Prototype, Visitor

CSCI 4448/5448: Object-Oriented Analysis & Design

Lecture 31

Acknowledgement & Materials Copyright

- I'd like to start by acknowledging Dr. Ken Anderson
- Ken is a Professor and the Chair of the Department of Computer Science
- Ken taught OOAD on several occasions, and has graciously allowed me to use his copyrighted material for this instance of the class
- Although I will modify the materials to update and personalize this class, the original materials this class is based on are all copyrighted © Kenneth M. Anderson; the materials are used with his consent; and this use in no way challenges his copyright

Head First Design Patterns

- Chapter 13 – Leftover Patterns
  - Bridge
  - Builder
  - Flyweight
  - Interpreter
  - Chain of Responsibility
  - Mediator
  - Memento
  - Prototype
  - Visitor

Prototype

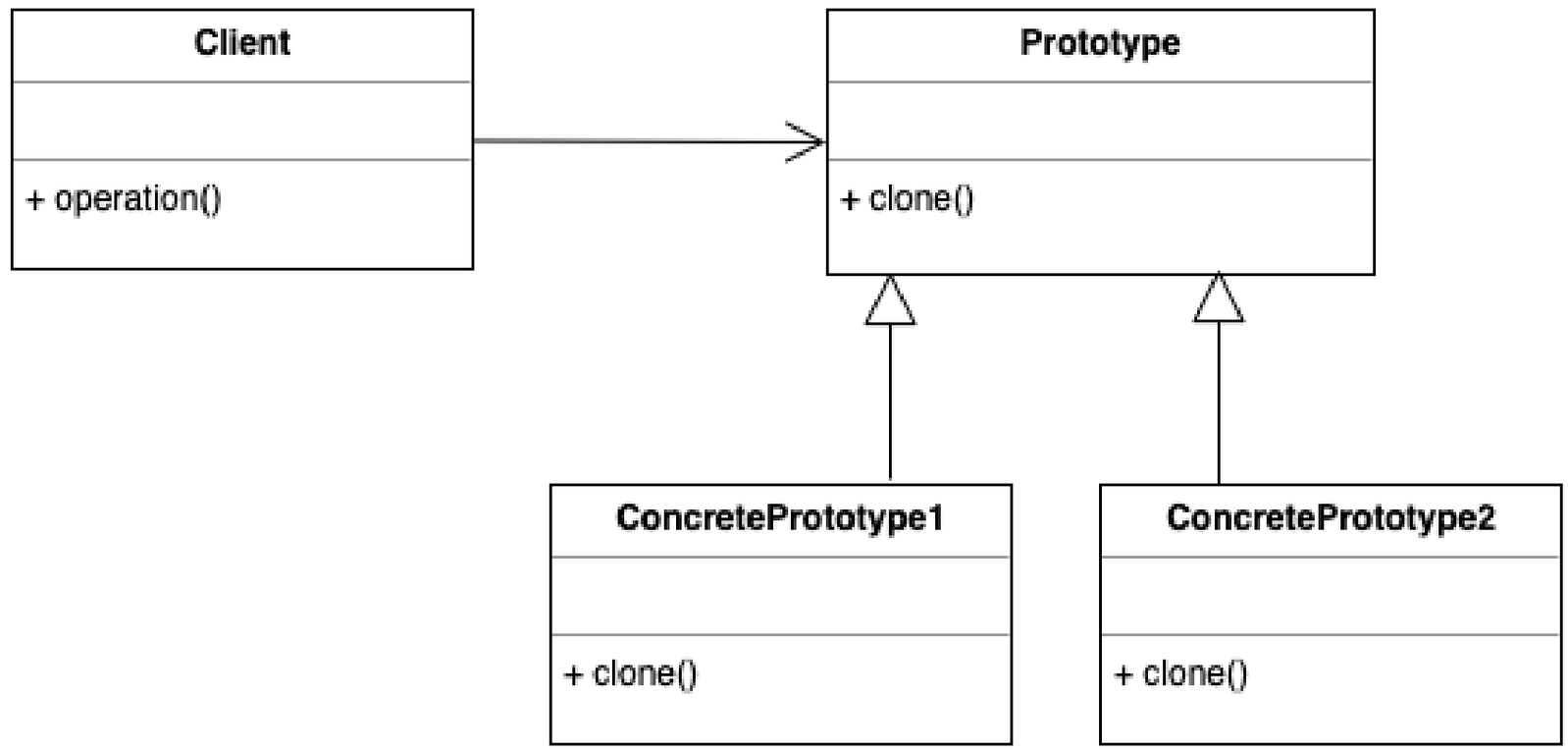
- The Prototype Pattern is used when creating an instance of a given class is either expensive or complicated
- Head First example:
  Back in the on-line RPG… It's about monsters.
  - Tons of different monsters
  - Monster characteristics that change based on landscape/setting
  - Advanced players can create their own monsters
  - …

Prototype Problem/Solution

- Problem: We want to decouple the code for the details of creating instances from code that needs to create instances on the fly
- Solution: Declare an abstract base class that specifies a pure virtual "clone" method, and, maintains a dictionary of all "cloneable" concrete derived classes.
  - Any class that needs a "polymorphic constructor" capability: derives itself from the abstract base class, registers its prototypical instance, and implements the clone() operation.
  - The client then, instead of writing code that invokes the "new" operator on a hard-wired class name, calls a "clone" operation on the abstract base class, supplying a string or enumerated data type that designates the particular concrete derived class desired.
  - Used when we don't want to keep creating “new” instances of a class
- https://sourcemaking.com/design_patterns/prototype

