Design Patterns

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Introduction

- About Patterns
  - The idea of patterns
  - What is a Pattern?
  - Pattern Definitions
  - Why Patterns?
  - Patterns Elements and Forms
    - GoF Pattern Form
    - Classification
  - Possible examples applied to the real life

The Idea of Patterns

- *Designing Object Oriented SW is HARD but, making it reusable is even HARDER!*

Erich Gamma

- *Unfortunately we live in a world where is "vital" create reusable applications*

… Me

The Idea of Patterns

- How to become a “Chess Master”
  - Learning the rules.
    - Name of the figures, allowed movements, geometry and table chess orientation.
  - Learning the principles
    - Value of the figures, strategic movements
  - BUT….
    - Being *as good as Kasparov* means studying, analyzing, memorized and constantly applied the matches of other Masters
  - There are **hundreds** of this matches

The Idea of Patterns

- How to become a SW Master
  - Learning the rules.
    - Algorithms, data structures, programming languages, etc.
  - Learning the principles
    - Structural programming, Modular programming, Object Oriented, etc.
  - BUT….
    - Being as *good as Kasparov* means studying, analyzing, memorized and constantly applied the "solutions" of other Masters
  - There are **hundreds** of these solutions (~patterns)

The Idea of Patterns

- *Each pattern describes a problem that happens several times in our environment, offering for it a solution in a way that it can be applied one million times without being the same twice.*
  - Christopher Alexander (1977)

Patterns

- What is a Pattern?
  - A **Solution** for a problem in a particular context.
  - **Recurrent** (applied to other situations within the same context)
  - Learning **tool**
  - With a **Name**
    - Identifies it as unique.
    - *Common* for the users community. (SIMBA)

Motivation of Patterns

- Capture the experience of the experts and make them accessible to the *"mortals"*
- Help the SW engineers and developers to ***understand*** a system when this is documented with the patterns which is using
- Help for the **redesign** of a system even if it was not assumed originally with them
- **Reusability**
    - A framework can support the code reusability

So… Why Patterns?

- Do you need more hints?
- *Designing Object Oriented SW is HARD but, making it reusable is even HARDER!*
  - *Why not to gather and document solutions that have worked in the past for similar problems applied in the same context?*
  - *Common tool to describe, identify and solve recurrent problems that allows a designer to be more productive*
  - *And the resulting designs to be more flexible and reusable*

Types of Software Patterns

- Riehle & Zullighoven *(Understanding and Using Patterns in SW development)*
- *Conceptual Pattern*
  - *Whose form is described by means of terms and concepts from the application domain.*
- ***Design Pattern***
  - *Whose form is described by means of SW design constructs (objects, classes, inheritance, etc.)*
- *Programming Pattern*
  - *Whose form is described by means of programming language constructs*

Gang Of Four

- There are several Design Patterns Catalogues
- Most of the Designers follow the book Design Patterns: Elements of Reusable Object Oriented Software
  - E. Gamma, R. Helm, R. Johnson, J. Vlissides.

Classification of Design Patterns

- **Purpose** (what a pattern does)
  - Creational Patterns
    - Concern the process of ***Object Creation***
  - Structural Patterns
    - Deal with de ***Composition*** of Classes and Objects
  - Behavioral Patterns
    - Deal with the ***Interaction*** of Classes and Objects

- **Scope** – what the pattern applies to
  - Class Patterns
    - Class, Subclass relationships
    - Involve Inheritance reuse
  - Object Patterns
    - Objects relationships
    - Involve Composition reuse

Essential Elements of Design Pattern

- ***Pattern Name***
  - Having a concise, meaningful name improves communication between developers
- ***Problem***
  - Context where we would use this pattern
  - Conditions that must be met before this pattern should be used

Essential Elements of Design Pattern

- ***Solution***
  - A description of the elements that make up the design pattern
  - Relationships, responsibilities and collaborations
  - Not a concrete design or implementation. Abstract
- ***Consequences***
  - Pros and cons of using the pattern
  - Includes impacts of reusability, portability…

Pattern Template

- Pattern **Name** and Classification
- **Intent**
  - What the pattern ***does***
- Also **Known As**
  - Other ***names*** for the pattern
- **Motivation**
  - A ***scenario*** that illustrates where the pattern would be useful
- **Applicability**
  - Situations where the pattern ***can be used***

Pattern Template - II

- **Structure**
  - Graphical ***representation*** of the pattern
- **Participants**
  - The ***classes & objects*** participating in the pattern
- **Collaborations**
  - How to do the participants interact to carry out their responsibilities?
- **Consequences**
- **Implementations**
  - Hints and Techniques for implementing it

Pattern Template - III

- **Sample Code**
  - Code fragments for a Sample Implementation
- **Known Uses**
  - Examples of the pattern in real systems
- **Related Patterns**
  - Other patterns closely related to the patterns

Pattern Groups (GoF)

Let’s go to the kernel !!

