CS 635 Advanced Object-Oriented Design & Programming
Spring Semester, 2010
Doc 13 Observer, Template Method, Prototype, Factory Method
March 9, 2010

References

Design Patterns: Elements of Reusable Object-Oriented Software, Gamma, Helm, Johnson, Vlissides, 1995, pp. 293-303, 117-126

Java API

VisualWorks Smalltalk API

Prototype-based Languages

http://en.wikipedia.org/wiki/Prototype-based_programming

JavaScript The Definite Guide 4'th Ed, Flanagan, O'Reilly Press, 2002

http://c2.com/cgi/wiki?TemplateMethodPattern WikiWiki comments on the Template Method

http://wiki.cs.uiuc.edu/PatternStories/TemplateMethodPattern Stories about the Template Method

Design Patterns: Elements of Resuable Object-Oriented Software, Gamma, Helm, Johnson, Vlissides, Addison Wesley, 1995, pp. 325-330, 107-116

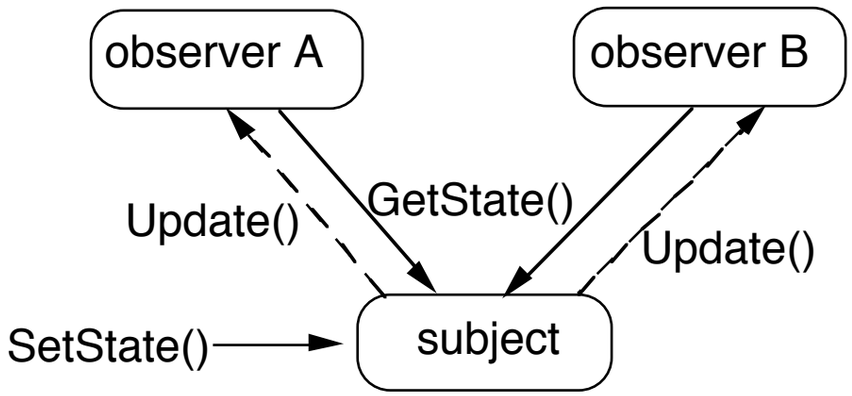
Observer

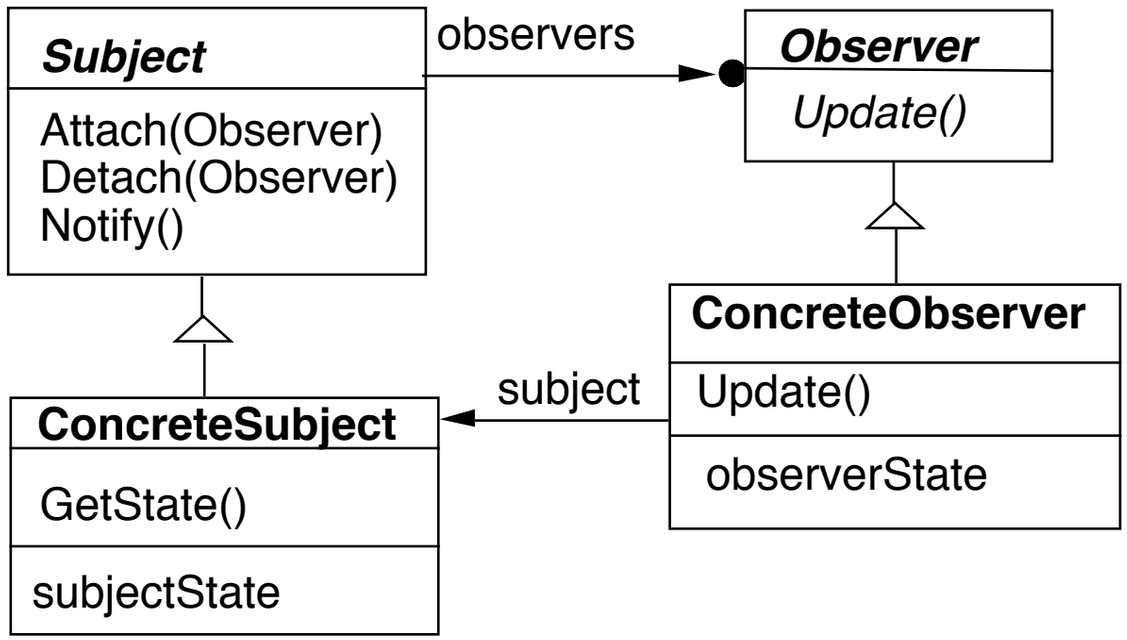
One-to-many dependency between objects

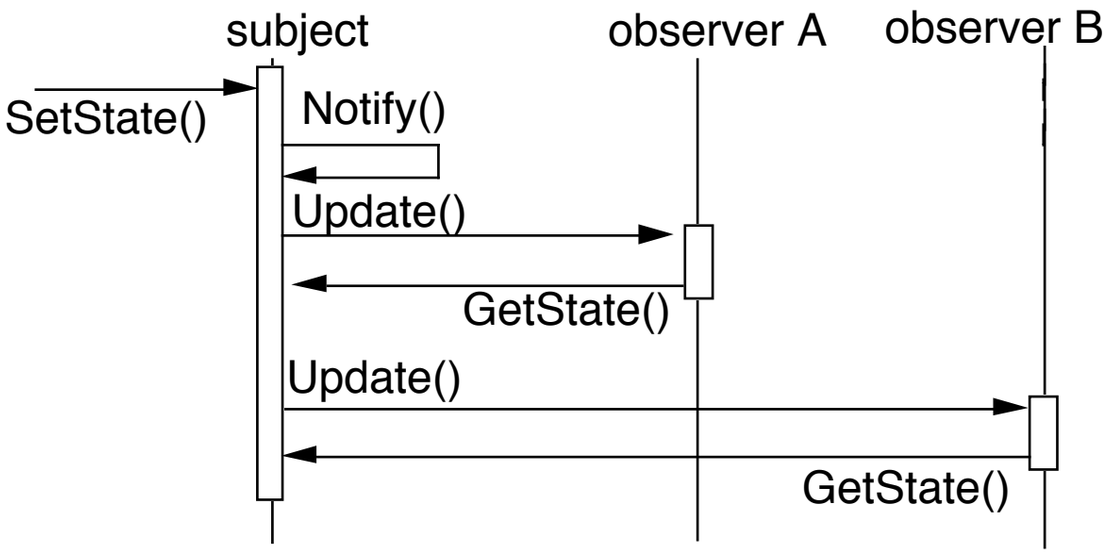
When one object changes state,

all its dependents are notified and updated automatically

Structure


observer A
observer B
Update()
GetState()
Update()
SetState()
subject


Subject
Attach(Observer)
Detach(Observer)
Notify()
observers
Observer
Update()
ConcreteObserver
Update()
observerState
subject
ConcreteSubject
GetState()
subjectState


subject
observer A
observer B
SetState()
Notify()
Update()
GetState()
Update()
GetState()

Pseudo Java Example

```
public class Subject {
   Window display;
   public void someMethod() {