Prototype Pattern: UML Class Diagram

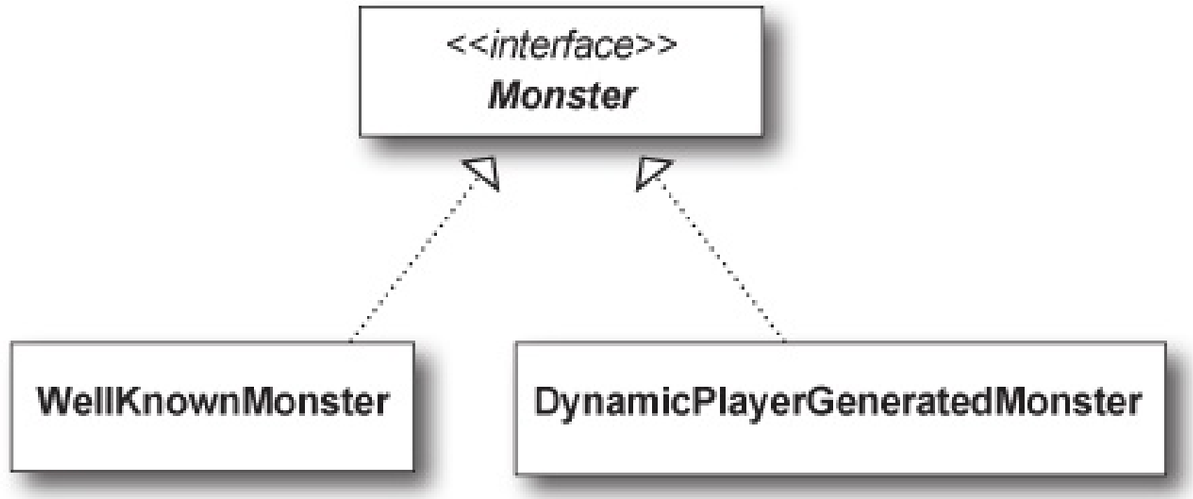
- The client is telling the prototype to clone itself and create an object
- Prototype is an interface and declares a method for cloning itself
- ConcretePrototype1 and ConcretePrototype2 implement the operation to clone themselves.



https://www.baeldung.com/java-pattern-prototype

Prototype Applied

- Prototype Pattern allows you to make new instances by copying existing instances.
- In Java this typically means using the clone() method, or de-serialization when you need deep copies.
- A key aspect of this pattern is that the client code can make new instances without knowing which specific class is being instantiated



MonsterMaker

```
makeRandomMonster() {
   Monster m =
      MonsterRegistry.getMonster();
}
```

The client needs a new monster appropriate to the current situation. (The client won't know what kind of monster he gets.)

MonsterRegistry

```
Monster getMonster() {
  // find the correct monster
  return correctMonster.clone();
}
```

The registry finds the appropriate monster, makes a clone of it, and returns the clone.

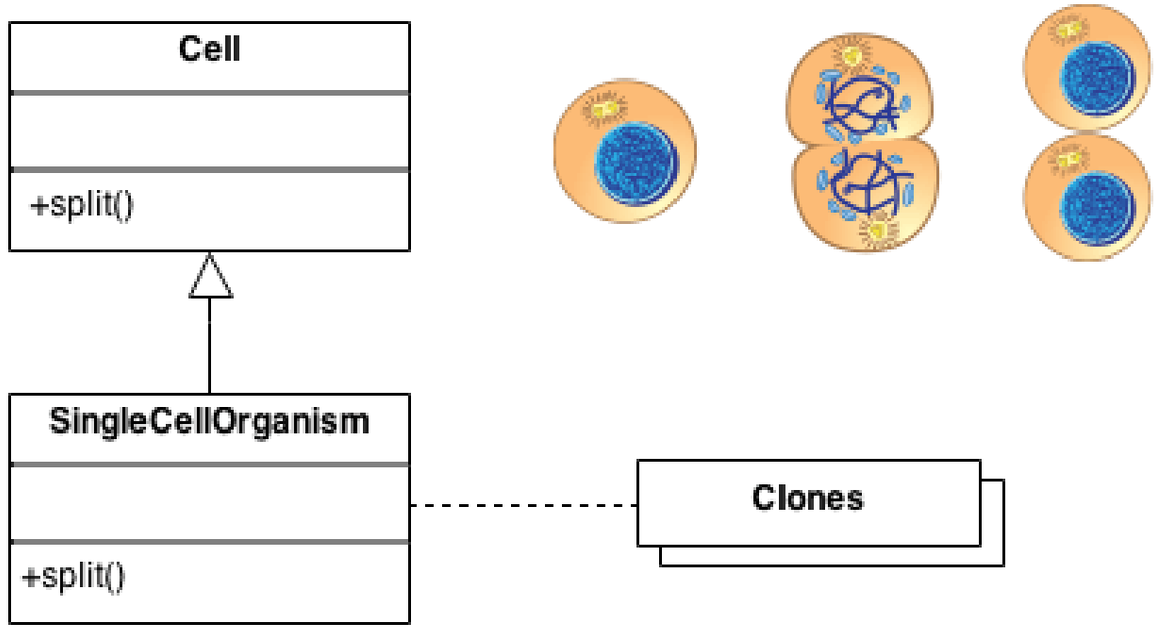
Prototype Considered

- We can implement this pattern in Java is by using the clone() method; to do this, we'd implement the Cloneable interface
- When we're trying to clone, we should decide between making a shallow or a deep copy depending on requirements
- For example, if the class contains only primitive and immutable fields, we may use a shallow copy (not including referred objects)
- If it contains references to mutable fields, we should go for a deep copy (includes copies of objects found in original)
  - Could do that with copy constructors or serialization/deserialization.

