CS 635 Advanced Object-Oriented Design & Programming
Fall Semester, 2018
Doc 16 Visitor, Prototype, Flyweight
Nov 7, 2018

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Visitor Pattern

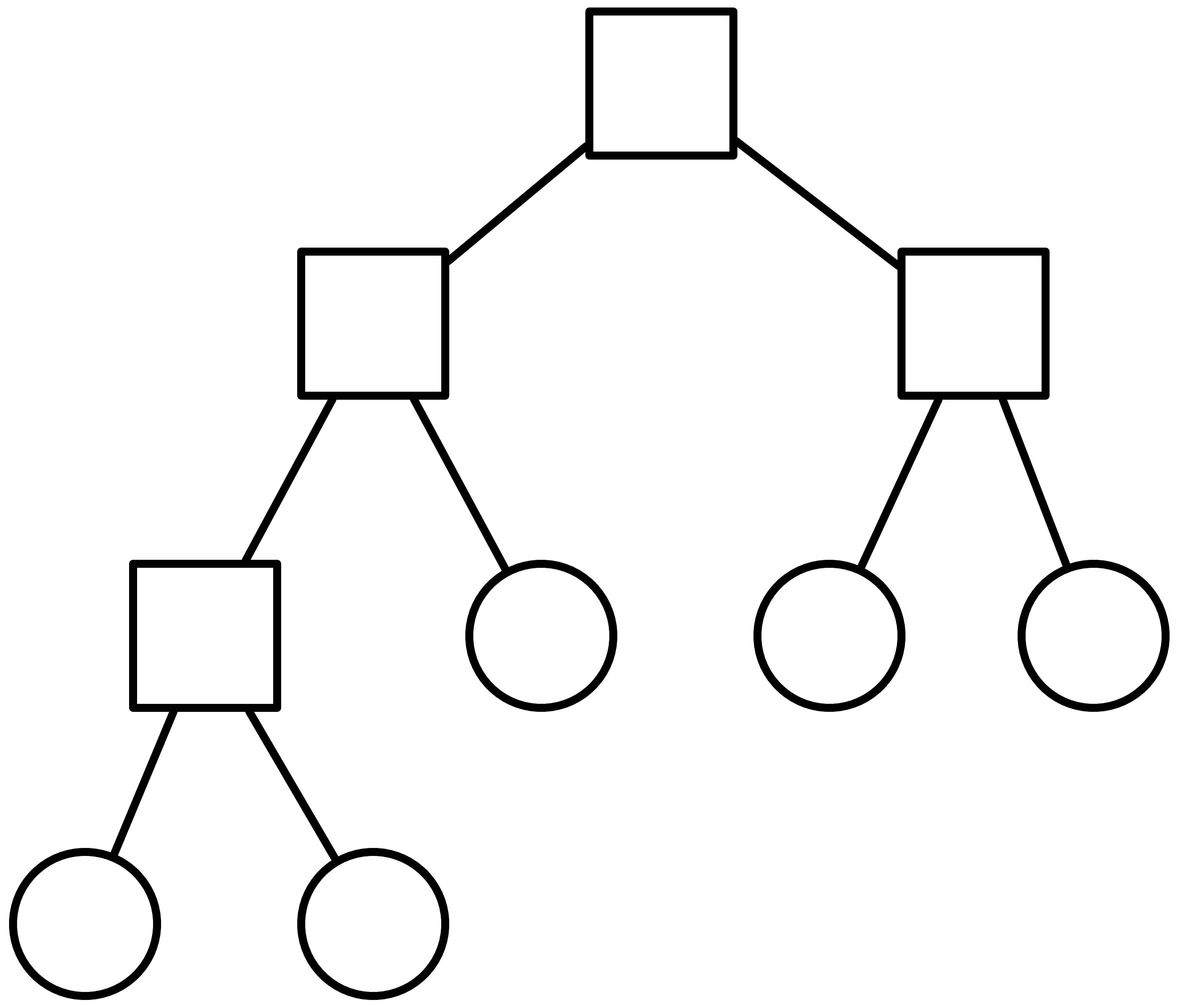
Visitor

Intent

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

Tree Example



class Node { ... }

class InnerNode extends Node {...}

class LeafNode extends Node {...}

class Tree { ... }

Tree Printing

HTML Print

PDF Print

TeX Print

RTF Print

Others likely in future

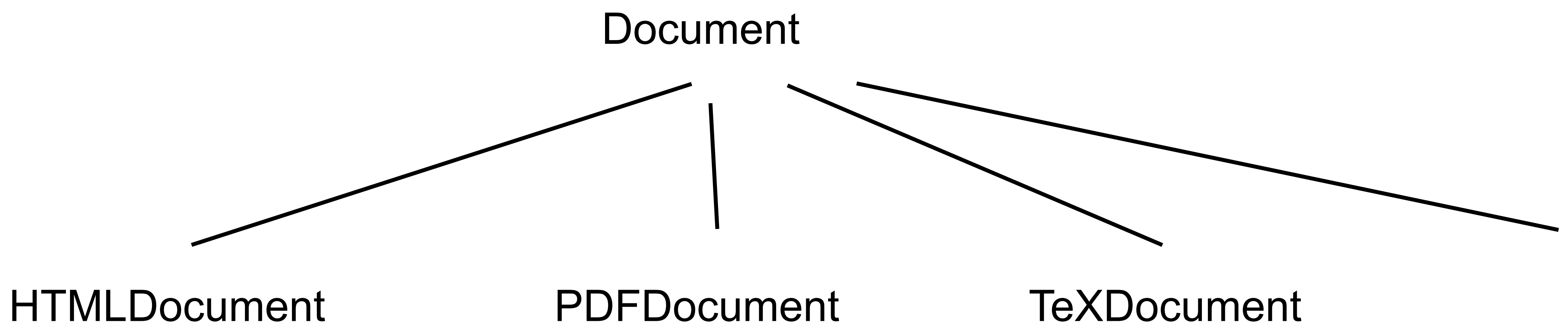
Operations are complex

Do different things on different types of nodes

Need to traverse tree

Not part of BST abstraction

Assume



First Attempt

```
print(Tree source, Document output) {
  foreach( Node current : source ) {
    if current.isInnerNode() && output.isHtml() {
      print inner node on html document
    } else if current.isLeafNode() && output.isHtml() {
      print leaf node on html document
    } else if current.isInnerNode() && output.isPDF() {
      print inner node on pdf document
    } else if current.isLeafNode() && output.isPDF() {
      print leaf node on pdf document
    } etc.
```

Second Attempt

Create Printer Classes

Use iterator to access all elements

Process each element

Second Attempt