      this.modifyMyStateSomeHow();
      display.addText( this.text() );
   }
}
```

Abstract coupling - Subject and Observer

Broadcast communication

Updates can take too long

```
public class Subject {
   ArrayList observers = new ArrayList();

   public void someMethod() {
      this.modifyMyStateSomeHow();
      changed();
   }

   private void changed() {
      Iterator needsUpdate = observers.iterator();
      while (needsUpdate.hasNext() )
         needsUpdate.next().update( this );
   }
}

public class SampleWindow {
   public void update(Object subject) {
      text = ((Subject) subject).getText();
      Thread.sleep(10000).
   }
}
```

Some Language Support

Smalltalk	Java	Ruby	Observer Pattern
Object	Observer		Abstract Observer class
Object & Model	Observable	Observable	Subject class

Smalltalk Implementation

Object implements methods for both Observer and Subject.

Actual Subjects should subclass Model

Java's Observer

Java	Observer Pattern
Interface Observer	Abstract Observer class
Observable class	Subject class

Class java.util.Observable

void addObserver(Observer o)
void clearChanged()
int countObservers()
void deleteObserver(Observer o)
void deleteObservers()
boolean hasChanged()
void notifyObservers()
void notifyObservers(Object arg)
void setChanged()

Observable object may have any number of Observers

Whenever the Observable instance changes,
it notifies all of its observers

Notification is done by calling the update() method on all observers.