- Taxonomy of Patterns
  - ***Creational Patterns***
    - They abstract the process of instances creation
  - ***Structural Patterns***
    - How objects and classes are used in order to get bigger structures
  - ***Behavioral Patterns***
    - Characterize the ways in which classes or objects interact and distribute responsibilities

Creational Patterns

- Deal with the best way to ***create*** instances of objects

```
Listbox list = new Listbox()
```

- Our program should not depend on how the objects are created
- The exact nature of the object created could vary with the needs of the program
  - Work with a special “creator” which abstracts the creation process

Creational Patterns (II)

- Factory Method
  - Simple decision making class that returns one of several possible subclasses of an abstract base class depending on the data we provided
- Abstract Factory Method
  - Interface to create and return one of several families of related objects
- Builder Pattern
  - Separates the construction of a complex object from its representation
- Prototype Pattern
  - Clones an instantiated class to make new instances rather than creating new instances
- Singleton Pattern
  - Class of which there can be no more than one instance. It provides single global point of access to that instance

Structural Patterns

- Describe how classes & objects can be ***combined*** to form ***larger structures***
- Concerning the **scope**
  - *Class Patterns: How inheritance can be used to provide more useful program interfaces*
  - *Object Patterns: How objects can be composed into larger structures (objects)*

Structural Patterns II

- Adapter
  - Match interfaces of different classes
- Bridge
  - Separates an object’s interface from its implementation
- Composite
  - A tree structure of simple and composite objects
- Decorator
  - Add responsibilities to objects dynamically
- Façade
  - A single class that represents an entire subsystem
- Flyweight
  - A fine-grained instance used for efficient sharing
- Proxy
  - An object representing another object

Behavioral Patterns

- Concerned with communication between objects
- It’s easy for an unique client to use one abstraction
- Nevertheless, it’s possible that the client may need multiple abstractions…
- …and may be it does not know before using them how many and what!
  - This kind of Patterns (observer, blackboard, mediator) will allow this communication

Behavioral Patterns

- Chain of Responsibility
  - A way of passing a request between a chain of objects
- Command
  - Encapsulate a command request as an object
- Interpreter
  - A way to include language elements in a program
- Iterator
  - Sequentially access the elements of a collection
- Mediator
  - Defines simplified communication between classes
- Memento
  - Capture and restore an object's internal state

Behavioral Patterns III

- Observer
  - A way of notifying change to a number of classes
- State
  - Alter an object's behavior when its state changes
- Strategy
  - Encapsulates an algorithm inside a class
- Template
  - Defer the exact steps of an algorithm to a subclass
- Visitor
  - Defines a new operation to a class without change