```
class TreePrinter {
  public void printTree (Tree toPrint, Document output) {
    foreach( Node current : source ) {
      if (current.isLeafNode())
        printLeafNode(current, output);
      else if (current.isInternalNode() )
        printInternalNode(current, output);
    }
  }

  private void printLeafNode(Node current, Document output) {
    if output.isHtml()
      print leaf node on html document
    else if output.isPDF()
      print leaf node on PDF document
    else if etc
  }
```

Hidden case statements

What we would like

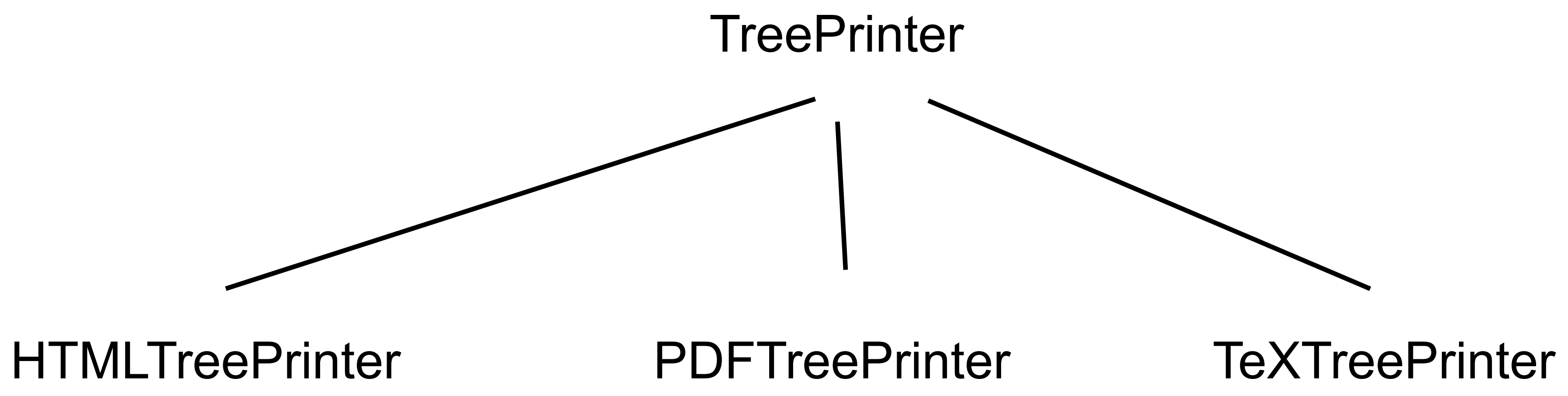
```
class TreePrinter {
  public void printTree (Tree source, Document output) {
    foreach( Node current : source ) {
        printNode(current, output);                    Compile Error
    }
  }

  private void printNode(InnerNode current, HTMLDocument output) {
    print inner node on html document
  }

  private void printNode(LeafNode current, HTMLDocument output) {
    print leaf node on html document
  }

  private void printNode(InnerNode current, PDFDocument output) {
    print inner node on PDF document
  }
  etc
```

Overloaded Methods

Which overloaded method to run

- Selected at compile time
- Based on declared type of parameter
- Does not use runtime information