Interface java.util.Observer

Allows all classes to be observable by instances of class Observer

Java Example

```
class Counter extends Observable  {
        public static final String INCREASE = "increase";
        public static final String DECREASE = "decrease";
        private int count = 0;
        private String label;

        public Counter( String label )    {       this.label = label; }

        public String label()                 {  return label; }
        public int value()                    {  return count; }
        public String toString()              {  return String.valueOf( count );}

        public void increase() {
                count++;
                setChanged();
                notifyObservers( INCREASE );
        }

        public void decrease()  {
                count--;
                setChanged();
                notifyObservers( DECREASE );
                }
        }
```

Java Observer

```
class IncreaseDetector implements Observer {
        public void update( java.util.Observable whatChanged,
                                                java.lang.Object message) {
                if ( message.equals( Counter.INCREASE) )  {
                        Counter increased = (Counter) whatChanged;
                        System.out.println( increased.label() + " changed to " +
                                                                increased.value());
                }
        }

        public static void main(String[] args) {
                Counter test = new Counter();
                IncreaseDetector adding = new IncreaseDetector();
                test.addObserver(adding);
                test.increase();
}
```

Ruby Example

```
require'observer'

class Counter
    include Observable

    attr_reader :count

    def initialize
        @count = 0
    end
    def increase
        @count += 1
        changed
        notify_observers(:INCREASE)
    end

    def decrease
        @count -= 1
        changed
        notify_observers(:DECREASE)
    end
end
```

```
class IncreaseDetector

    def update(type)
        if type == :INCREASE
            puts('Increase')
        end
    end
end

count = Counter.new()
puts count.count
count.add_observer(IncreaseDetector.new)
count.increase
count.increase
puts count.count
```

Implementation Issues

Mapping subjects(Observables) to observers

Use list in subject

Use hash table

```
public class Observable {
    private boolean changed = false;
    private Vector obs;

public Observable() {
        obs = new Vector();
    }

public synchronized void addObserver(Observer o) {
        if (!obs.contains(o)) {
            obs.addElement(o);
        }
    }
```

Observing more than one subject

If an observer has more than one subject how does it know which one changed?

Pass information in the update method

Deleting Subjects

In C++ the subject may no longer exist

Java/Smalltalk observer may prevent subject from garbage collection

Who Triggers the update?

Have methods that change the state trigger update

```
class Counter extends Observable  {              // some code removed
        public void increase()  {
                count++;
                setChanged();
                notifyObservers( INCREASE );
        }
}
```

Have clients call Notify at the right time

```
class Counter extends Observable  {        // some code removed
                public void increase()  {    count++;  }
}

Counter pageHits = new Counter();
pageHits.increase();
pageHits.increase();
pageHits.increase();
pageHits.notifyObservers();
```

Subject is self-consistent before Notification

```
class ComplexObservable extends Observable {
        Widget frontPart = new Widget();
        Gadget internalPart = new Gadget();

        public void trickyChange() {
                frontPart.widgetChange();
                internalpart.anotherChange();
                setChanged();
                notifyObservers( );
        }
}

class MySubclass extends ComplexObservable {
        Gear backEnd = new Gear();

        public void trickyChange() {
                super.trickyChange();
                backEnd.yetAnotherChange();
                setChanged();
                notifyObservers( );
        }
}
```

Adding information about the change

push models - add parameters in the update method

```
class IncreaseDetector extends Counter implements Observer { // stuff not shown

        public void update( Observable whatChanged, Object message) {
            if ( message.equals( INCREASE) )
                increase();
        }
}

class Counter extends Observable {          // some code removed
        public void increase()  {
            count++;
            setChanged();
            notifyObservers( INCREASE );
        }
}
```

Adding information about the change

pull model - observer asks Subject what happened

```
class IncreaseDetector extends Counter implements Observer {
        public void update( Observable whatChanged ) {
                if ( whatChanged.didYouIncrease() )
                        increase();
        }
}

class Counter extends Observable {          // some code removed
        public void increase() {
                count++;
                setChanged();
                notifyObservers( );
        }
}
```

