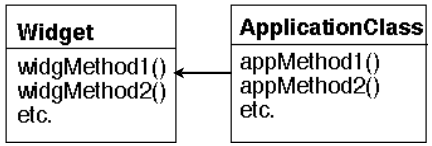
Creational Patterns

Overview of creational patterns

- Abstract the instantiation process
- Help make a system independent of how its objects are created, composed, represented
- Class creational pattern
  - uses inheritance to vary the class that's instantiated
  - *Factory Method*
- Object creational pattern
  - delegates instantiation to another object
  - *Abstract Factory, Prototype, Singleton, Builder*

Let's start simple...



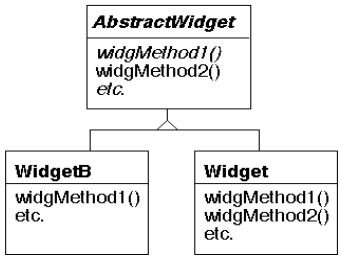

```
class ApplicationClass   {
   Widget a;
   Widget b;

   public appMethod1()   {
      Widget d = new Widget();
      d.widgetMethod1();
      // . . .
      Widget e = new Widget();
      // . . .
   }

   public appMethod2()   {
      // . . .
      Widget f = new Widget();
      f.widgetMethod1();
      // . . .
      Widget g = new Widget();
      // . . .
   }
   // etc. etc . . .
```

We can modify the internal **`Widget`** code without modifying the **`ApplicationClass`**

Problems with Changes

- What happens when we discover a new widget and would like to use in the **`ApplicationClass`**?
- Multiple coupling between **`Widget`** and **`ApplicationClass`**
  - **`ApplicationClass`** knows the interface of **`Widget`**
  - **`ApplicationClass`** explicitly uses the **`Widget`** type
    - hard to change because Widget is a concrete class
  - **`ApplicationClass`** explicitly creates new Widgets in many places
    - if we want to use the new **`Widget`** instead of the initial one, changes are spread all over the code

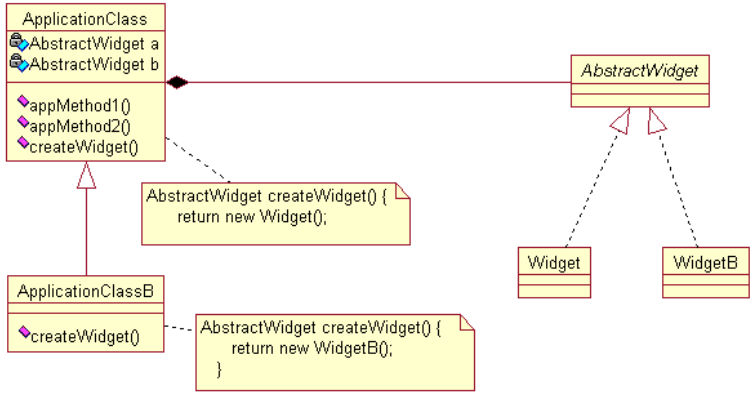
Apply "Program to an Interface"




```
class ApplicationClass   {
   AbstractWidget a;
   AbstractWidget b;

   public appMethod1()   {
      AbstractWidget d = new Widget();
      d.widgetMethod1();
      // . . .
      AbstractWidget e = new Widget();
      blah;
   }

 etc.
}
```

- **`ApplicationClass`** depends now on an (abstract) interface
- But we still have hard coded which widget to create!
  - should I copy-paste? ;-)

Use a Factory Method




```
class ApplicationClass   {
   AbstractWidget a;
   AbstractWidget b;

   // If C++ make this a virtual function
   // and use pointers to ApplicationClass obj.

   public AbstractWidget createWidget() {
      return new Widget();
   }

   public appMethod1()   {
      AbstractWidget d = createWidget();
      d.widgetMethod1();
      // . . .
      AbstractWidget e = createWidget();
      // . . .
   }
   // . . .
}
class ApplicationClassB extends ApplicationClass {
   public AbstractWidget createWidget() {
      return new WidgetB();
   }
}
```

Elsewhere ...

```
ApplicationClass test = new ApplicationClassB();
test.appMethod1();
```