Use Subclasses



Third Attempt

```
class TreePrinter {
  Document output;
  public void printTree (Tree toPrint) {
    foreach( Node current : source ) {
      if (current.isLeafNode())
        printLeafNode(current, output);
      else if (current.isInternalNode() )
        printInternalNode(current, output);
    }
  }

  public Document getDocument() { return output;}

  private abstract void printLeafNode(Node current);
  private abstract void printInnerNode(Node current);

  }
```

Third Attempt

```
class HTMLTreePrinter extends TreePrinter {

  private void printLeafNode(Node current) {
      print leaf node on html document
  }

  private void printInnerNode(Node current) {
      print inner node on html document
  }
}
```

Overloaded Method

```
class TreePrinter {
  Document output;
  public void printTree (Tree toPrint) {
    foreach( Node current : source ) {
      printNode(current);
    }
  }

  public Document getDocument() { return output;}

  private abstract void printNode(LeafNode current);
  private abstract void printNode(InnerNode current);
  }
```

Compile Error

Key Idea

Receiver of method is determined at runtime

```
x.toString();
```

Send a message to Nodes to determine what type of node we have

Add Methods to Nodes

```
class Node {
   abstract public void print(TreePrinter printer);
}



class InnerNode extends Node {
    public void print(TreePrinter printer) {
       printer.printInnerNode( this );
    }
}

class LeafNode extends Node {
    public void print(TreePrinter printer) {
       printer.printLeafNode( this );
    }
}
```

Now we can Use Polymorphism

```
class TreePrinter {
  Document output;
  public void printTree (Tree toPrint) {
    foreach( Node current : source ) {
          current.print(this);
    }
  }

  public Document getDocument() { return output;}

  public abstract void printLeafNode(Node current);
  public abstract void printInnerNode(Node current);

  }
```

What Have we gained

No if statements

Can add more types of Documents by adding subclasses

Work for a Document is in one place

Divided work into small parts

We can use method overloading

```
class TreePrinter {
  Document output;
  public void printTree (Tree toPrint) {
    foreach( Node current : source ) {
        current.print(this);
    }
  }

  public Document getDocument() { return output;}

  public abstract void printNode(InnerNode current);
  public abstract void printNode(LeafNode current);

  }
```

```
class InnerNode extends Node {
   public void print(TreePrinter printer) {
      printer.printNode( this );
   }
}

class LeafNode extends Node {
   public void print(TreePrinter printer) {
      printer.printNode( this );
   }
}
```

But We don’t gain anything

```
class TreePrinter {
  Document output;
  public void printTree (Tree toPrint) {
    foreach( Node current : source ) {
        current.print(this);
    }
  }

  public Document getDocument() { return output;}

  public abstract void printNode(InnerNode current);
  public abstract void printNode(LeafNode current);

  }
```

Still need to know about each node type

One Last Problem

Modified the nodes for a specific issue

For each issue need to add methods to node!?!

Make the structure generic

In The Nodes

```
class Node {
   abstract public void accept(Visitor aVisitor);
}



class BinaryTreeNode extends Node {
    public void accept(Visitor aVisitor) {
        aVisitor.visitBinaryTreeNode( this );
    }
}

class BinaryTreeLeaf extends Node {
    public void accept(Visitor aVisitor) {
        aVisitor.visitBinaryTreeLeaf( this );
    }
}
```

Visitor

```
abstract class Visitor {

   abstract void visitBinaryTreeNode( BinaryTreeNode );

   abstract void visitBinaryTreeLeaf( BinaryTreeLeaf );
}

class HTMLPrintVisitor extends Visitor {

   public void visitBinaryTreeNode( BinaryTreeNode x ) {
      HTML print code here
   }

   public void visitBinaryTreeLeaf( BinaryTreeLeaf x){ ...}
}
```

```
Visitor printer = new HTMLPrintVisitor();
Tree toPrint;

Iterator nodes = toPrint.iterator();
foreach( Node current : source ) {
   current.accept(printer);
}
```

← Node object calls correct method in Printer

Tree Example

```
class BinaryTreeNode extends Node {
    public void accept(Visitor aVisitor) {
        aVisitor.visitBinaryTreeNode( this );
    }
}

class BinaryTreeLeaf extends Node {
    public void accept(Visitor aVisitor) {
        aVisitor.visitBinaryTreeLeaf( this );
    }
}

abstract class Visitor {
    abstract void visitBinaryTreeNode( BinaryTreeNode );
    abstract void visitBinaryTreeLeaf( BinaryTreeLeaf );
}

class HTMLPrintVisitor extends Visitor {
    public void visitBinaryTreeNode( BinaryTreeNode x ) {
        HTML print code here
    }
    public void visitBinaryTreeLeaf( BinaryTreeLeaf x){ ...}
}
```