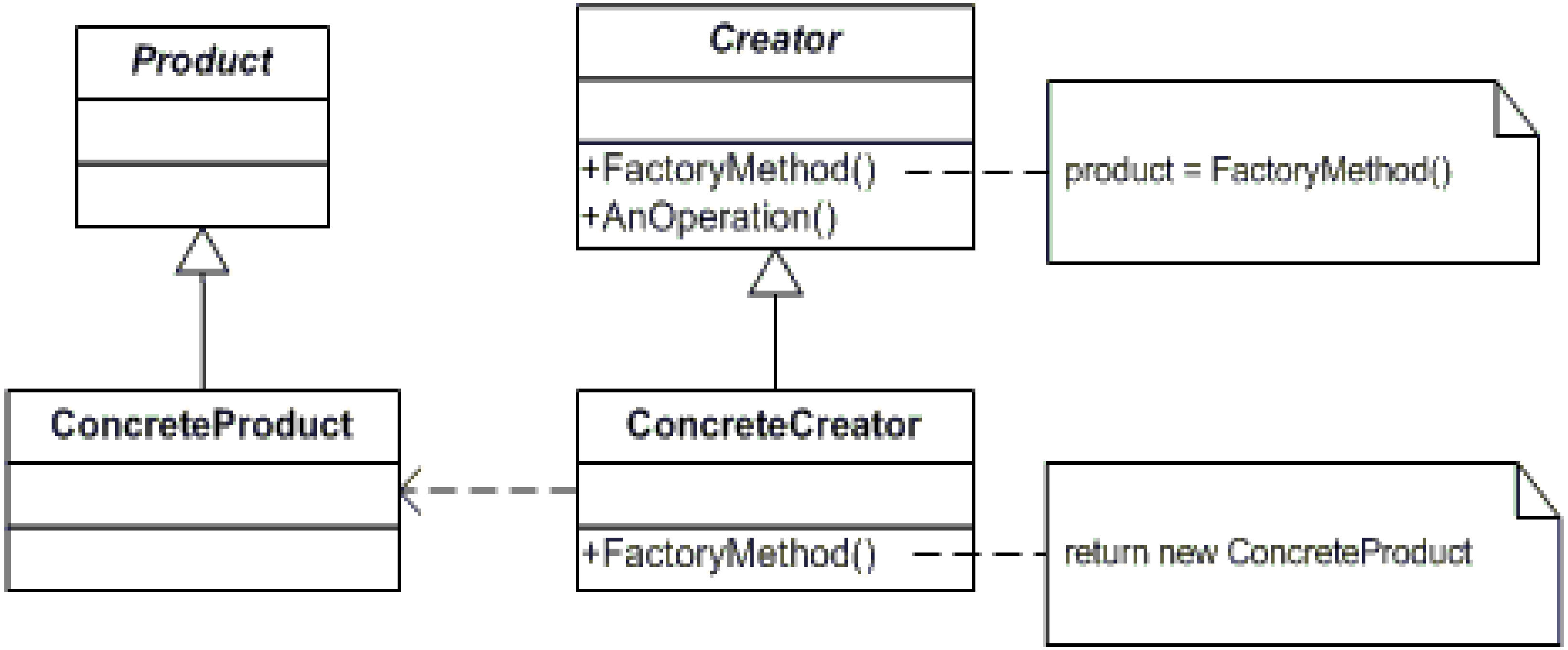
Examples applied to real life

Creational Pattern Example

- Factory
  - Define an interface for creating an object, but let subclasses decide which class to instantiate.
  - Factory Method lets a class defer instantiation to subclasses.
- Participants
  - **Product (Page)**
    - defines the interface of objects the factory method creates
  - **ConcreteProduct (SkillsPage, EducationPage, ExperiencePage)**
    - implements the Product interface
  - **Creator (Document)**
    - declares the factory method, which returns an object of type Product. Creator may also define a default implementation of the factory method that returns a default ConcreteProduct object.
    - may call the factory method to create a Product object.
  - **ConcreteCreator (Report, Resume)**
    - overrides the factory method to return an instance of a ConcreteProduct.

Creational Pattern Examples

- UML Diagram



Sample Code (Factory)

```
// Factory Method pattern –

using System;
using System.Collections;

// "Product"

abstract class Product
{
}

// "ConcreteProductA"

class ConcreteProductA :
Product
{
}

// "ConcreteProductB"

class ConcreteProductB :
Product
{  }
```

```
// "Creator"

abstract class Creator
{
  // Methods
  abstract public Product
FactoryMethod();
}

// "ConcreteCreatorA"

class ConcreteCreatorA :
Creator
{
  // Methods
  override public Product
FactoryMethod()
  {
    return new
ConcreteProductA();
  }
}
```

Sample Code (Factory)

-
  ```
  // "ConcreteCreatorB"

  class ConcreteCreatorB :
  Creator
  {
    // Methods
    override public
  Product FactoryMethod()
    {
      return new
  ConcreteProductB();
    }
  }
  ```

-
  ```
  class Client
  {
    public static void Main(
  string[] args )
    {

      // FactoryMethod
  returns ProductA
      Creator c = new
  ConcreteCreatorA();
      Product p =
  c.FactoryMethod();
      Console.WriteLine(
  "Created {0}", p );

      // FactoryMethod
  returns ProductB
      c = new
  ConcreteCreatorB();
      p = c.FactoryMethod();
      Console.WriteLine(
  "Created {0}", p );

    }
  }
  ```

Sample Code (Factory)

-
  ```
  using System;
  using System.Collections;

  // "Product"

  abstract class Page
  {
  }

  // "ConcreteProduct"

  class SkillsPage : Page
  {
  }

  // "ConcreteProduct"

  class EducationPage : Page
  {
  }

  // "ConcreteProduct"

  class ExperiencePage : Page
  {
  }
  ```

-
  ```
  // "ConcreteProduct"

  class IntroductionPage : Page
  {
  }
  // "ConcreteProduct"

  class ResultsPage : Page
  {
  }

  // "ConcreteProduct"

  class ConclusionPage : Page
  {
  }

  // "ConcreteProduct"

  class SummaryPage : Page
  {
  }
  ```

Sample Code (Factory)

```
// "Creator"

abstract class Document
{
  // Fields
  protected ArrayList pages = new ArrayList();

  // Constructor
  public Document()
  {
    this.CreatePages();
  }

  // Properties
  public ArrayList Pages
  {
    get{ return pages; }
  }

  // Factory Method
  abstract public void CreatePages();
}
```