Evaluation of Factory Method Solution

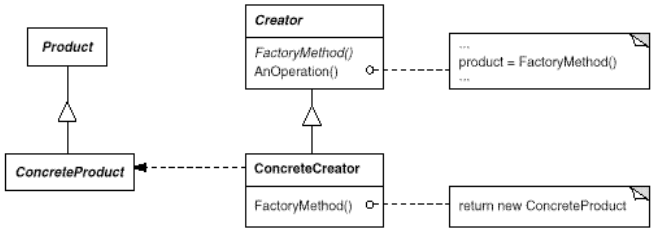
- Explicit creation of **`Widget`** objects is not anymore dispersed
  - easier to change
- Functional methods in **`ApplicationClass`** are decoupled from various concrete implementations of widgets
- Avoid ugly code duplication in **`ApplicationClassB`**
  - subclasses reuse the functional methods, just implementing the concrete Factory Method needed
- Disadvantages
  - create a subclass only to override the factory-method
  - can't change the **`Widget`** at run-time

Factory Method

Basic Aspects

- Intent
  - Define an interface for creating an object, but let subclasses decide which class to instantiate.
  - Factory Method lets a class defer instantiation to subclasses
- Also Known As
  - Virtual Constructor
- Applicability
  - A class can't anticipate the class of objects it must create
  - A class wants its subclasses to specify the objects it creates
  - Classes delegate responsibility to one of several helper subclasses

Structure



Participants & Collaborations

- Product
  - defines the interface of objects that will be created by the FM
  - Concrete Product implements the interface
- Creator
  - declares the FM, which returns a product of type Product.
    - may define a default implementation of the FM
    - may call the FM to create a product
- ConcreteCreator
  - overrides FM to provide an instance of ConcreteProduct

Creator relies on its subclasses to define the factory method so that it returns an instance of the appropriate ConcreteProduct

Consequences

- Eliminate binding of application specific classes into your code.
  - creational code only deals with the Product interface
- Provide hooks for subclassing
  - subclasses can change this way the product that is created
- Clients might have to subclass the Creator just to create a particular ConcreteProduct object.

Implementation Issues

- Varieties of Factory Methods
  - Creator class is **abstract**
    - does not provide an implementation for the FM it declares
    - requires subclasses
  - Creator is a **concrete** class
    - provides default implementation
    - FM used for flexibility
    - Create objects in a separate operation so that subclasses can override it
- Parametrization of Factory Methods
  - A variation on the pattern lets the factory method create multiple kinds of products
  - a parameter identifies the type of Product to create
  - all created objects share the Product interface

Parameterizing the Factory

```
class Creator {
    public Product create(productId) {
      if (id == MINE) return new MyProduct;
      if (id == YOURS) return new YourProduct;
    }
}

class MyCreator extends Creator  {
  public Product create(productId) {
   if (id == MINE) return new YourProduct;
   if (id == YOURS) return new MyProduct;
   if (id == THEIRS) return new TheirProduct;
   return super.create(id); // called if others fail
}
```

- selectively extend or change products that get created

Static Factory Method

```
abstract class Shape {
  public abstract void draw();
  public abstract void erase();
  public static Shape factory(String type) {
    if(type.equals("Circle")) return new Circle();
    if(type.equals("Square")) return new Square();
    throw new RuntimeException("Bad shape creation: " + type);
  }
}

class Circle extends Shape {
  Circle() {} // Package-access constructor
  public void draw() {
    System.out.println("Circle.draw");
  }
  public void erase() {
    System.out.println("Circle.erase");
  }
}
```

Java: `forName` and Factory Methods

```
class Creator {
     public Product FactoryMethod(String productType) {
        Class productClass = Class.forName(productType);
        return (Product) productClass.newInstance();
     }
}

Product theBest = new Creator().FactoryMethod("ProductA");

theBest.newInstance();
```



```
import java.util.*;

class AbstractFactory {
    public Product make(String c) {
     try {
         Class prod = Class.forName(c);
         return (Product) prod.newInstance();
     }
     catch(Exception e) {
         System.out.println("Error");
         System.exit(1);
         return null;
     }
    }
}

class Main {
    public static void main(String[] args) {
     AbstractFactory af = new AbstractFactory();

     af.make(args[0]).doSomething();
    }
}
```

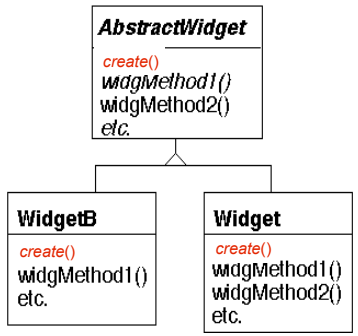
```
abstract class Product {
    abstract public void doSomething();
}

class ProductA extends Product {
    public void doSomething() {
     System.out.println("ProductA");
    }
}

class ProductB extends Product {
    public void doSomething() {
     System.out.println("ProductB");
    }
}
```


Idea 3: Factory Method in Product

- Make the product responsible for creating itself
  - e.g. let the Door know how to construct an instance of it rather than the MazeGame
- The client of the product needs a reference to the "creator"
  - specified in the constructor
- see next slide...

