Visitor and Factory Patterns

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Outcomes

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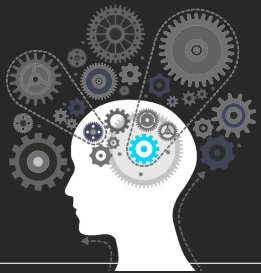
After today's lecture you will be able to:

- Have a good understanding about the design and use of the following patterns:
  - Visitor
  - Factory Method
  - Abstract Factory
- Understand the design principles that these patterns enforce/work with
- Be capable of implementing these patterns in your own code



Visitor Pattern

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Visitor Pattern

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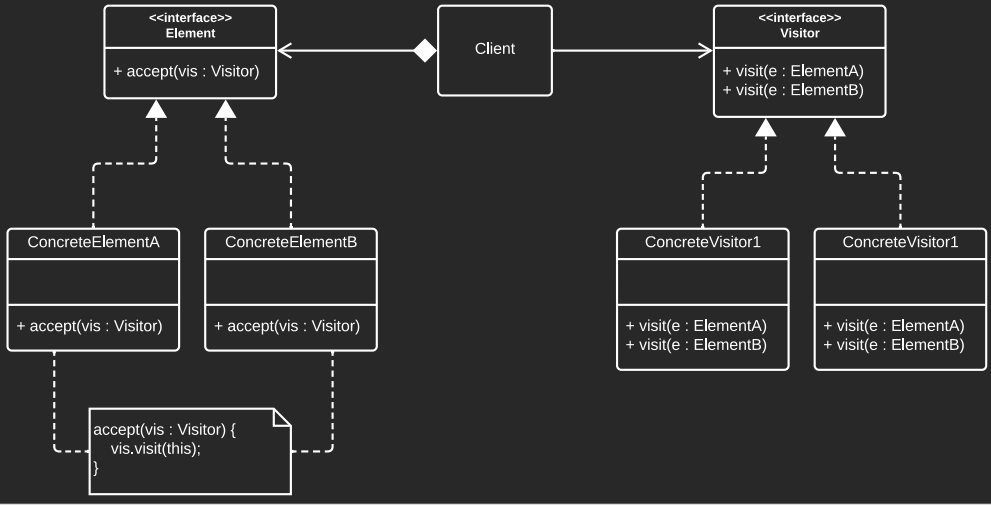
Intent

The Visitor Pattern enables us to add new behavior to existing classes in a fixed class hierarchy without changing this hierarchy

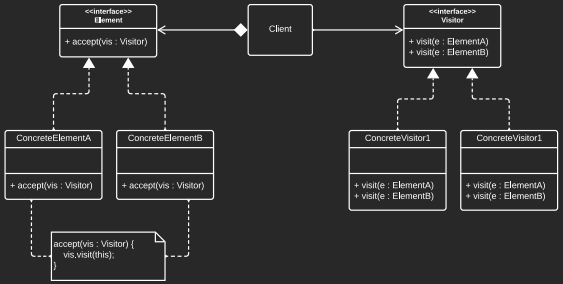
Solution Idea

Represent additional operations to be performed on the elements of an object structure (additional feature) as objects (of type Visitor)

Structure


<<interface>>
Element
+ accept(vis : Visitor)
Client
<<interface>>
Visitor
+ visit(e : ElementA)
+ visit(e : ElementB)
ConcreteElementA
+ accept(vis : Visitor)
ConcreteElementB
+ accept(vis : Visitor)
ConcreteVisitor1
+ visit(e : ElementA)
+ visit(e : ElementB)
ConcreteVisitor1
+ visit(e : ElementA)
+ visit(e : ElementB)
accept(vis : Visitor) {
vis.visit(this);
}

Structure



- The `Visitor` interface declares a `visit` method per element type in the object structure
- A `Visitor` interface describes how to "treat" the element types
- Concrete visitor classes implement the interface specifically, i.e., treat elements differently

- A concrete visitor class corresponds to a particular feature to be added to the object structure
- Elements in the object structure provide the method `accept(visitor)`
- On being asked to `accept` a visitor passed to it as a parameter, an element asks the visitor to `visit` it.