- Python has copy and deepcopy functions for shallow/deep copies

Another Prototype Example

- The Prototype pattern specifies the kind of objects to create using a prototypical instance
- Prototypes of new products are often built prior to full production, but in this example, the prototype is passive and does not participate in copying itself
- The mitotic division of a cell - resulting in two identical cells - is an example of a prototype that plays an active role in copying itself and thus, demonstrates the Prototype pattern
- When a cell splits, two cells of identical genotype result. In other words, the cell clones itself
- https://sourcemaking.com/design_patterns/prototype



Prototype in Java

```
public class Tree implements Cloneable {

    // ...
    @Override
    public Tree clone() {
        Tree tree = null;
        try {
            tree = (Tree) super.clone();
        } catch (CloneNotSupportedException e) {
            // ...
        }
        return tree;
    }

    // ...
}
```

https://www.baeldung.com/java-pattern-prototype

```
public class TreePrototypesUnitTest {

    @Test
    public void TreeCloner() {
        // ...

        Tree tree = new Tree(mass, height);
        tree.setPosition(position);
        Tree anotherTree = tree.clone();
        anotherTree.setPosition(otherPosition);

        assertEquals(position, tree.getPosition());
        assertEquals(otherPosition,
            anotherTree.getPosition());
    }
}
```

Prototype and other Patterns

- Sometimes creational patterns are competitors: there are cases when either Prototype or Abstract Factory could be used properly. At other times they are complementary: Abstract Factory might store a set of Prototypes from which to clone and return product objects. Abstract Factory, Builder, and Prototype can use Singleton in their implementations.
- Abstract Factory classes are often implemented with Factory Methods, but they can be implemented using Prototype.
- Factory Method: creation through inheritance. Prototype: creation through delegation.
- Often, designs start out using Factory Method (less complicated, more customizable, subclasses proliferate) and evolve toward Abstract Factory, Prototype, or Builder (more flexible, more complex) as the designer discovers where more flexibility is needed.
- https://sourcemaking.com/design_patterns/prototype

Prototype and other Patterns

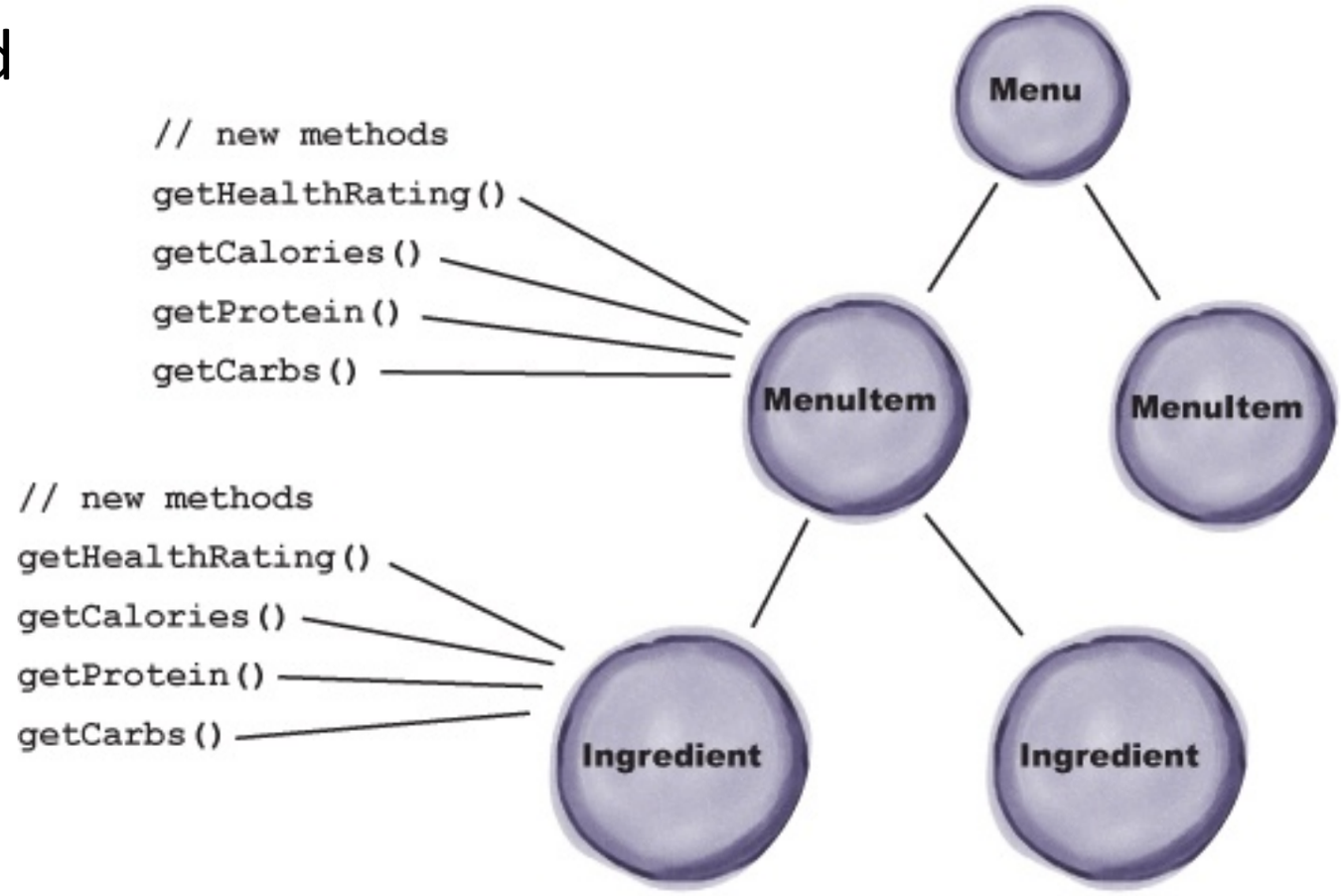
- Prototype doesn't require subclassing, but it does require an "initialize" operation. Factory Method requires subclassing, but doesn't require Initialize.
- Designs that make heavy use of the Composite and Decorator patterns often can benefit from Prototype as well.
- Prototype co-opts one instance of a class for use as a breeder of all future instances.
- Prototype is unique among the other creational patterns in that it doesn't require a class – only an object. Object-oriented languages like Self and Omega that do away with classes completely rely on prototypes for creating new objects.
- https://sourcemaking.com/design_patterns/prototype