Solution 2.1: Product Creates Itself

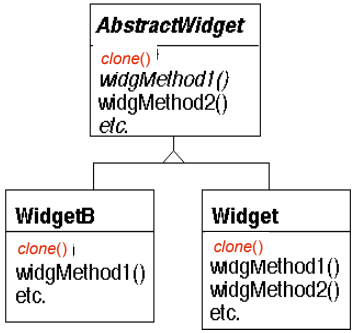
- Provide the `Widgets` with a polymorphic creational method




```
class Widget {
   int data;

   public WidgetB create() {
     return new WidgetB();
   }
}
```

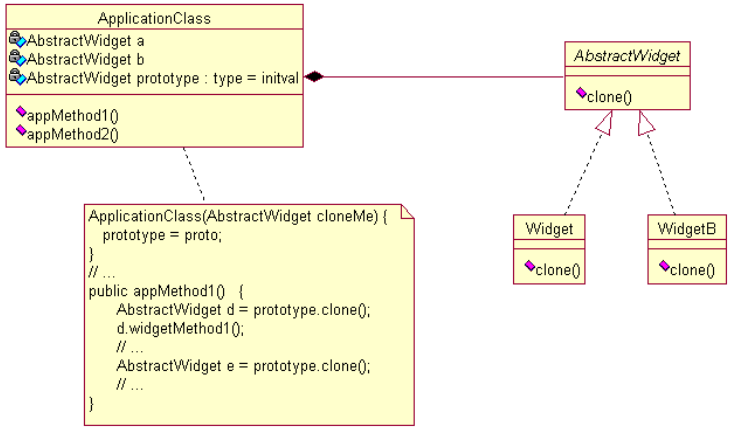
Solution 2.2: Product Clones Itself

- Provide the **`Widgets`** with a clone method
  - make a copy of an existing Widget object




```
class Widget {
   int data;

   public Widget clone() {
      Widget aCopy = new Widget();
      aCopy.data = data;
      return aCopy;
   }
}
```


Using the Clone




```
class ApplicationClass   {
   AbstractWidget a;
   AbstractWidget b;
   AbstractWidget prototype;

   public ApplicationClass(AbstractWidget cloneMe ) {
      prototype = cloneMe;
   }

   public appMethod1()   {
      AbstractWidget d = prototype.clone();
      d.widgetMethod1();
      // . . .
      AbstractWidget e = prototype.clone();
      // . . .
   }

   // ...etc. etc...
}
```

Elsewhere:

```
ApplicationClass test =
   new ApplicationClass( new Widget() );

ApplicationClass testB =
   new ApplicationClass( new WidgetB() );
```


Advantages

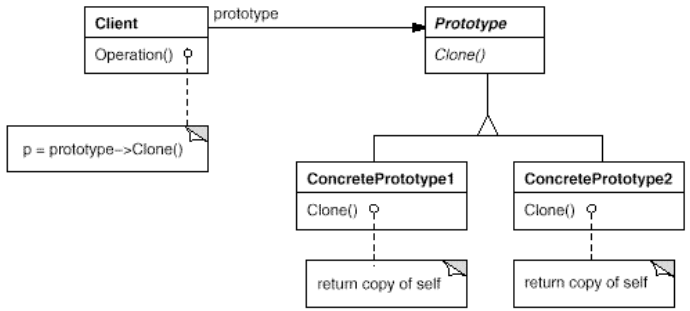
- Classes to instantiate may be specified dynamically
  - client can install and remove prototypes at run-time
- We avoided subclassing of **`ApplicationClass`**
  - **Remember**: Favor Composition over Inheritance! :-)
- Totally hides concrete product classes from clients
  - Reduces implementation dependencies

The Prototype Pattern

Basic Aspects

- Intent
  - Specify the kinds of objects to create using a prototypical instance
  - Create new objects by copying this prototype
- Applicability
  - when a client class should be independent of how its products are created, composed, and represented **and**
  - when the classes to instantiate are specified at run-time

Structure



Participants & Collaborations

- Prototype
  - declares an interface for cloning itself.
- ConcretePrototype
  - implements an operation for cloning itself.
- Client
  - creates a new object by asking a prototype to clone itself.
- A client asks a prototype to clone itself.
- The client class must initialize itself in the constructor
  - with the proper concrete prototype.