Sample Code (Factory)

-
  ```
  // "ConcreteCreator"

  class Resume : Document
  {
    // Factory Method

   override public void
   CreatePages()
     {
       pages.Add( new
                  SkillsPage() );
       pages.Add( new
                 EducationPage() );
       pages.Add( new
                  ExperiencePage()
  );
     }
  }
  ```

-
  ```
  // "ConcreteCreator"

  class Report : Document
  {
    // Factory Method

   override public void
   CreatePages()
     {
       pages.Add( new
         IntroductionPage() );
       pages.Add( new
         ResultsPage() );
       pages.Add( new
         ConclusionPage() );
       pages.Add( new
         SummaryPage() );
       pages.Add( new
         BibliographyPage() );
     }
  }
  ```

Sample Code (Factory)

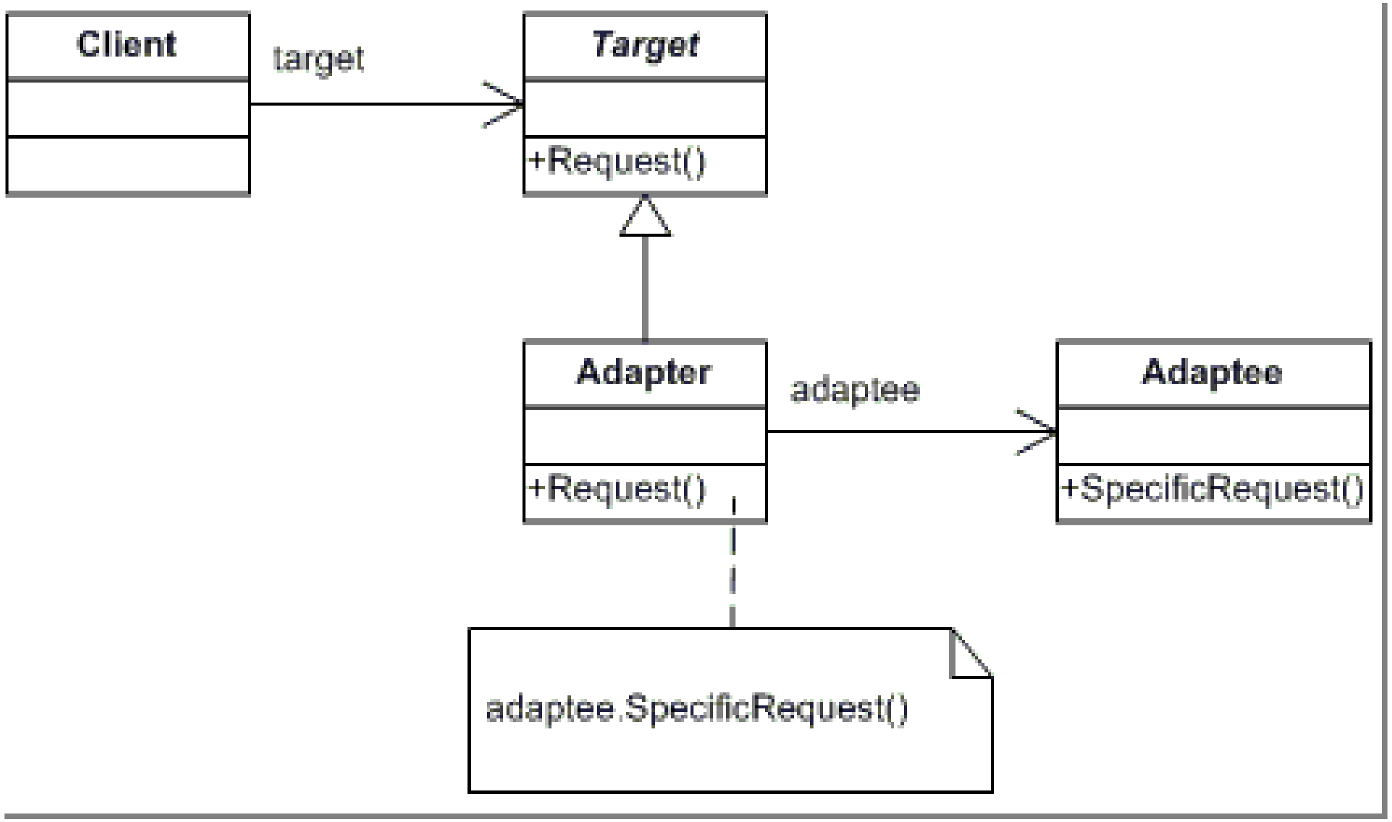
-
  ```
  /// <summary>
  ///  FactoryMethodApp test
  /// </summary>
  class FactoryMethodApp
  {
    public static void Main( string[] args )
    {
      Document[] docs = new Document[ 2 ];

      // Note: constructors call Factory Method
      docs[0] = new Resume();
      docs[1] = new Report();

      // Display document pages
      foreach( Document document in docs )
      {
        Console.WriteLine( "\n" + document + " ------- " );
        foreach( Page page in document.Pages )
          Console.WriteLine( " " + page );
      }
    }
  }
  ```