Put operations into separate object - a visitor

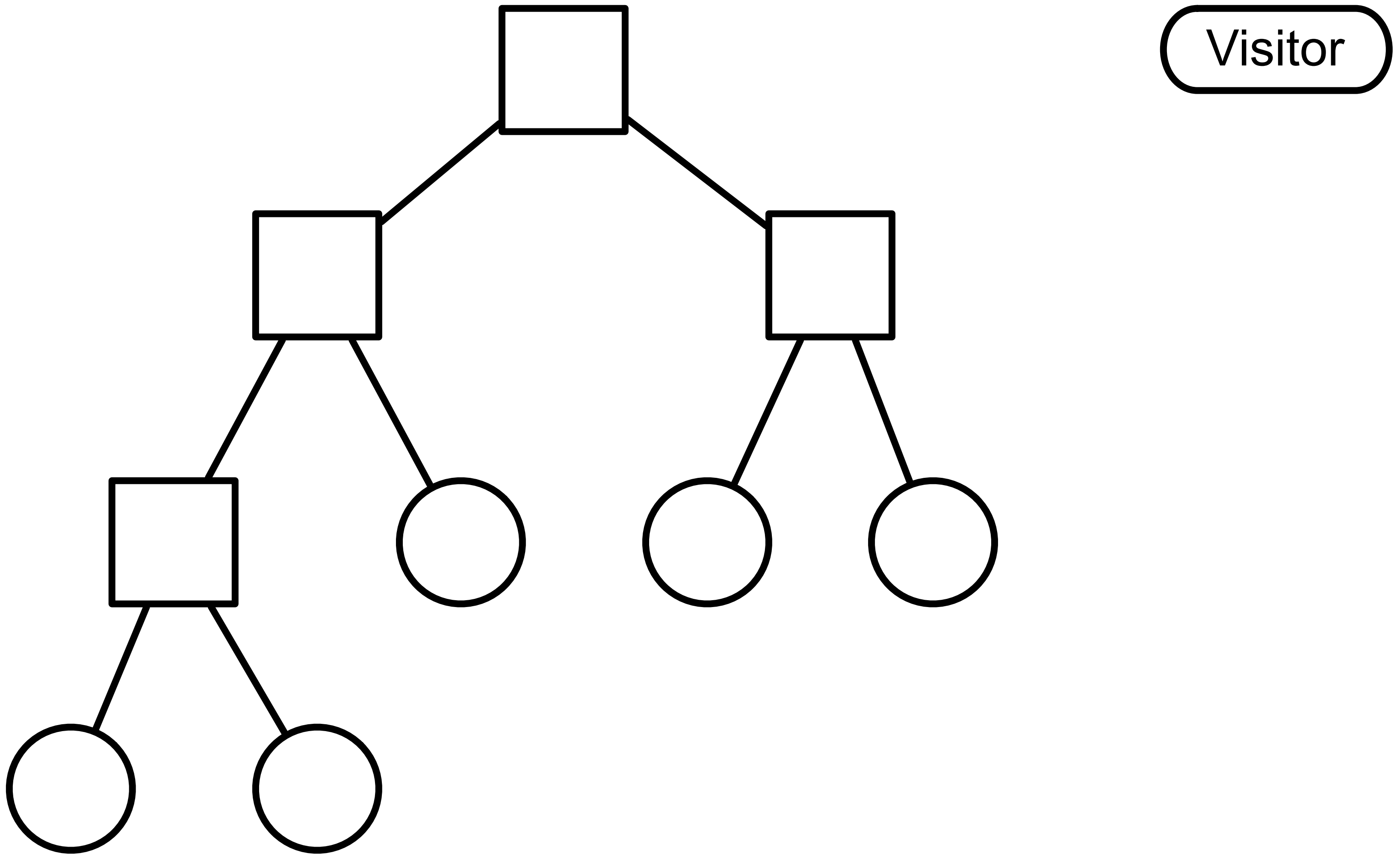
Pass the visitor to each element in the structure

The element then activates the visitor

Visitor performs its operation on the element

Each visitX method only deals with on type of element

Tree Example



Double Dispatch

Note that a visit to one node requires two method calls

```
Node example = new BinaryTreeLeaf();
Visitor traveler = new HTMLPrintVisitor();
example.accept( traveler );
```

$$\begin{tikzcd}
\text{example.accept(traveler)} \arrow[d] & \\
\text{BinaryTreeLeaf} \arrow[r, "\text{traveler.visitLeafNode(this)}"'] & \text{HTMLPrintVisitor}
\end{tikzcd}$$

Issue - Who does the traversal?