Case Study: Arithmetic Expressions

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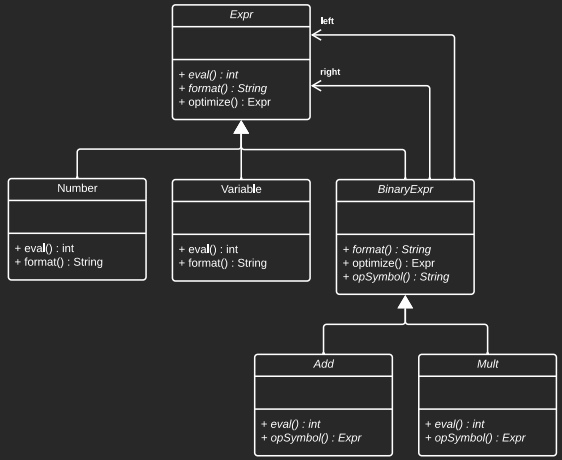
Requirements:

- A library for (arithmetic) expressions must provide different functionality for:
  - Formatting an expression to a string
  - Computing the value of an expression
  - Optimizing an expression
- The library must be extensible with new functionality
  - Generate code for different machines
  - Various refactorings, e.g., rename variables
- The library must be extensible with new kinds of expressions



Case Study: Arithmetic Expressions

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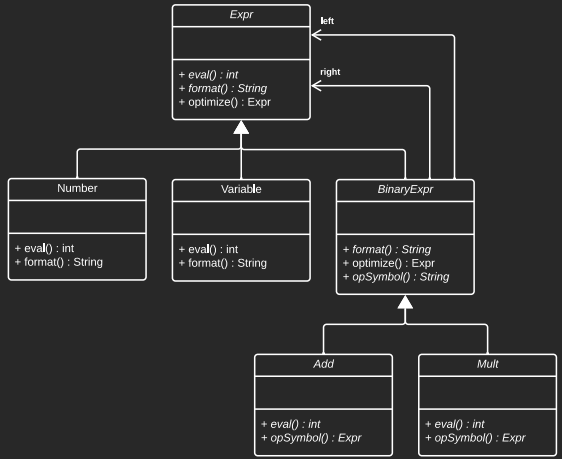
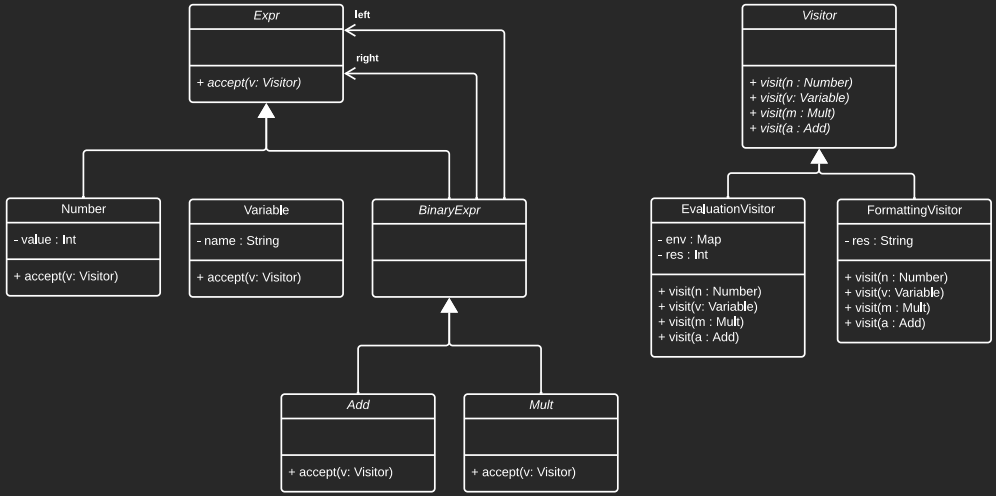
Design Issues:

- Impossible to reuse part of library functionality
- Changing one feature can destabilize other features (SDP)
- New features cannot be incrementally added (OCP)



Visitor Based Design



Advantages of the Visitor

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- **New operations are easy to add** without changing element classes (add a new concrete visitor).
  - Different concrete elements do not have to implement their part of a particular algorithm
- Related behavior focused in a single concrete visitor
- **Visiting across hierarchies:** Visited classes are not forced to share a common base class
- **Accumulating state:** Visitors can accumulate state as they visit each element, thus, encapsulating the algorithm and all its data.

Issues of the Visitor

- If we add a new type to a hierarchy
  - we need to modify all the visitors to handle the type.
- Many visitors will have empty methods to comply to the interface
- Sometimes data structures are extended, but it's optional to process extensions

Summary

- Visitor brings functional-style decomposition to OO designs
- Use Visitor for Stable element hierarchies
  - Visitor works well in data hierarchies where new elements are never or at least not very often added.
- Do not use it, if new elements are a likely change
- Visitor only makes sense if we have to add new operations often! In this case Visitor closes our design against these changes.