Scaling the Pattern

Java Event Model

AWT/Swing components broadcast events to Listeners

JDK1.0 AWT components broadcast an event to all its listeners

A listener normally not interested all events

Broadcasting to all listeners was too slow with many listeners

Java 1.1+ Event Model

Each component supports different types of events:

Component supports

ComponentEvent	FocusEvent
KeyEvent	MouseEvent

Each event type supports one or more listener types:

MouseEvent

MouseListener	MouseMotionListener

Each listener interface replaces update with multiple methods

MouseListener

mouseClicked()	mouseEntered()
mousePressed()	mouseReleased()

Listeners

- Only register for events of interest
- Don't need case statements to determine what happened

Small Models

Often an object has a number of fields(aspects) of interest to observers

Rather than make the object a subject make the individual fields subjects

- Simplifies the main object
- Observers can register for only the data they are interested in

VisualWorks ValueHolder

Subject for one value

ValueHolder allows you to:

- Set/get the value
  - Setting the value notifies the observers of the change
- Add/Remove dependents

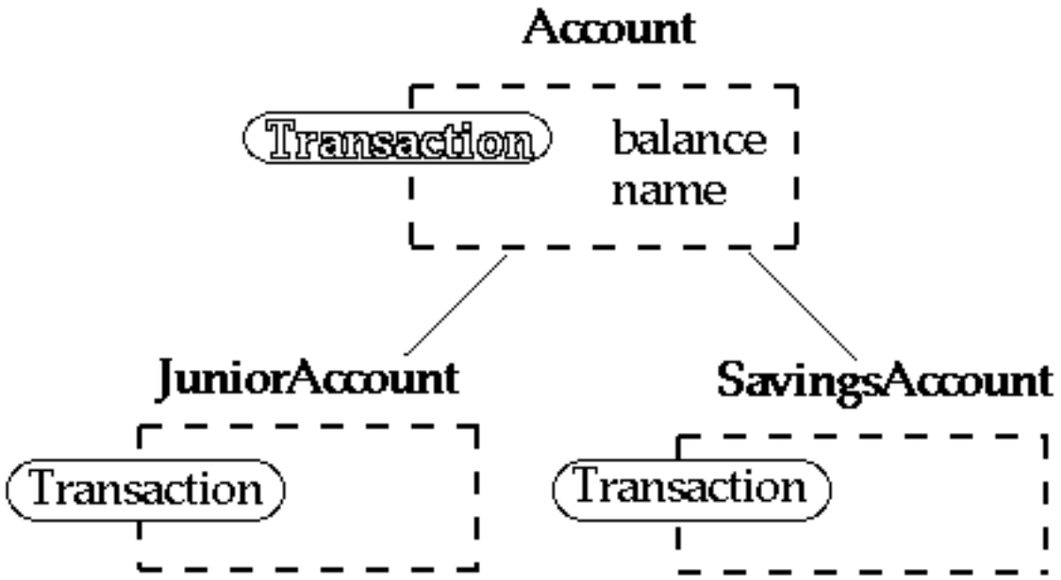
Template Method

Polymorphism

```
class Account {
        public:
                void virtual Transaction(float amount)
                                { balance += amount;}
                Account(char* customerName, float InitialDeposit = 0);
        protected:
                char* name;
                float balance;
}

class JuniorAccount : public Account {
        public:      void Transaction(float amount) {//code here}
}

class SavingsAccount : public Account {
        public:      void Transaction(float amount) {//code here}
}

Account* createNewAccount(){
        // code to query customer and determine what type of
        // account to create
};
```

```
main() {
        Account*  customer;
        customer = createNewAccount();
        customer->Transaction(amount);
}
```

