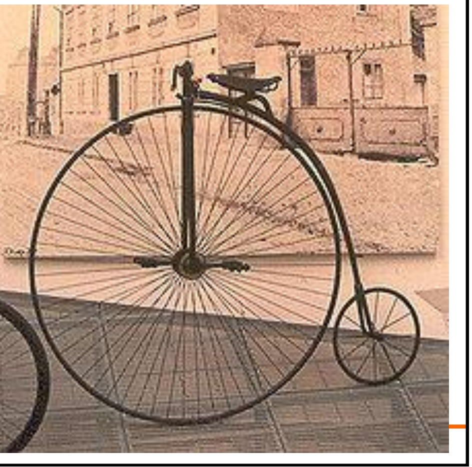
Penny farthing

- 1870
- Larger front wheel
  - More speed
  - More comfort
  - unstable



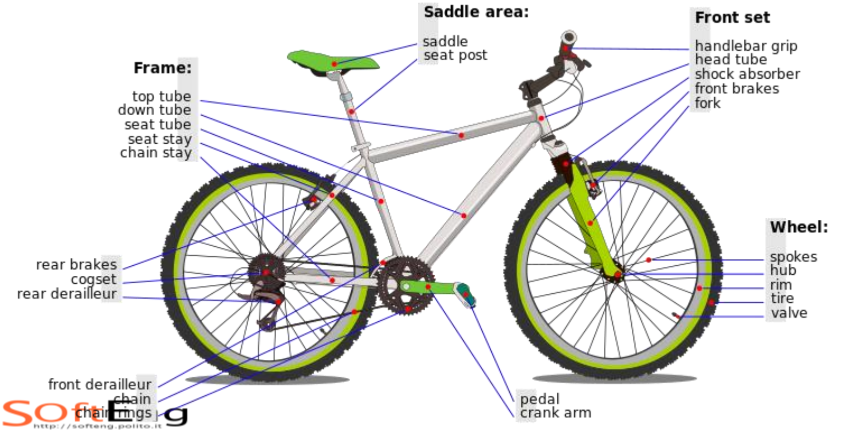
Dwarf ordinary

- Smaller front wheel, seat backwards
- More stable, less speed, less confort

And ..

- 1870, chain drive
  - Solves problem of steering and pedaling on front wheel
  - Pedals in middle, power to rear wheel
- 1885, seat tube (diamond frame)
- 1888, pneumatic tire (Dunlop)
  - Comfort
- 1890
  - Rear freewheel (coasting)
- 1905
  - Derailleur gears

Dominant design



Other designs

Requirements – bike

- Functional requirements
  - transport one person from place to place
    - Steer
    - accelerate
    - brake
- Non functional requirements
  - Efficiency : speed from 10 km/h to 50 km/h
    - (Speed from 10 km/h to 150 km/h)
  - Efficiency : weight between 10 and 15kg
  - Efficiency: reasonable torque to start: < 40Nmeters
  - Usability: out of 50 average users, at least 60% of them find the bicycle easy to use
  - Only human power (no engines)
  - Safety (no harm to driver)
  - Security (difficult to steal)
  - Cost (between 100 and 200 euro)

Design vs requirements

	Draisine	Velocipede	Penny farthing	Another design	Dominant design
Transport one person	y	Y	Y	Y	Y
Eff – speed	< 10kmh	Y	Y	Y	Y
Eff – torque at start	Y	N	N	Y	Y
Eff – weight	y	Y	Y	Y	y
Human power	y	Y	Y	Y	Y
safety	Driver less high	Driver vey high	Driver even higher	Y	Y
Reduce speed	With feet on road	Applying negative force to pedal	Applying negative force to pedal	Y	y brakes