Factory Method Pattern

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The Problem With “New”

- Each time we invoke the “new” command to create a new object, we violate the “Code to an Interface” design principle.
- Example:
  - `Duck duck = new DecoyDuck()`
- Even though our variable’s type is set to an “interface”, in this case “Duck”, the class that contains this statement depends on “DecoyDuck”
- In addition, if you have code that checks a few variables and instantiates a particular type of class based on the state of those variables, then the containing class depends on each referenced concrete class

```
if (hunting) {
   return new DecoyDuck();
} else {
   return new RubberDuck();
}
```

Obvious Problem: needs to be recompiled each time a dependency changes

- add new classes –> change this code
- remove existing classes –> change this code

PizzaStore Example

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- We have a pizza store program that wants to separate the process of creating a pizza with the process of preparing/ordering a pizza
- Initial code: mixed the two processes

```
public class PizzaStore {
    Pizza orderPizza(String type) {
        Pizza pizza;
        // Creation code
        if (type == "cheese") {
           pizza = new CheesePizza();
        } else if (type == "greek") {
           pizza = new GreekPizza();
        } else if (type == "pepperoni") {
           pizza = new PepperoniPizza();
        }
        // Coding to Interface
        pizza.prepare();
        pizza.bake();
        pizza.cut();
        pizza.box();

        return pizza;
    }
}
```

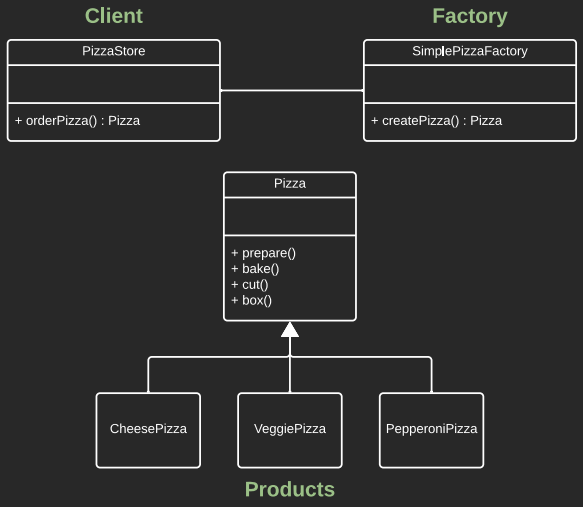
Encapsulate Creation Code

- A simply way to encapsulate this code is to put it in a separate class
  - That new class depends on the concrete classes, but those dependencies no longer impact the preparation code.

```
public class PizzaStore {
    private SimplePizzaFactory factory;

    public PizzaStore(SimplePizzaFactory factory) {
        this.factory = factory;
    }

    public Pizza orderPizza(String type) {
        Pizza pizza = factory.createPizza(type);

        pizza.prepare();
        pizza.bake();
        pizza.cut();
        pizza.box();
        return pizza;
    }
}
```

```
public class SimplePizzaFactory {

    public Pizza createPizza(String type) {
        if (type == "cheese") {
            return new CheesePizza();
        } else if (type == "greek") {
            return new GreekPizza();
        } else if (type == "pepperoni") {
            return new PepperoniPizza();
        }
    }
}
```

Class Diagram of New Solution



Factory Method

- To demonstrate the factory method pattern, the pizza store example evolves
  - to include the notion of different franchises
  - that exist in different parts of the country (California, New York, and Chicago)

- Each franchise will need its own factory to create pizzas that match the proclivities of the locals
  - However, we want to retain the preparation process that has made `PizzaStore` such a great success

Factory Method

- The Factory Method Design Pattern allows you to do this by
  - placing abstract, “code to an interface” code in a superclass
  - placing object creation code in a subclass
- `PizzaStore` becomes an abstract class with an abstract create Pizza() method
- We then create subclasses that override `createPizza()` for each region.

New PizzaStore Class

```
public abstract class PizzaStore {

    protected abstract createPizza(String type);

    public Pizza orderPizza(String type) {

        Pizza pizza = createPizza(type);

        pizza.prepare();
        pizza.bake();
        pizza.cut();
        pizza.box();

        return pizza;
    }
}
```

Beautiful Abstract Base Class!

Factory Method

- This class is a (very simple) OO framework. The framework provides one service “prepare pizza”.
- The framework invokes the `createPizza()` factory method to create a pizza that it can prepare using a well-defined, consistent process.
- A “client” of the framework will subclass this class and provide an implementation of the `createPizza()` method.
- Any dependencies on concrete “product” classes are encapsulated in the subclass.