Visitor

Elements in the Structure

Iterator

When to Use the Visitor

Have many classes of objects with differing interfaces, and you want to perform operations on these objects that depend on their concrete classes

When many distinct and unrelated operations need to be preformed on objects in an object structure and you want to avoid cluttering the classes with these operations

When the classes defining the structure rarely change, but you often want to define new operations over the structure

Consequences

Visitors makes adding new operations easier

Visitors gathers related operations, separates unrelated ones

Adding new ConcreteElement classes is hard

Visiting across class hierarchies

Accumulating state

Breaking encapsulation

Avoiding the accept() method

- Visitor pattern requires elements to have an accept method
- Sometimes this is not possible
    - You don’t have the source for the elements

Aspect Oriented Programming

AspectJ eleminates the need for an accept method in aspect oriented Java

AspectS provides a similar process for Smalltalk

Example - Magritte

Web applications have data (domain models)

We need to

- Display the data
- Enter the data
- Validate data
- Store Data

Magritte

For each field in a domain model (class) provide a description

Description contains

- Data type
- Display string
- Field name
- Constraints

```
descriptionFirstName
   ^ (MAStringDescription auto: 'firstName' label: 'First Name' priority: 20)
         beRequired;
         yourself.


descriptionBirthday
   ^ (MADateDescription auto: 'birthday' label: 'Birthday' priority: 70)
         between:(Date year: 1900) and:Datetoday;
         yourself
```

Magritte

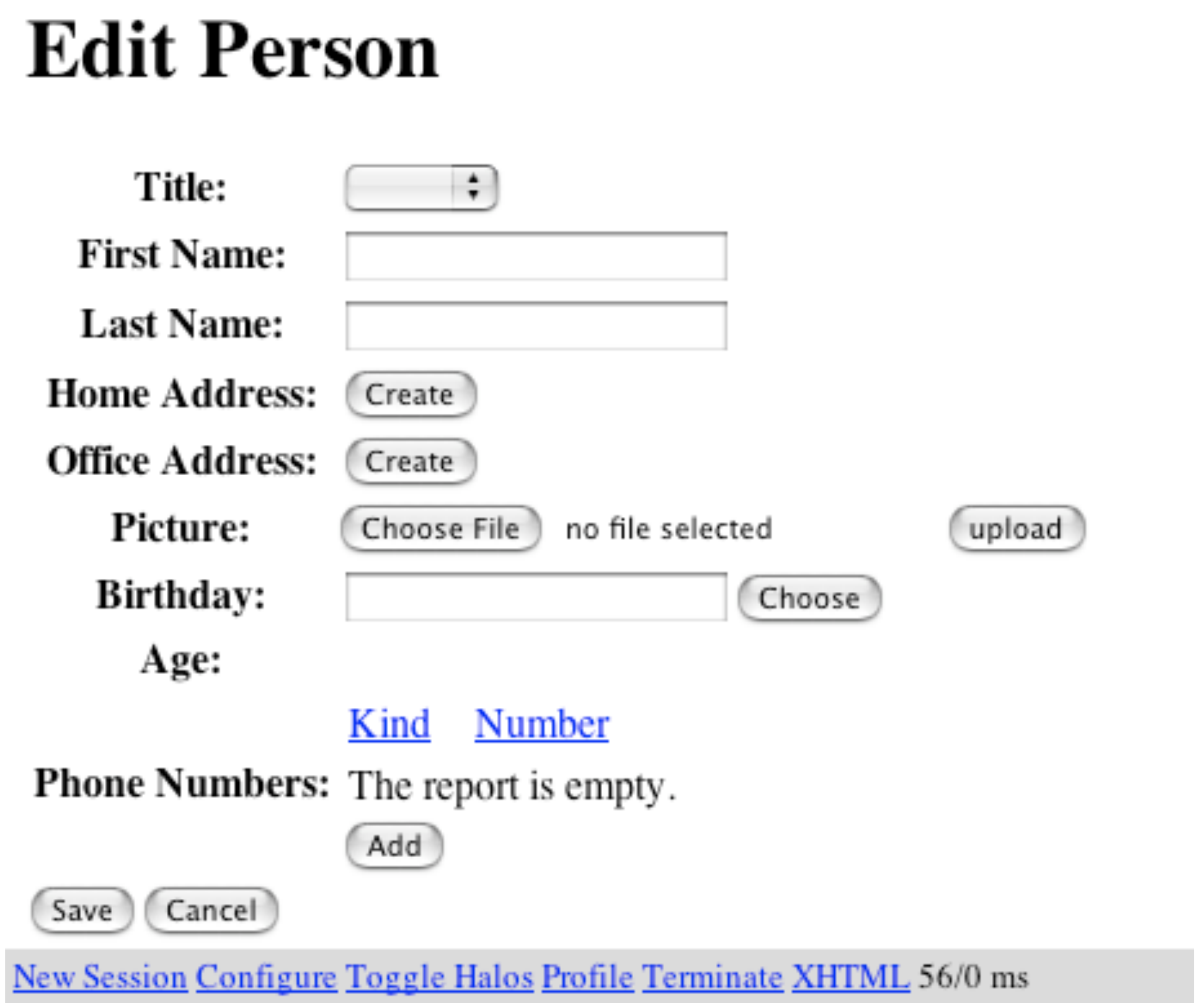
Each domain model has a collection of descriptions

Different visitors are used to

- Generate html to display data
- Generate form to enter the data
- Validate data from form
- Save data in database

Sample Page

```
editor := (Person new  asComponent)
            addValidatedSwitch;
            yourself.
result := self call: editor.
```