Consequences

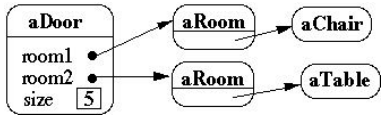
- Adding and removing products at run-time
- Reduced subclassing
  - avoid parallel hierarchy for creators
- Each subclass of Prototype must implement `clone`
  - difficult when classes already exist or
  - internal objects don't support copying or have circular references

Implementation Issues

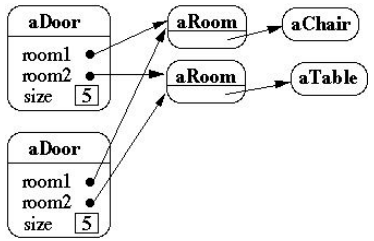
- Using a Prototype manager
  - number of prototypes isn't fixed
    - keep a registry → **prototype manager**
  - clients instead of knowing the prototype know a manager
    - associative store
- Initializing clones
  - heterogeneity of initialization methods
  - write an `Initialize` method
- Implementing the `clone` operation
  - shallow vs. deep copy

Shallow Copy vs. Deep Copy

Original

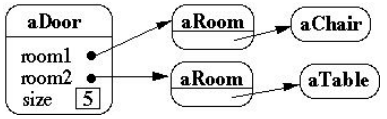


Shallow Copy

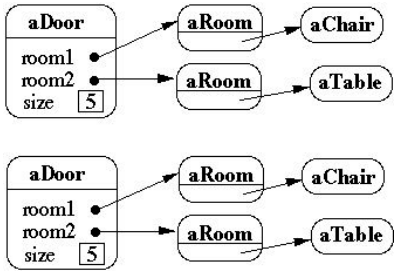


Shallow Copy vs. Deep Copy (2)

Original



Deep Copy



Cloning in Java – `Object clone()`

`protected Object clone() throws CloneNotSupportedException`

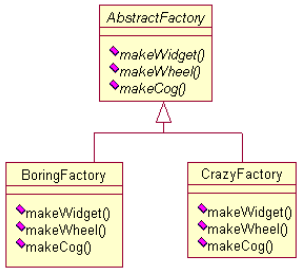
- Creates a clone of the object.
  - allocate a new instance and,
  - place a *bitwise clone* of the current object in the new object.

```
class Device implements Cloneable  {
  public void Initialize( Widget a, Widget b) {
    w1 = a; w2 = b;
  }

  public Object clone() throws CloneNotSupportedException {
          return super.clone();
  }
  Widget w1, w2;
}
```


More Changes

- What if ApplicationClass uses other "products" too...
  - e.g. Wheels, Cogs, etc.
- Each one of these stays for an object family
  - i.e. all of these have subclasses
- Assume that there are restrictions on what type of Widget can be used with which type of Wheel or Cog
- Factory Methods or Prototypes can handle each type of product but it get hard to insure the wrong types of items are not used together

Solution: Create an Abstract Factory



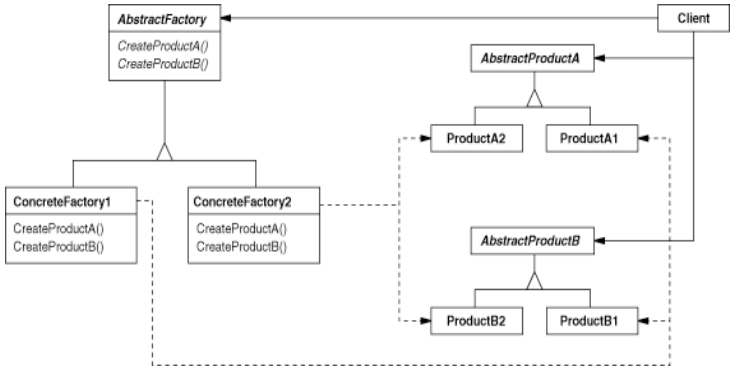

```
class ApplicationClass   {
   AbstractWidget a;
   AbstractCog b;
   AbstractFactory partFactory;

   public ApplicationClass(AbstractFactory aFactory)
   {
      partFactory = aFactory;
   }

   public appMethod1()
   {
      AbstractWidget d = partFactory.makeWidget();
      d.widgetMethod1();
      // ...
      AbstractCog e = partFactory.makeCog();
   } // ....
}
```