Prototype – Key Points

- Hides the complexities of making new instances from the client
- Provides the option for the client to generate objects whose type is not known
- In some circumstances, copying an object can be more efficient than creating a new object
- Prototype should be considered when a system must create new objects of many types in a complex class hierarchy
- Prototypes are useful when object initialization is expensive, and you anticipate few variations on the initialization parameters. In this context, Prototype can avoid expensive "creation from scratch", and support cheap cloning of a pre-initialized prototype.
- A drawback to using the Prototype is that making a copy of an object can sometimes be complicated

Visitor

- The Visitor Pattern is used when you want to add capabilities to a composite of objects (and encapsulation is not important)
- Head First example:
  The diner example… Customers asking for nutritional information on meals and on ingredients.
- Initial thought is to add new methods to menu items and ingredients
- But concerns that this won't scale well with new items or new methods…

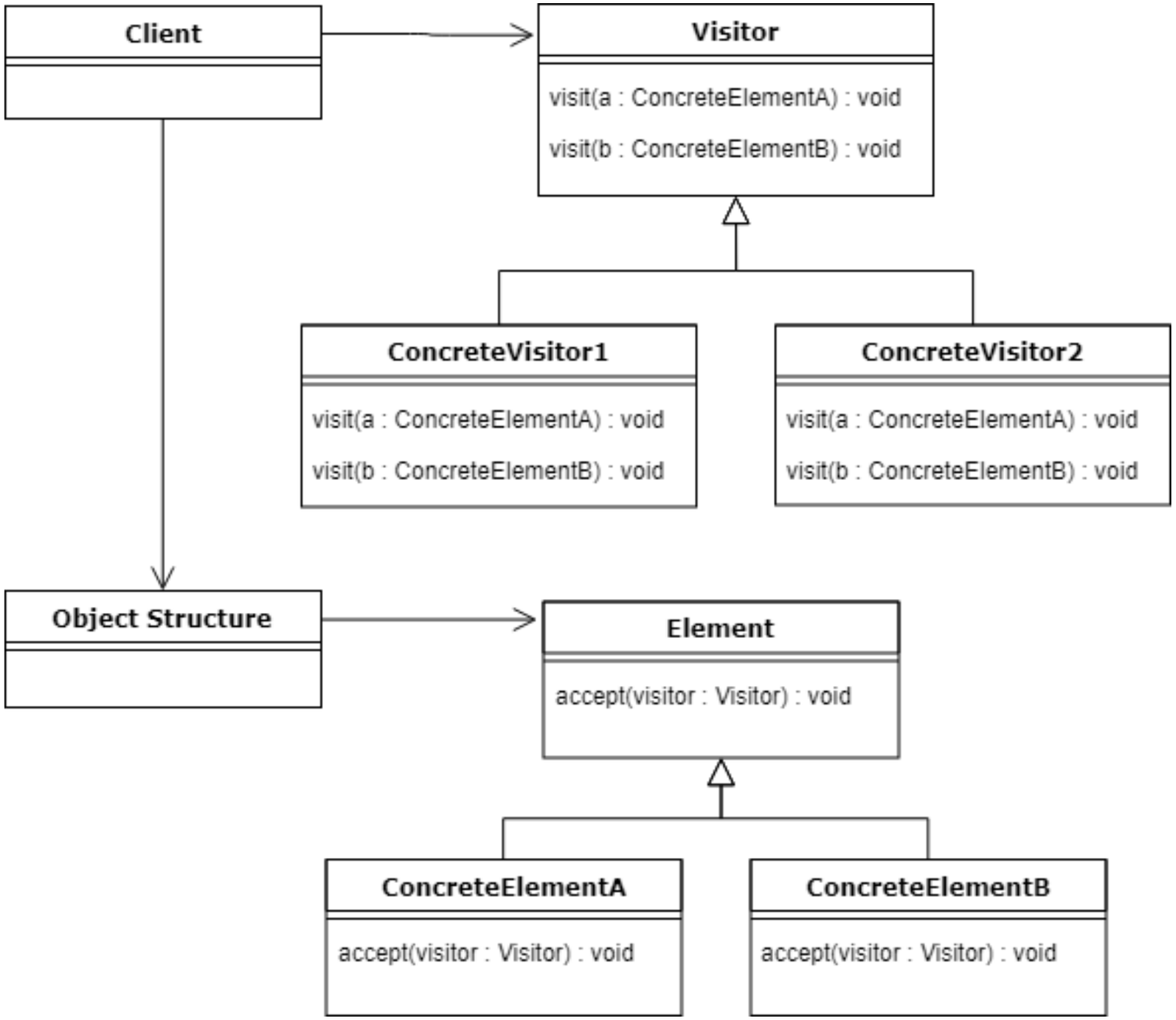


Visitor Problem/Solution

- Problem: Many distinct and unrelated operations need to be performed on node objects in a heterogeneous aggregate structure.
- You want to avoid "polluting" the node classes with these operations.
- And, you don't want to have to query the type of each node and cast the pointer to the correct type before performing the desired operation.
- Solution: Represent an operation to be performed on the elements of an object structure. Visitor lets you define a new operation without changing the classes of the elements on which it operates.
- https://sourcemaking.com/design_patterns/visitor

Visitor Pattern: UML Class Diagram

- Imagine that we have a composite object which consists of components; the object's structure is fixed – we either can't change it, or we don't plan to add new types of elements to the structure
- The Visitor design pattern adds a function which accepts the visitor class to each element of the structure
- That way our components will allow the visitor implementation to “visit” them and perform any required action on that element.
- In other words, we'll extract the algorithm which will be applied to the object structure from the classes.
- Consequently, we'll make good use of the Open/Closed principle as we won't modify the code, but we'll still be able to extend the functionality by providing a new Visitor implementation.