Edit Person

Title:	
First Name:	
Last Name:	
Home Address:	Create
Office Address:	Create
Picture:	Choose File no file selected upload
Birthday:	Choose
Age:	
	Kind Number
Phone Numbers:	The report is empty.
	Add

Save Cancel

New Session Configure Toggle Halos Profile Terminate XHTML 56/0 ms

Refactoring: Move Accumulation to Visitor

A method accumulates information from heterogenous classes

so

Move the accumulation task to a Visitor that can visit each class to accumulate the information

Clojure, Lisp & Multi-methods

```
(defmulti printNode (fn [node document] [(class node) (class document)]))


(defmethod printNode [InnerNode HTMLDocument]
  [node document]
  code to print InnerNode on HTMLDocument)

(defmethod printNode [InnerNode PDFDocument]
  [node document]
  code to print InnerNode on PDFDocument)

 (defmethod printNode [LeafNode PDFDocument]
   [node document]
   code to print InnerNode on PDFDocument)


 etc.
```

Clojure, Lisp & Multi-methods

Multi-methods in Clojure do select overloaded method

- At run-time
- Based on argument types

No need for visitor pattern

Prototype

Prototype

Specify the kinds of objects to create using a prototypical instance, and create new objects by copying this prototype

Applicability

Use the Prototype pattern when

- A system should be independent of how its products are created, composed, and represented; and
- When the classes to instantiate are specified at run-time; or
- To avoid building a class hierarchy of factories that parallels the class hierarchy of products; or
- When instances of a class can have one of only a few different combinations of state.

Insurance Example

Insurance agents start with a standard policy and customize it

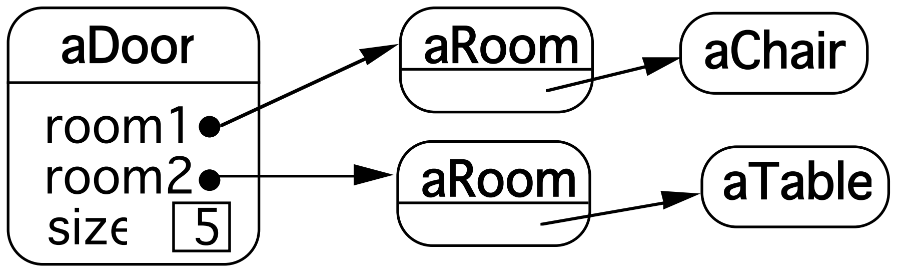
Two basic strategies:

- Copy the original and edit the copy
- Store only the differences between original and the customize version in a decorator