Structural Pattern Example

- Adapter
  - Convert the interface of a class into another interface clients expect.
  - Adapter lets classes work together that couldn't otherwise because of incompatible interfaces
- **Participants**
  - **Target (ChemicalCompound)**
    - defines the domain-specific interface that Client uses.
  - **Adapter (Compound)**
    - adapts the interface Adaptee to the Target interface.
  - **Adaptee (ChemicalDatabank)**
    - defines an existing interface that needs adapting.
  - **Client (AdapterApp)**
    - collaborates with objects conforming to the Target interface.

Sample Code (Adapter)

- UML Diagram



Sample Code (Adapter)

```
using System;

// "Target"

class ChemicalCompound
{
  // Fields
  protected string name;
  protected float boilingPoint;
  protected float meltingPoint;
  protected double
      molecularWeight;
  protected string
      molecularFormula;

  // Constructor
   public ChemicalCompound
      ( string name )
  {
    this.name = name;
  }
```

```
// Properties
public float BoilingPoint
  {
    get{ return boilingPoint; }
  }

public float MeltingPoint
  {
    get{ return meltingPoint; }
  }

public double MolecularWeight
  {
    get{ return
      molecularWeight; }
  }

public string MolecularFormula
  {
    get{ return
      molecularFormula; }
  }
}
```

Sample Code (Adapter)

```
// "Adapter"

class Compound : ChemicalCompound
{
  // Fields
  private ChemicalDatabank bank;

  // Constructors
  public Compound( string name ) : base( name )
  {
    // We use now the Adaptee
    bank = new ChemicalDatabank();
    // Adaptee request methods
    boilingPoint = bank.GetCriticalPoint( name, "B" );
    meltingPoint = bank.GetCriticalPoint( name, "M" );
    molecularWeight = bank.GetMolecularWeight( name );
    molecularFormula = bank.GetMolecularStructure( name );
  }

  // Methods
  public void Display()
  {
    Console.WriteLine("\nCompound: {0} ------ ",name );
    Console.WriteLine(" Formula: {0}",MolecularFormula);
    Console.WriteLine(" Weight : {0}",MolecularWeight );
    Console.WriteLine(" Melting Pt: {0}",MeltingPoint );
    Console.WriteLine(" Boiling Pt: {0}",BoilingPoint );
  }
}
```

Sample Code (Adapter)

```
// "Adaptee"

class ChemicalDatabank
{
 // Methods -- the Databank 'legacy API'
 public float GetCriticalPoint( string
compound, string point )
 {
  float temperature = 0.0F;
  // Melting Point
  if( point == "M" )
  {
   switch( compound.ToLower() )
   {
    case "water": temperature = 0.0F;
break;
    case "benzene" : temperature = 5.5F;
break;
    case "alcohol": temperature = -
114.1F; break;
   }
  }
  // Boiling Point
  else
  {
   switch( compound.ToLower() )
   {
    case "water": temperature =
100.0F;break;
    case "benzene" : temperature =
80.1F; break;
    case "alcohol": temperature = 78.3F;
break;
   }
  }
  return temperature;
 }
```

```
public string GetMolecularStructure(
 string compound )
  {
   string structure = "";
   switch( compound.ToLower() )
   {
    case "water": structure =
 "H20"; break;
    case "benzene" : structure =
 "C6H6"; break;
    case "alcohol": structure =
 "C2H6O2"; break;
   }
   return structure;
  }

  public double GetMolecularWeight(
 string compound )
  {
   double weight = 0.0;
   switch( compound.ToLower() )
   {
    case "water": weight = 18.015;
 break;
    case "benzene" : weight =
 78.1134; break;
    case "alcohol": weight =
 46.0688; break;
   }
   return weight;
  }
 }
```

Sample Code (Adapter)