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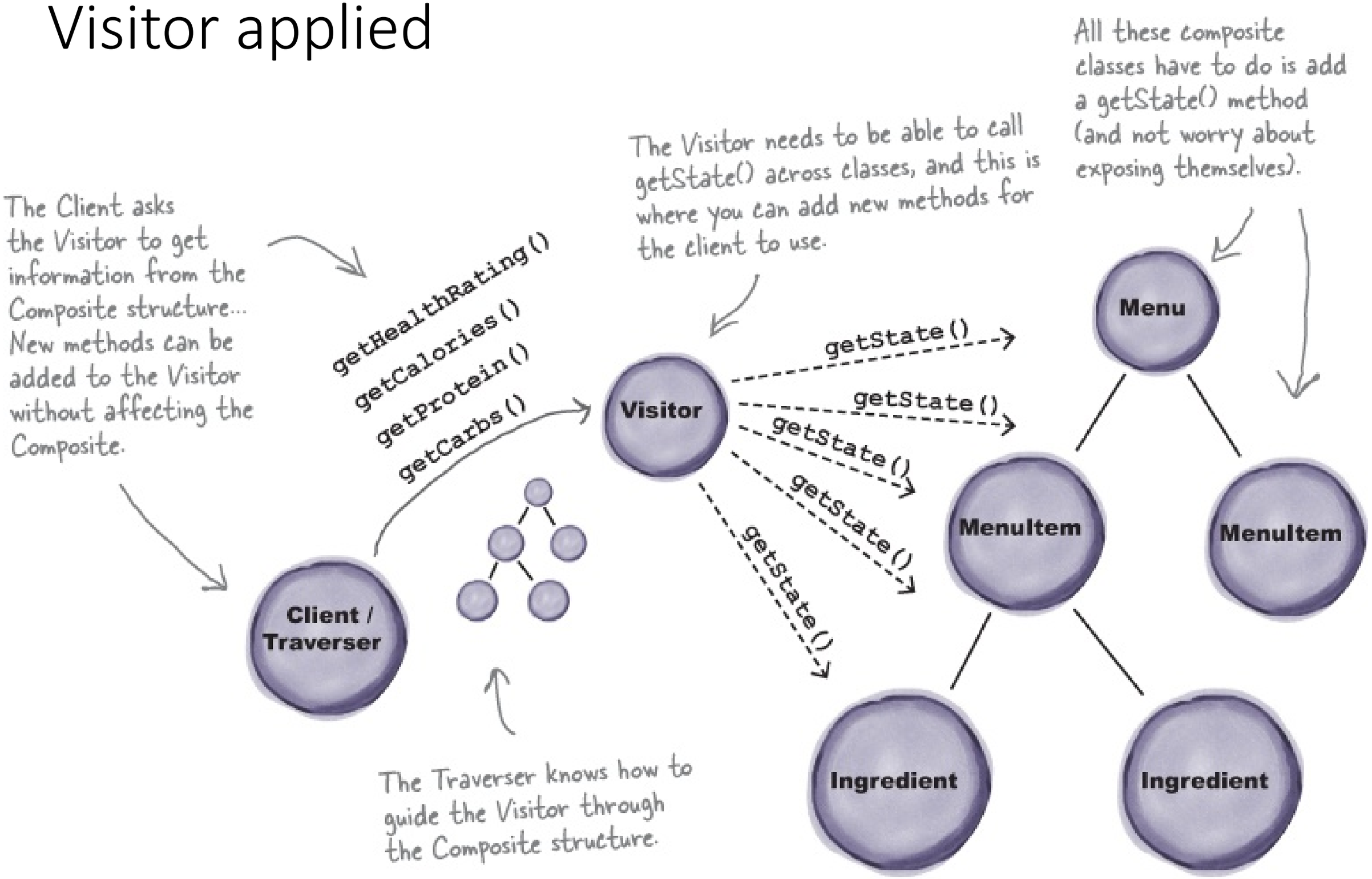
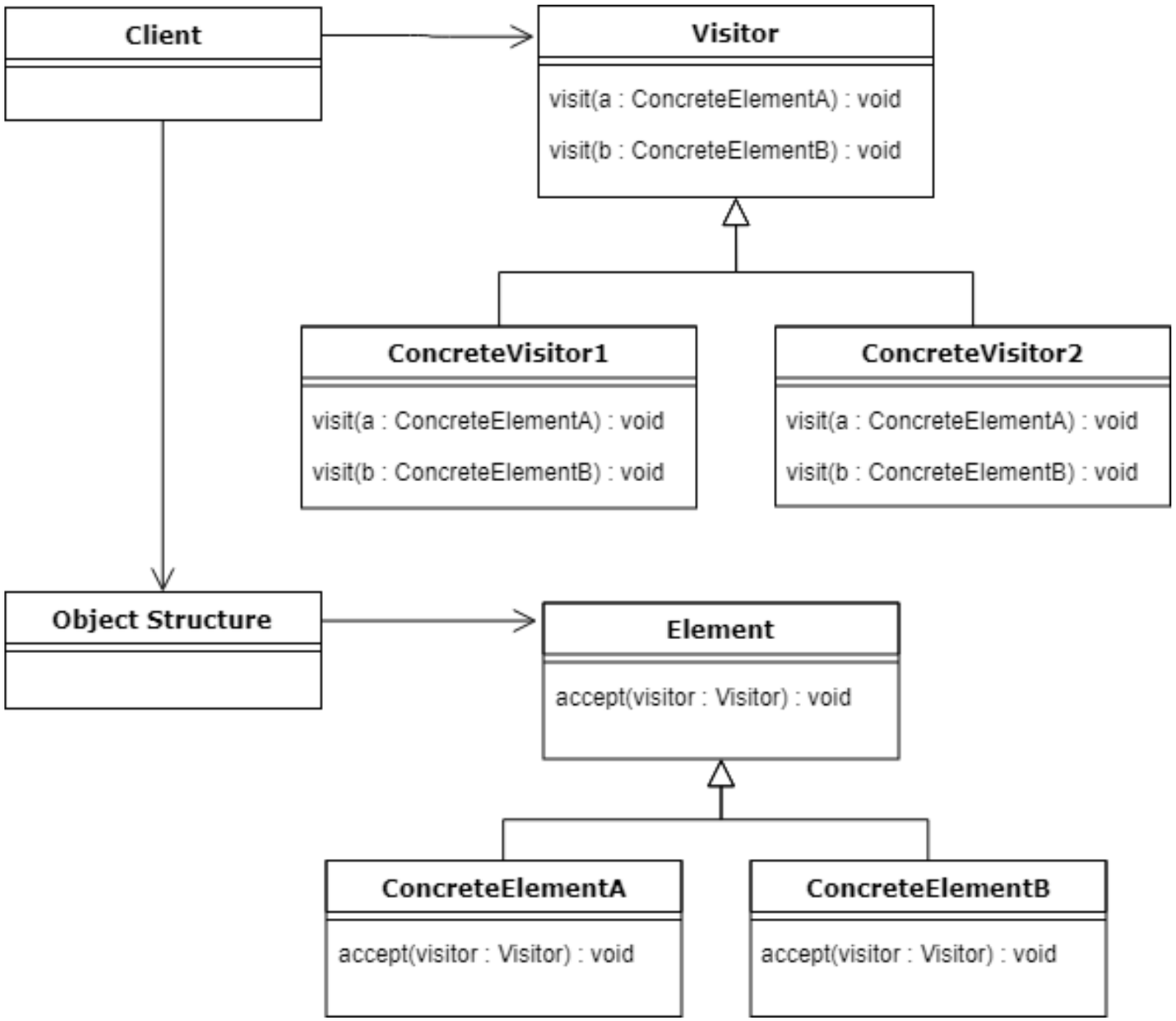
Visitor applied



Visitor in Use

- When the client needs an operation to be performed, they creates an instance of the Visitor object, traversing the composite structure, and calling the accept() method on each Element object, passing the Visitor object
- The accept() method causes flow of control to find the correct Element subclass
- Then when the visit() method is invoked, flow of control is vectored to the correct Visitor subclass. accept() dispatch plus visit() dispatch equals double dispatch



Visitor Considered

- Visitor implements "double dispatch“
- OO messages routinely manifest "single dispatch" - the operation that is executed depends on: the name of the request, and the type of the receiver
- In "double dispatch", the operation executed depends on: the name of the request, and the type of TWO receivers (the type of the Visitor and the type of the element it visits).
- An acknowledged objection to the Visitor pattern is that it represents a regression to functional decomposition - separate the algorithms from the data structures
  - Alternate view: promoting non-traditional behavior to full object status.