New York Pizza Store

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```
public class NYPizzaStore extends PizzaStore {
    public Pizza createPizza(String type) {
        if (type == "cheese") {
            return new NYCheesePizza();
        } else if (type == "greek") {
            return new NYGreekPizza();
        } else if (type == "pepperoni") {
            return new NYPepperoniPizza();
        }
        return null;
    }
}
```

Nice and Simple

- If you want a NY-Style Pizza, you create an instance of this class and call `orderPizza()` passing in the type.
- The subclass makes sure that the pizza is created using the correct style.
- If you need a different style, create a new subclass.

Factory Method: Definition and Structure

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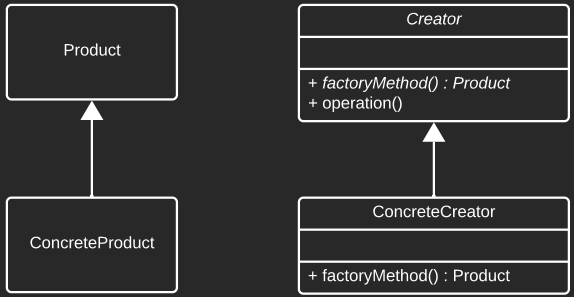
- The factory method design pattern defines an interface for creating an object, but lets subclasses decide which class to instantiate. Factory Method lets a class defer instantiation to subclasses.



Factory Method leads to the creation of parallel class hierarchies; `ConcreteCreators` produce instances of `ConcreteProducts` that are operated on by Creator's via the Product interface

Abstract Factory Pattern

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Dependency Inversion Principle

- Factory Method is one way of following the dependency inversion principle
  - "Depend upon abstractions. Do not depend upon concrete classes."
- Normally "high-level" classes depend on "low-level" classes;
  - Instead, they BOTH should depend upon an abstract interface
- `DependentPizzaStore` depends on eight concrete `Pizza` subclasses
  - `PizzaStore`, however, depends on the `Pizza` interface, as do the Pizza subclasses
- In this design, `PizzaStore` (the high-level class) no longer depends on the `Pizza` subclasses (the low level classes); they both depend on the abstraction "Pizza". Nice.

Dependency Inversion Principle: How To?

- To achieve the dependency inversion principle in your own designs, follow these GUIDELINES:
  - No variable should hold a reference to a concrete class
  - No class should derive from a concrete class
  - No method should override an implemented method of its base class

- These are guidelines because if you were to blindly follow these instructions you would never produce a system that could be compiled or executed
  - Instead use them as instructions to help optimize your design

- And remember, not only should low-level classes depend on abstractions, but high-level classes should to… this is the very embodiment of “code to an interface”

Demonstration

- Lets look at some code
  - The `FactoryMethod` directory of src.zip file contains an implementation of the pizza store using the factory method design pattern
    - It even includes a file called `DependentPizzaStore.java` that shows how the code would be implemented without using this pattern
  - `DependentPizzaStore` is dependent on 8 different concrete classes and 1 abstract interface (Pizza)
  - `PizzaStore` is dependent on just the Pizza abstract interface (nice!)
    - Each of its subclasses is only dependent on 4 concrete classes.
    - furthermore, they shield the superclass from these dependencies

Moving On

- The factory method approach to the pizza store is a big success allowing our company to create multiple franchises across the country quickly and easily
  - But, bad news, we have learned that some of the franchises
    - while following our procedures (the abstract code in `PizzaStore` forces them to)
    - are skimping on ingredients in order to lower costs and increase margins
  - Our company's success has always been dependent on the use of fresh quality ingredients
    - so "Something Must Be Done!"

Abstract Factory to the Rescue!

- We will alter our design such that a factory is used to supply the ingredients that are needed during the pizza creation process
  - Since different regions use different types of ingredients, we'll create region-specific subclasses of the ingredient factory to ensure that the right ingredients are used
  - But, even with region-specific requirements, since we are supplying the factories, we'll make sure that ingredients that meet our quality standards are used by all franchises
    - They'll have to come up with some other way to lower costs.

First, We need a Factory Interface

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```
public interface PizzaIngredientFactory {

    public Dough createDough();
    public Sauce createSauce();
    public Cheese createCheese();
    public Veggies[] createVeggies();
    public Pepperoni createPepperoni();
    public Clams createClam();

}
```

Note the introduction of more abstract classes:

`Dough`, `Sauce`, `Cheese`, etc.