Abstract Factory

Basic Aspects

- Intent
  - Provide an interface for creating **families of related or dependent objects** without specifying their concrete classes
- Applicability
  - System should be independent of how its products are created, composed and represented
  - System should be configured with one of multiple families of products
  - Need to **enforce** that a family of product objects is used together

Structure



Participants & Collaborations

- Abstract Factory
  - declares an interface for operations to create abstract products
- ConcreteFactory
  - implements the operations to create products
- AbstractProduct
  - declares an interface for a type of product objects
- ConcreteProduct
  - declares an interface for a type of product objects
- Client
  - uses only interfaces decl. by AbstractFactory and AbstractProduct
- A single instance of a ConcreteFactory created.
  - create products having a particular implementation

Consequences

- Isolation of concrete classes
  - appear in `ConcreteFactories` not in client's code
- Exchanging of product families becomes easy
  - a `ConcreteFactory` appears only in one place
    - easy to change
- Promotes consistency among products
  - all products in a family change **at once**, and change **together**
- Supporting new kinds of products is difficult
  - requires a change in the interface of AbstractFactory
  - ... and consequently all subclasses

Implementation Issues

- Factories as Singletons
  - to assure that only one `ConcreteFactory` per product family is created
- Creating the Products
  - collection of Factory Methods
  - can be also implemented using Prototype
    - define a prototypical instance for each product in `ConcreteFactory`
- Defining Extensible Factories
  - a single factory method with parameters
  - more flexible, less safe!

Creating Products...

- ...using own factory methods

```
abstract class WidgetFactory {
   public Window createWindow();
   public Menu createMenu();
   public Button createButton();
}
```

```
class MacWidgetFactory extends WidgetFactory {
     public Window createWindow()
       { return new MacWindow() }
     public Menu createMenu()
       { return new MacMenu() }
     public Button createButton()
       { return new MacButton()  }
}
```


Creating Products...

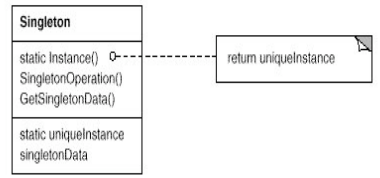
- ... using product's factory methods
  - subclass just provides the concrete products in the constructor
  - spares the re-implementation of FM's in subclasses

```
abstract class WidgetFactory {
   private Window windowFactory;
   private Menu menuFactory;
   private Button buttonFactory;

  protected WidgetFactory(Window w, Menu m, Button b) {
      windowFactory = w; menuFactory = m; buttonFactory = b;
  }

   public Window createWindow()
      { return windowFactory.createWindow() }
   public Menu createMenu();
      { return menuFactory.createMenu() }
   public Button createButton()
      { return buttonFactory.createButton() }
}
```

```
class MacWidgetFactory extends WidgetFactory {
   public MacWidgetFactory() {
      super(new MacWindow(), new MacMenu(), new MacButton();
   }
}
```


Singletons

```
public class Singleton {
   protected Singleton() {
     // ... }


   static private Singleton _instance = null;

   static public Singleton instance() {
      if(null == _instance) {
         _instance = new Singleton();
      }
      return _instance;
   }


}
```



Why Use Singletons?

- Controlled access to sole instance
- Permits refinement of operations and representation
- Permits a variable (but precise) number of instances

One Singleton for many Instances ;-)

```
/* if a class implements this interface it . */
public interface SingletonFactoryMethod {
   /* returns an instance of the singleton. */
   public Singleton createInstance();
}

public class SingletonWrapper {
   static private SingletonFactoryMethod _factory = null;

   static private Singleton _instance = null;

   static public Singleton instance() {
      if(null == _instance)
         if(null == _factory) _instance = new Singleton();
         else _factory.createInstance();
      }
      return _instance;
   }

  static public void setFactory(SingletonFactoryMethod factory) {
      _factory = factory; _instance = null;}
}
```