Another Visitor Example

- The Visitor pattern represents an operation to be performed on the elements of an object structure without changing the classes on which it operates
- This pattern can be observed in the operation of a taxi company
- When a person calls a taxi company (accepting a visitor), the company dispatches a cab to the customer
- Upon entering the taxi the customer, or Visitor, is no longer in control of his or her own transportation, the taxi (driver) is

Cab company dispatcher

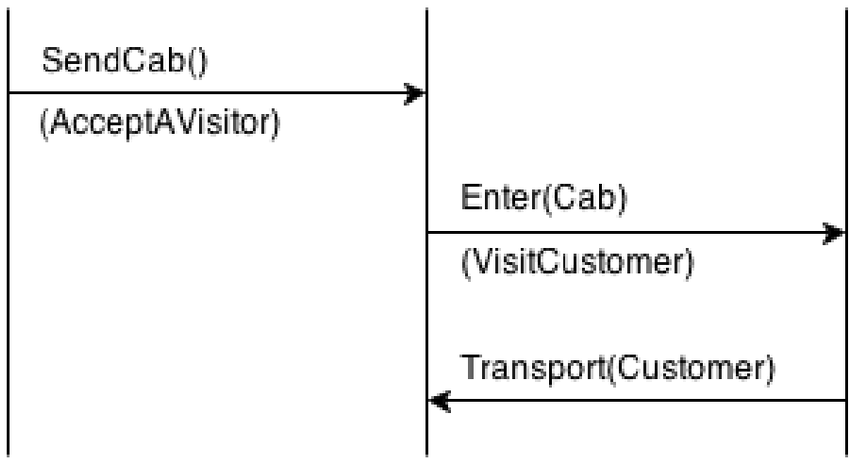
Object structure is list of Customers

Customer

Concrete element of Customers list

Taxi

Visitor



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Visitor in Java - Elements

```
interface ItemElement
{
   public int accept(ShoppingCartVisitor visitor);
}
 class Book implements ItemElement
{
   private int price;
   private String isbnNumber;
   public Book(int cost, String isbn)
   {
      this.price=cost;
      this.isbnNumber=isbn;
   }
    public int getPrice()
   {
      return price;
   }
    public String getIsbnNumber()
   {
      return isbnNumber;
   }
    @Override
   public int accept(ShoppingCartVisitor visitor)
   {
      return visitor.visit(this);
   }
}
```

```
class Fruit implements ItemElement
{
   private int pricePerKg;
   private int weight;
   private String name;

   public Fruit(int priceKg, int wt, String nm)
   {
      this.pricePerKg=priceKg;
      this.weight=wt;
      this.name = nm;
   }

   public int getPricePerKg()
   {
      return pricePerKg;
   }

   public int getWeight()
   {
      return weight;
   }

   public String getName()
   {
      return this.name;
   }

   @Override
   public int accept(ShoppingCartVisitor visitor)
   {
      return visitor.visit(this);
   }

}
```

https://www.geeksforgeeks.org/visitor-design-pattern/

Visitor in Java – Visitor, Client

```
interface ShoppingCartVisitor
{
      int visit(Book book);
   int visit(Fruit fruit);
}
class ShoppingCartVisitorImpl implements ShoppingCartVisitor
{
   @Override
   public int visit(Book book)
   {
      int cost=0;
      //apply 5$ discount if book price is greater than 50
      if(book.getPrice() > 50)
      {     cost = book.getPrice()-5;    }
      else  cost = book.getPrice();
      System.out.println("Book ISBN::"+
                  book.getIsbnNumber() + " cost ="+cost);
      return cost;
   }
   @Override
   public int visit(Fruit fruit)
   {
      int cost = fruit.getPricePerKg()*fruit.getWeight();
      System.out.println(fruit.getName() + " cost = "+cost);
      return cost;
   }

}
```

https://www.geeksforgeeks.org/visitor-design-pattern/

```
class ShoppingCartClient
{

   public static void main(String[] args)
   {
      ItemElement[] items = new ItemElement[]{new Book(20, "1234"),
                  new Book(100, "5678"), new Fruit(10, 2, "Banana"),
                  new Fruit(5, 5, "Apple")};

      int total = calculatePrice(items);
      System.out.println("Total Cost = "+total);
   }

   private static int calculatePrice(ItemElement[] items)
   {
      ShoppingCartVisitor visitor = new ShoppingCartVisitorImpl();
      int sum=0;
      for(ItemElement item : items)
      {
         sum = sum + item.accept(visitor);
      }
      return sum;
   }

}
```

Output:

```
Book ISBN::1234 cost =20
Book ISBN::5678 cost =95
Banana cost = 20
Apple cost = 25
Total Cost = 160
```