A Region-Specific Factory

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```
public class ChicagoPizzaIngredientFactory
        implements PizzaIngredientFactory {
    public Dough createDough() {
        return new ThickCurstDough();
    }

    public Sauce createSauce() {
        return new PlumTomatoSauce();
    }

    public Cheese createCheese() {
        return new MozzarellaCheese();
    }
    public Veggies[] createVeggies() {
        Veggies veggies[] = { new BlackOlives(),
           new Spinach(), new Eggplant() };
        return veggies;
    }
    public Pepperoni createPepperoni() {
        return new SlicedPepperoni();
    }

    public Clams createClam() {
        return new FrozenClams();
    }
}
```

This factory ensures that quality ingredients are used during the pizza creation process…

… while also taking into account the tastes of people who live in Chicago

But how (or where) is this factory used?

Within Pizza Subclasses…


```
public abstract class Pizza {
    String name;
    Dough dough;
    Sauce sauce;
    Veggies veggies[];
    Cheese cheese;
    Pepperoni pepperoni;
    Clams clam;

    abstract void prepare();

    void back() {
        System.out.println("Back for 25 min at 350");
    }

    void cut() {...}
}
```

First, alter the Pizza abstract base class to make the prepare method abstract…

Within Pizza Subclasses...

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```
public class CheesePizza extends Pizza {
    PizzaIngredientFactory ingredientFactory;

    public CheesePizza(PizzaIngredientFactory ingredientFacotry) {
        this.ingredientFactory = ingredientFactory;
    }

    void prepare() {
        System.out.println("Preparing " + name);
        dough = ingredientFactory.createDough();
        sauce = ingredientFactory.createSauce();
        cheese = ingredientFactory.createCheese();
    }
}
```

Then, update `Pizza` subclasses to make use of the factory! Note: we no longer need subclasses like `NYCheesePizza` and `ChicagoCheesePizza` because the ingredient factory no handles regional differences

One Last Step…


```
public class ChicagoPizzaStore extends PizzaStore {

    protected Pizza createPizza(String item) {
        Pizza pizza = null;
        PizzaIngredientFactory ingredientFactory = new ChicagoPizzaIngredientFacotry();

        if (item == "cheese") {
            pizza = new CheesePizza(ingredientFactory);
            pizza.setName("Chicago Style Cheese Pizza");
        } else if (item == "veggie") {
            pizza = new VeggiePizza(ingredientFactory);
            pizza.setName("Chicago Style Veggie Pizza");
        }
        ...
    }
}
```

We need to update our `PizzaStore` subclasses to create the appropriate ingredient factory and pass it to each `Pizza` subclass in the `createPizza` factory method

Summary: What Did We Just Do?

1. We created an ingredient factory interface to allow for the creation of a family of ingredients for a particular pizza

2. This abstract factory gives us an interface for creating a family of products
   2.1 The factory interface decouples the client code from the actual factory implementations that produce context-specific sets of products

3. Our client code (`PizzaStore`) can then pick the factory appropriate to its region, plug it in, and get the correct style of pizza (Factory Method) with the correct set of ingredients (Abstract Factory)

Demonstration

- Examine and execute the code located in the Abstract Factory directory of the src.zip file associated with this lecture

Abstract Factory: Definition and Structure

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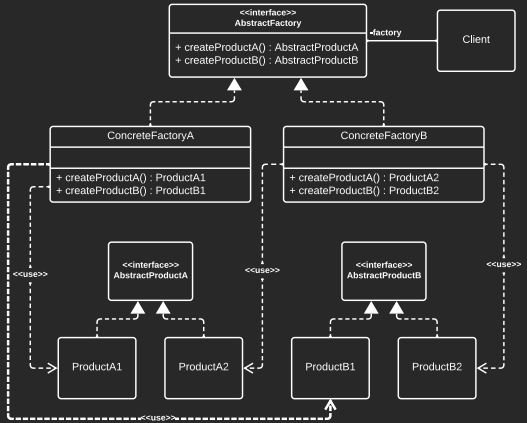
- The abstract factory design pattern provides an interface for creating families of related or dependent objects without specifying their concrete classes.



Factory Wrapup

- All factories encapsulate object creation
  - Simple Factory is not a bona fide design pattern but it is simple to understand and implement
  - Factory Method relies on inheritance: object creation occurs in subclasses
  - Abstract Factory relies on composition: object creation occurs in concrete factories

- Both can be used to shield your applications from concrete classes
  - And both can aid you in applying the dependency inversion principle in your designs

For Next Time

- Review this Lecture
- Watch Lecture 24

Are there any questions?