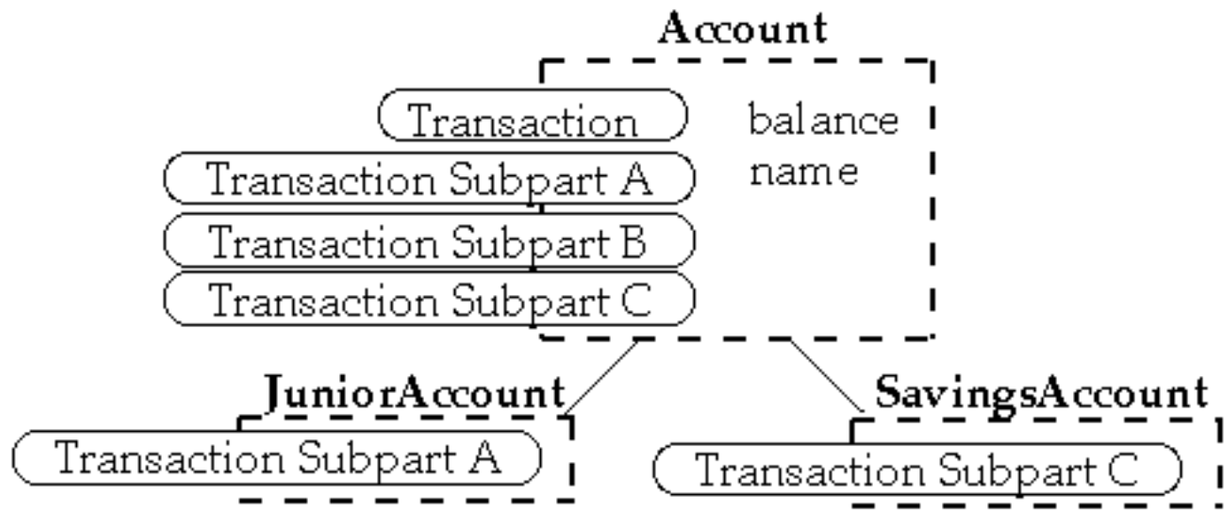
Deferred Methods




```
class Account {
      public:
            void virtual Transaction() = 0;
}

class JuniorAccount : public Account {
      public
            void Transaction() { put code here}
}
```

Template Method

```
class Account {
        public:
                void Transaction(float amount);
        protected:
                void virtual TransactionSubpartA();
                void virtual TransactionSubpartB();
                void virtual TransactionSubpartC();
}
```




```
void Account::Transaction(float amount)  {
        TransactionSubpartA();          TransactionSubpartB();
        TransactionSubpartC();          // EvenMoreCode;
}

class JuniorAccount : public Account {
        protected:        void virtual TransactionSubpartA(); }

class SavingsAccount : public Account {
        protected:        void virtual TransactionSubpartC(); }

Account*  customer;
customer = createNewAccount();
customer->Transaction(amount);
```

Intent

Define the skeleton of an algorithm in an operation, deferring some steps to subclasses

Template Method lets subclasses redefine certain steps of an algorithm without changing the algorithm's structure

Java Example

```
import  java.awt.*;
class  HelloApplication  extends  Frame
      {
      public  void  paint(  Graphics  display  )
            {
            int startX  =  30;
            int startY  =  40;
            display.drawString(  "Hello World", startX,
startY  );
            }
      }
```

Ruby LinkedList Example

```
class LinkedList
  include Enumerable

  def [](index)
    Code not shown
  end

  def size
    Code not shown
  end

  def each
     Code not shown
  end

  def push(object)
   Code note shown
  end

end
```

```
def testSelect
  list = LinkedList.new
  list.push(3)
  list.push(2)
  list.push(1)

  a = list.select {|x| x.even?}
  assert(a == [2])
end
```

Where does list.select come from?

Methods defined in Enumerable

all?	any?	collect	detect
each_cons	each_slice	each_with_index	entries
enum_cons	enum_slice	enum_with_index	find
find_all	grep	include?	inject
map	max	member?	min
partition	reject	select	sort
sort_by	to_a	to_set	zip

All use "each"

Implement "each" and the above will work

java.util.AbstractCollection

Subclass AbstractCollection

Implement

- iterator
- size
- add

Get

- addAll
- clear
- contains
- containsAll
- isEmpty
- remove
- removeAll
- retainAll
- size
- toArray
- toString

Consequences

This is the most commonly used of the 23 GoF patterns

Important in class libraries

Inverted control structure

Parent class calls subclass methods

Java's paint method is a primitive operation called by a parent method

Beginning Java programs don't understand how the following works:

```
import  java.awt.*;
class  HelloApplication  extends  Frame
        {
        public  void  paint(  Graphics  display  )
                {
                int startX  =  30;
                int startY  =  40;
                display.drawString(  "Hello World", startX, startY  );
                }
        }
```