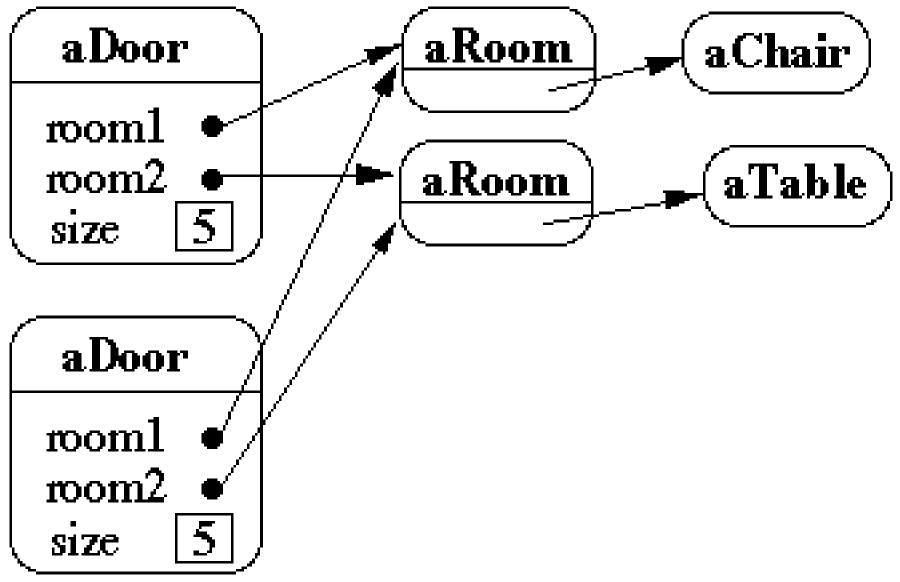
Copying Issues

Shallow Copy Verse Deep Copy

Original Objects

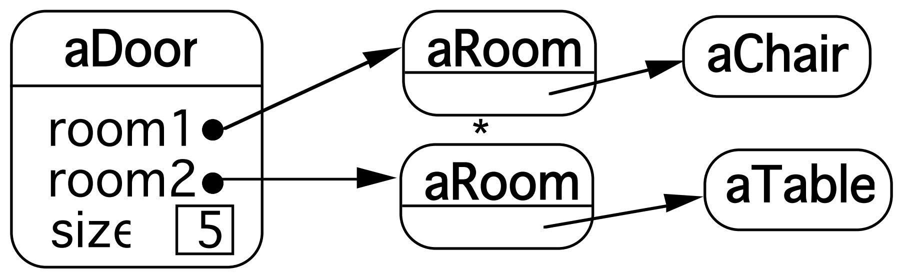


Shallow Copy

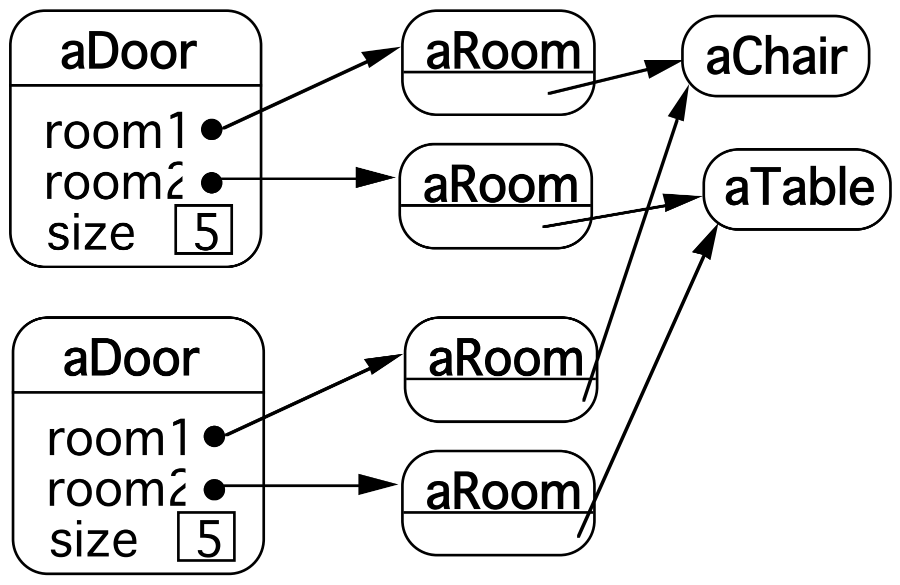


Shallow Copy Verse Deep Copy

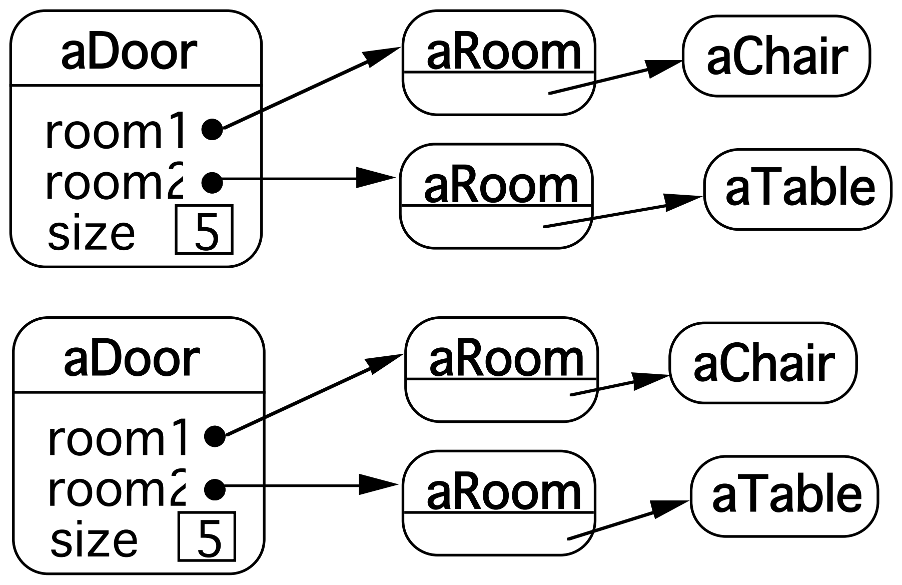
Original Objects



Deep Copy



Deeper Copy



Prototype-based Languages

No classes

Behavior reuse (inheritance)

- Cloning existing objects which serve as prototypes

Some Prototype-based languages

- Self
- JavaScript
- Squeak (eToys)
- Perl with Class::Prototyped module

Flyweight

Flyweight

Use sharing to support large number of fine-grained objects efficiently

Text Example

A document has many instances of the character 'a'

Character has

- Font
- width
- Height
- Ascenders
- Descenders
- Where it is in the document

Most of these are the same for all instances of 'a'

Use one object to represent all instances of 'a'

Java String Example

```
public void testInterned() {
   String a1 = "catrat";
   String a2 = "cat";
   assertFalse(a1 == (a2+ "rat"));

   String a3 = (a2 + "rat").intern();
   assertTrue(a1 == a3);
   String a4 = "cat" + "rat";
   assertTrue(a1 == a4);
   assertTrue(a3 == a4);
}
```

public String intern()

Returns a canonical representation for the string object.

A pool of strings, initially empty, is maintained privately by the class String.