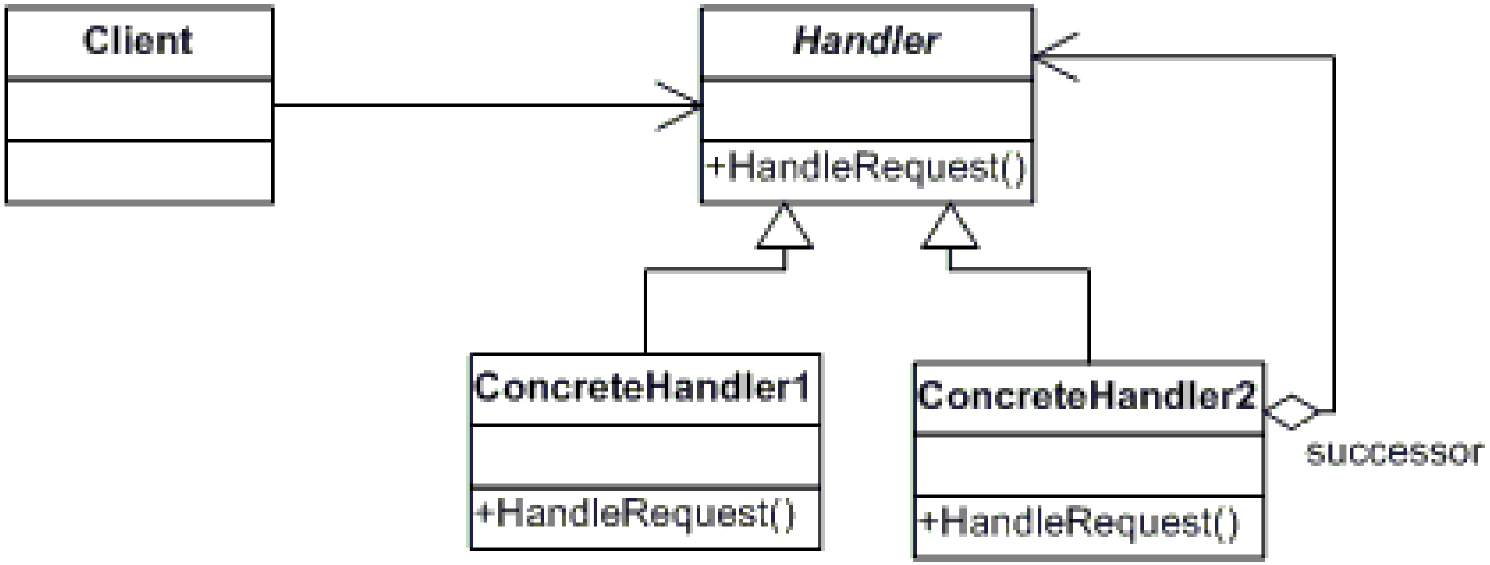
```
/// <summary>
/// AdapterApp test application
/// </summary>
public class AdapterApp
{
  public static void Main(string[] args)
  {
    // Retrieve and display water characteristics
    Compound water = new Compound( "Water" );
    water.Display();

    // Retrieve and display benzene characteristics
    Compound benzene = new Compound( "Benzene" );
    benzene.Display();

    // Retrieve and display alcohol characteristics
    Compound alcohol = new Compound( "Alcohol" );
    alcohol.Display();

  }
}
```

Behavioral Patterns Example

- Chain of Responsibility
  - Avoid coupling the sender of a request to its receiver by giving more than one object a chance to handle the request. Chain the receiving objects and pass the request along the chain until an object handles it.
- Participants
  - **Handler (Approver)**
    - defines an interface for handling the requests
    - (optional) implements the successor link
  - **ConcreteHandler (Director, VicePresident, President)**
    - handles requests it is responsible for
    - can access its successor
    - if the ConcreteHandler can handle the request, it does so; otherwise it forwards the request to its successor
  - **Client (ChainApp)**
    - initiates the request to a ConcreteHandler object on the chain

Sample Code (Chain of Respons.)

- UML Diagram



Sample Code (Chain of Respons.)

-
  ```
  // Chain of Responsibility pattern -- Real World
  example
  using System;

  // "Handler"

  abstract class Approver
  {
    // Fields
    protected string name;
    protected Approver successor;

    // Constructors
    public Approver( string name )
    {
      this.name = name;
    }

    // Methods
    public void SetSuccessor( Approver successor )
    {
      this.successor = successor;
    }

    abstract public void ProcessRequest(
                         PurchaseRequest request );
  }
  ```

-
  ```
  // "ConcreteHandler"

  class Director : Approver
  {
    // Constructors
    public Director ( string name ) : base( name ) {}

    // Methods
    override public void ProcessRequest(
                         PurchaseRequest request )
    {
      if( request.Amount < 10000.0 )
        Console.WriteLine( "{0} {1} approved
  request# {2}",
          this, name, request.Number);
      else
        if( successor != null )
          successor.ProcessRequest( request );
    }
  }
  ```

Sample Code (Chain of Respons.)