Visitor and other Patterns

- The abstract syntax tree of Interpreter is a Composite (therefore Iterator and Visitor are also applicable).
- Iterator can traverse a Composite. Visitor can apply an operation over a Composite.
- The Visitor pattern is like a more powerful Command pattern because the visitor may initiate whatever is appropriate for the kind of object it encounters.
- The Visitor pattern is the classic technique for recovering lost type information without resorting to dynamic casts.
- https://sourcemaking.com/design_patterns/visitor

Visitor – Key Points

- Allows you to add operations to a Composite structure without changing the structure itself (supports Open/Closed principle)
- Adding new operations is relatively easy
- The code for operations performed by the Visitor is centralized
- The Composite classes' encapsulation is broken when the Visitor is used
- Because the traversal function is involved, changes to the Composite structure are more difficult
- The Visitor pattern makes adding new operations (or utilities) easy - simply add a new Visitor derived class, but… if the subclasses in the aggregate node hierarchy are not stable, keeping the Visitor subclasses in sync requires a prohibitive amount of effort
- Visitor downside: its usage **makes it more difficult to maintain the code if we need to add new elements to the object's structure**
- For example, if we add new a new element, then we need to update all existing concrete visitors with the new method desired for processing this element
- When using this pattern, the business logic related to one particular object gets spread over all visitor implementations

Midterm Exam

- Many perfect or near perfect scores, so no curve
- I will be asking the graders to give full credit for this question:

Attempts: 146 out of 146

The USFS simulation has three different kinds of trees that all inherit from a common Tree class - Pines, which evolved to depend on frequent, low-intensity fires; Spruce, which live high in the mountains to avoid fires; and Aspens, which grow back quickly after fires because they connect underground through a mat of roots. They all grow and they all burn, so the USFS programmers just put a grow() method and a burn() method in the Tree class that checks the kind of tree to decide how they grow/burn. Recently they added a separate Shrub class that also grows and burns, but Shrubs are managed by the USFS in a completely different way than Trees.

What are good OO design suggestions for the USFS programming team: (Select all correct)

Encapsulate variance in behavior using the Strategy pattern. You can dynamically assign grow and burn behavior at runtime.	130 respondents	**89 %**	✓
You should create two different class hierarchies for the Tree and Shrub that both have grow() and burn() methods. That way Shrubs don't have to behave like Trees.	39 respondents	27 %	
Define interfaces for growing and burning behavior. Then Tree and Shrub classes can implement those interfaces for growing and burning even though they're managed differently.	134 respondents	**92 %**	✓
If trees and shrubs all grow and burn, you should have Shrub inherit from the Tree class. You can make the management of the Shrub more specific in the subclass.	39 respondents	27 %	

49% answered correctly

Giant In-Class Coding Exercise on Friday!

- Friday 11/5 we will hold an in-class coding exercise worth up to **five** bonus points
- Teams of 1-3 students, the exercise will run for the class period
- You will need access to a Java IDE, the class Canvas page, and the web
- More details when it happens on Friday
- I will make a version of this exercise available to folks attending asynchronously as well…
- Know your Java patterns…
- Please plan to be there!

Final Exam

- Our last class is Wed 12/8
- The Final for the OOAD class will open on Sat AM 12/11 and run until midnight Mon 12/13, so you'll have approximately 3 days to choose a time to take it
- Similar to the Midterm, the Final will be on Canvas and will be open notes/book/etc.; It will be available for 2 hours (4 hours for those with accommodations) after you start it, but is targeted at about an hour in length
- It will only cover material reviewed after what was covered on the Midterm (I'll review the specific coverage in class when it's closer)
- The Final exam is **optional**
  - If you do not take the Final exam, you will get the same grade for the Final that you received for your Midterm
  - If you take the Final exam, your Final exam grade will be the larger of:
    - your Midterm grade and
    - the grade you make on the Final
  - Therefore, you cannot score less on the Final than you did on the Midterm
  - Please note that taking the Final does not affect your Midterm grade
- Let me know if you have questions about the Final or your situation
- **Please remember that the grade shown in Canvas is NOT your final grade – calculate your points earned against 1000 possible points (or 1250 for 5448) to determine your percentage grade!**

Next Steps

- Project 5 design package is **due Wed 11/3**
  - Project 6 review on Wednesday
  - Project 6 will include Zoom or in-person code demonstration sign-ups
- Graduate peer review is **due Wed 11/3**
  - Details on assignments in Canvas Files/Class Files
  - We'll talk about Pecha Kuchas (and see an example) and look at the final research presentation on Wednesday
- New Quiz running now, **due Wed 11/3**
- Coming soon…
  - Design techniques
  - ORMs/Databases
  - Refactoring
  - Dependency Injection
  - Reflection
  - Architecture
  - APIs
  - Anti-/Other Patterns

- In class coding exercise on Fri 11/5 – up to 5 bonus points – you'll need a Java environment for your team of 1 to 3
- New Piazza topic this week for your comments for Participation Grade
- Piazza article posts now available for extra bonus points (if you're not getting points in class)
- Office hours and GitHub user IDs for class staff are on Piazza and Canvas
- If you'd like to see Dwight, Max, or Roshan at times other than their office hours, ping them on Piazza or email
- If you'd like to see Bruce outside of office hours, use my appointment app: https://brucem.appointlet.com