Intrinsic State

Information that is independent from the object's context

The information that can be shared among many objects

So can be stored inside of the flyweight

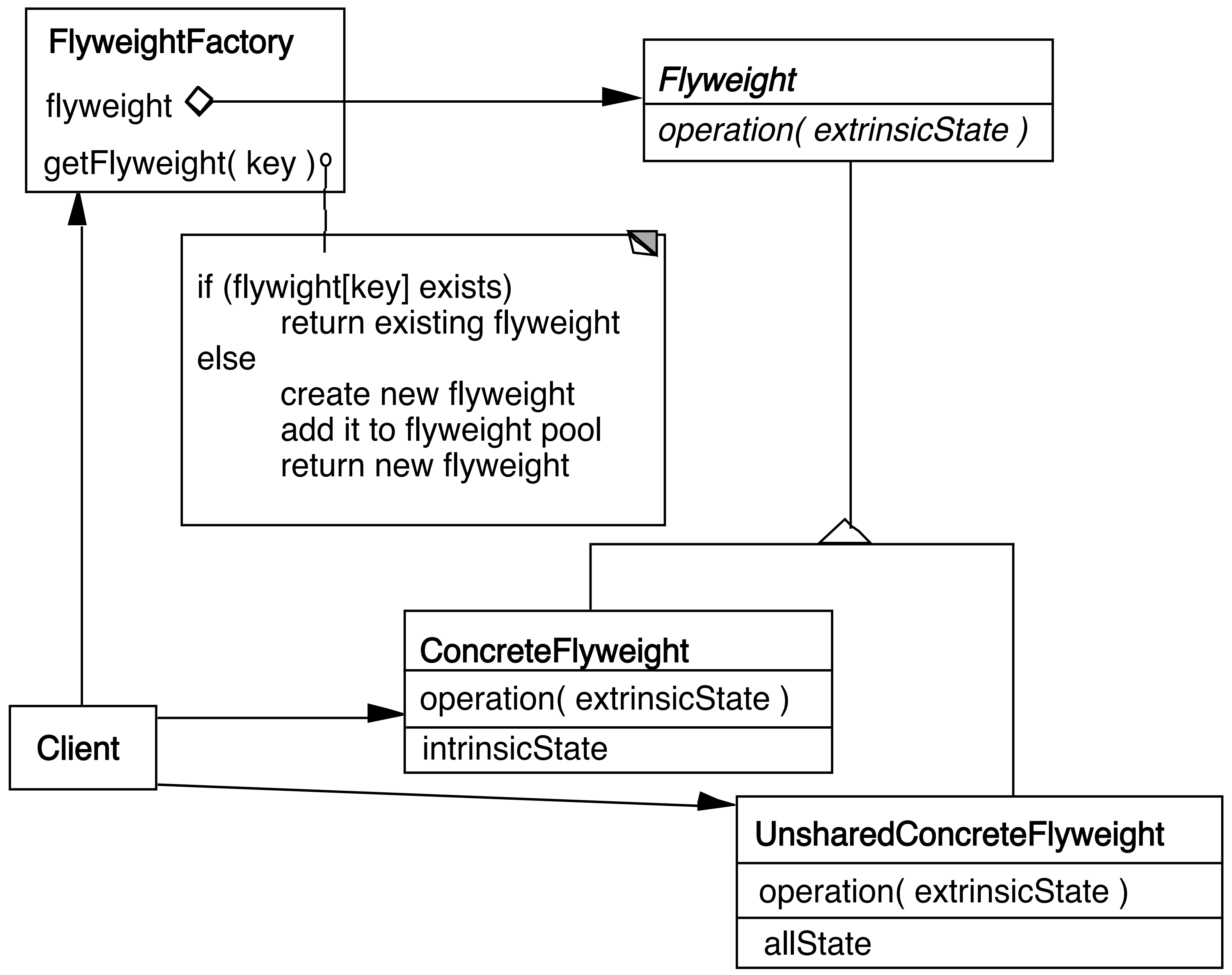
Extrinsic State

Information that is dependent on the object's context

The information that can not be shared among objects

So has to be stored outside of the flyweight

Structure


FlyweightFactory
flyweight
getFlyweight(key)
Flyweight
operation(extrinsicState)
if (flywight[key] exists)
return existing flyweight
else
create new flyweight
add it to flyweight pool
return new flyweight
ConcreteFlyweight
operation(extrinsicState)
intrinsicState
Client
UnsharedConcreteFlyweight
operation(extrinsicState)
allState

The Hard Part

Separating state from the flyweight

How easy is it to identify and remove extrinsic state

Will it save space to remove extrinsic state

Example Text

Run Arrays

aaaaabaaaaaaaaaaaaaaaaaaaa

a b a
5 1 20

Text Example

Lexi Document Editor

Uses character objects with font information
(To support graphic elements)

"A Cat in the hat came ***back*** the very next day"

Use run array to store font information (extrinsic state)

Normal	Bold	Normal
22	4	18