- // "ConcreteHandler"

```
class VicePresident : Approver
{
  // Constructors
  public VicePresident ( string name ) :
base( name ) {}

  // Methods
  override public void ProcessRequest(
            PurchaseRequest request )
  {
    if( request.Amount < 25000.0 )
      Console.WriteLine( "{0} {1} approved
request# {2}",
        this, name, request.Number);
    else
      if( successor != null )
        successor.ProcessRequest( request
);
  }
}
```

- // "ConcreteHandler"

```
class President : Approver
{
  // Constructors
  public President ( string name ) : base(
name ) {}
  // Methods
  override public void ProcessRequest(
      PurchaseRequest request )
  {
    if( request.Amount < 100000.0 )
      Console.WriteLine( "{0} {1} approved
request# {2}",
        this, name, request.Number);
    else
      Console.WriteLine( "Request# {0}
requires " +
        "an executive meeting!",
request.Number );
  }
}
```

Sample Code (Chain of respons.)

```
// Request details

class PurchaseRequest
{
  // Member Fields
  private int number;
  private double amount;
  private string purpose;

  // Constructors
  public PurchaseRequest(
      int number,
      double amount, string purpose )
  {
    this.number = number;
    this.amount = amount;
    this.purpose = purpose;
  }
```

```
// Properties
  public double Amount
  {
    get{ return amount; }
    set{ amount = value; }
  }

  public string Purpose
  {
    get{ return purpose; }
    set{ purpose = value; }
  }

  public int Number
  {
    get{ return number; }
    set{ number = value; }
  }
}
```

Sample Code (Chain of Respons.)

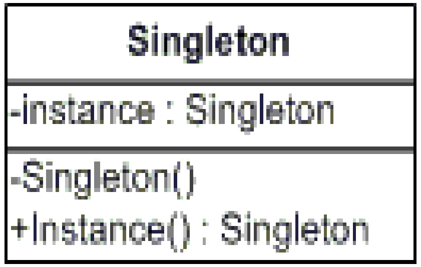
```
/// <summary>
///  ChainApp Application
/// </summary>
public class ChainApp
{
  public static void Main( string[] args )
  {
    // Setup Chain of Responsibility
    Director Larry = new Director( "Larry" );
    VicePresident Sam = new VicePresident( "Sam" );
    President Tammy = new President( "Tammy" );
    Larry.SetSuccessor( Sam );
    Sam.SetSuccessor( Tammy );

    // Generate and process different requests
    PurchaseRequest rs = new PurchaseRequest( 2034, 350.00, "Supplies" );
    Larry.ProcessRequest( rs );

    PurchaseRequest rx = new PurchaseRequest( 2035, 32590.10, "Project X" );
    Larry.ProcessRequest( rx );

    PurchaseRequest ry = new PurchaseRequest( 2036, 122100.00, "Project Y" );
    Larry.ProcessRequest( ry );

  }
}
```

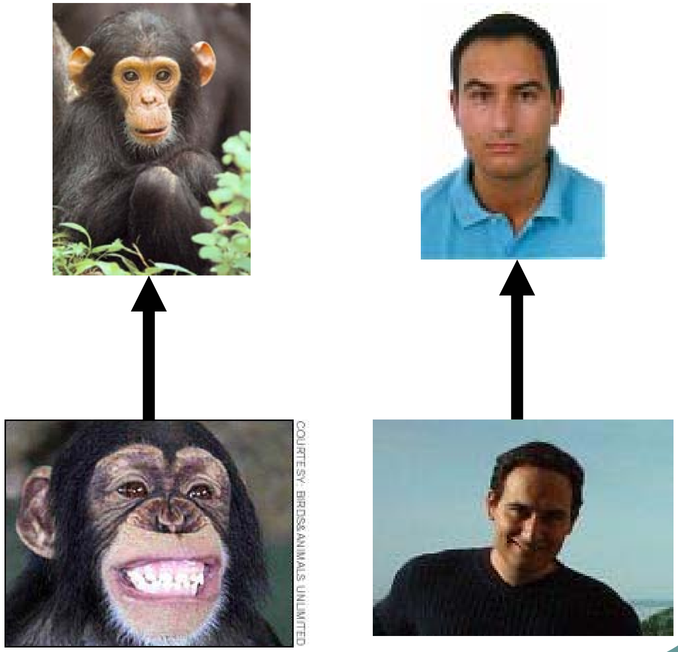
Conclusion

- Software Design Patterns **are NOT**
  - ***Restricted*** to Object Oriented designs
  - ***Untested*** ideas/theories/inventions
  - Solutions that have worked only once
  - Abstract Principles
  - Universally applicable for every context
  - A ***“silver bullet”*** or a panacea

The Darwin’s case

- Before we thought that the evolution could be modeled by a Singleton Pattern
  - Ensure a class has **only one instance** and provide a global point of access to it.

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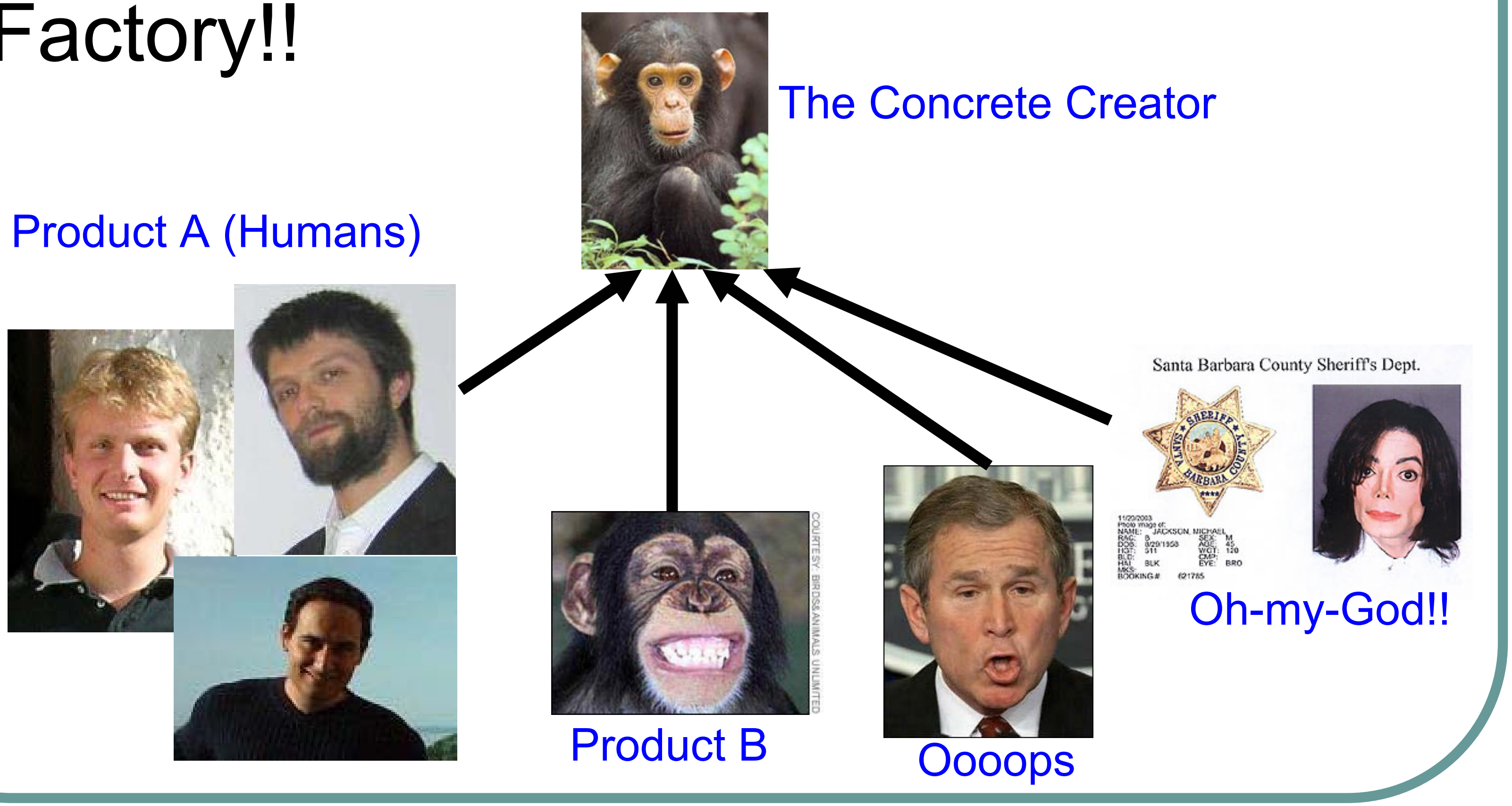
The Darwin's case

- But, hopefully Darwin discovered the Factory!!



The Concrete Creator

Product A (Humans)

Product B

Oooops

Oh-my-God!!

Santa Barbara County Sheriff's Dept.
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Conclusion

- Software Design Patters are
  - ***Recurring*** solutions to ***common*** design *problems*
  - ***Concrete*** solutions to real world problems
  - Context ***Dependants***
  - A literary form for ***documenting best practices***
  - ***Shared*** for the community
  - Excessively ***hyped***!!!!!

That’s all!

- References
  - Design Patterns: Elements of Reusable Object Oriented Software
    - E. Gamma, R. Helm, R. Johnson, J. Vlissides.
  - Understanding and Using Patterns in SW development
    - Riehle & Zullighoven
  - The ***www*** is plenty of interesting patterns and examples.