Consequences

Template methods tend to call:

- Concrete operations
- Primitive (abstract) operations
- Factory methods
- Hook operations

Provide default behavior that subclasses can extend

It is important to denote which methods

- Must overridden
- Can be overridden
- Can not be overridden

Refactoring to Template Method

Simple implementation

- Implement all of the code in one method
- The large method you get will become the template method

Break into steps

- Use comments to break the method into logical steps
- One comment per step

Make step methods

- Implement separate methods for each of the steps

Call the step methods

- Rewrite the template method to call the step methods

Repeat above steps

- Repeat the above steps on each of the step methods
- Continue until:
  - All steps in each method are at the same level of generality
  - All constants are factored into their own methods

Design Patterns Smalltalk Companion pp. 363-364.

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

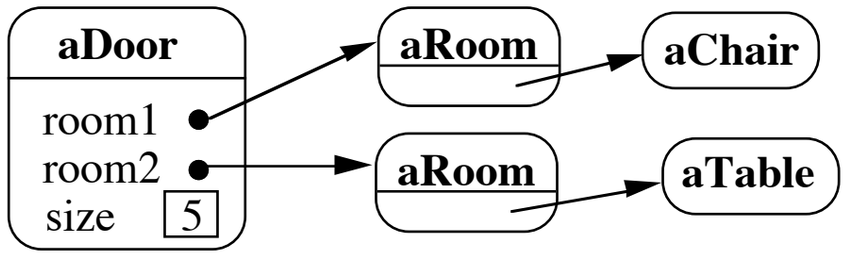
Two basic strategies:

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

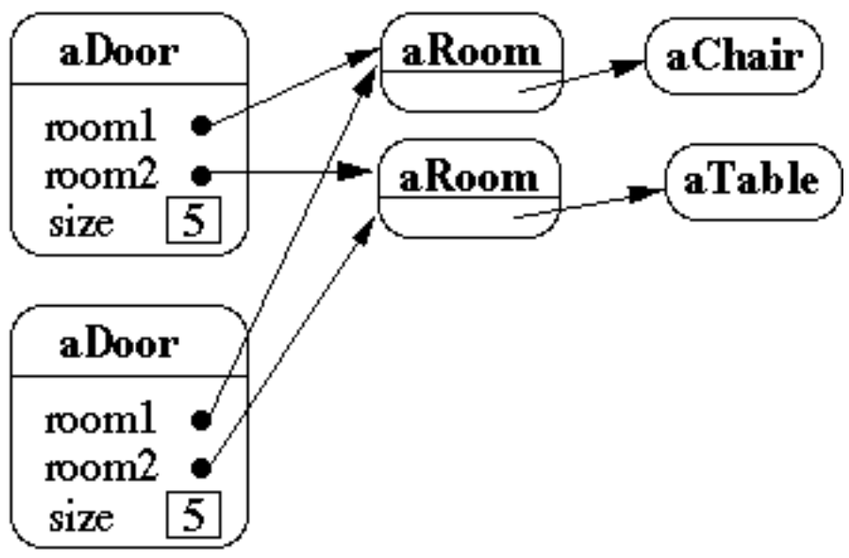
Copying Issues

Shallow Copy Verse Deep Copy

Original Objects

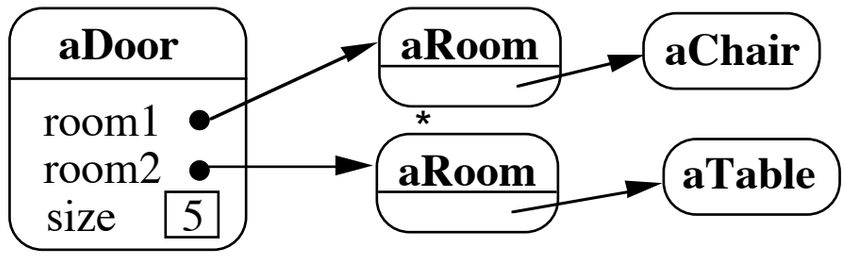


Shallow Copy

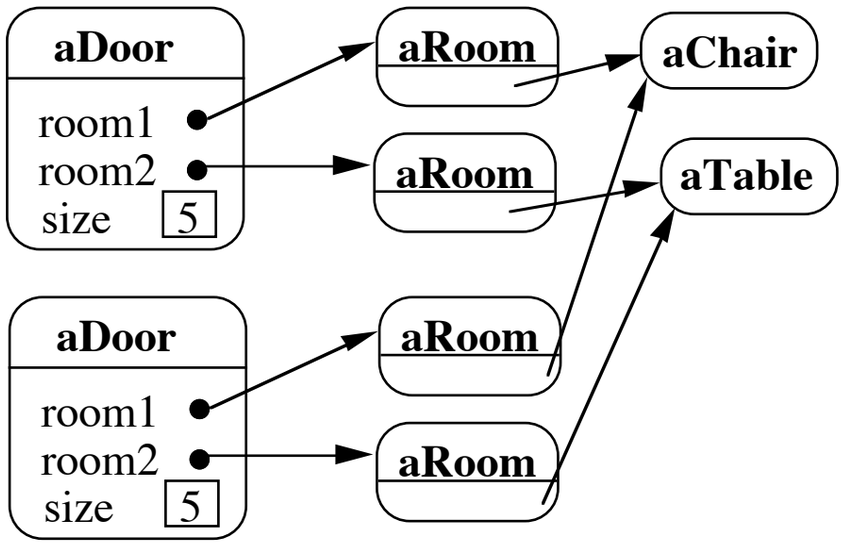


Shallow Copy Verse Deep Copy

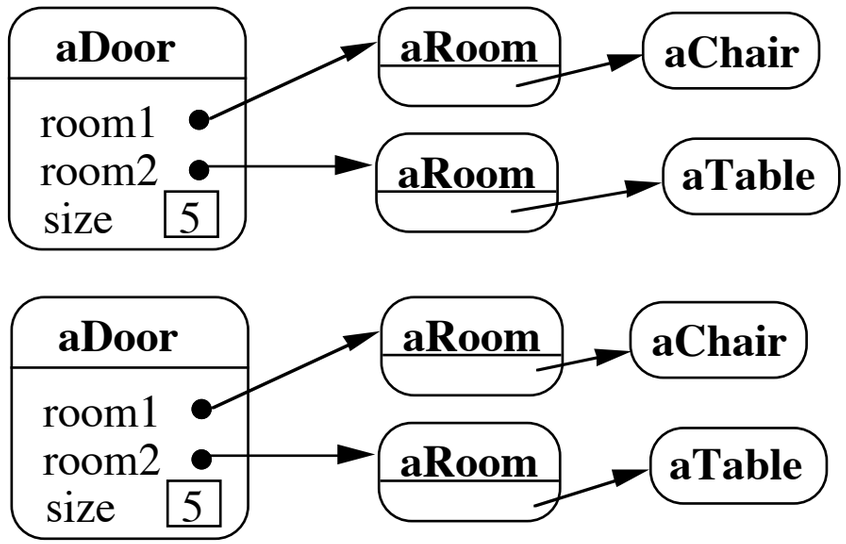
Original Objects



Deep Copy



Deeper Copy



Cloning Issues - C++ Copy Constructors

```
class Door {
        public:
                Door();
                Door( const Door&);
                virtual Door* clone() const;

                virtual void Initialize( Room*, Room* );
                // stuff not shown
        private:
                Room* room1;
                Room* room2;
        }

Door::Door ( const Door& other ) //Copy constructor {
        room1 = other.room1;
        room2 = other.room2;
        }

Door* Door::clone()  const {
        return new Door( *this );
        }
```

Cloning Issues - Java Clone

Shallow Copy

```
class Door implements Cloneable {
        private Room room1;
        private Room room2;

        public Object clone() throws  CloneNotSupportedException {
                return super.clone();
        }
}
```

Deep Copy

```
public class Door implements Cloneable {
        private Room room1;
        private Room room2;

        public Object clone() throws CloneNotSupportedException {
                Door thisCloned =(Door) super.clone();
                thisCloned.room1 = (Room)room1.clone();
                thisCloned.room2 = (Room)room2.clone();
                return thisCloned;
        }
}
```

Prototype-based Languages

No classes

Behaviour reuse (inheritance)

Cloning existing objects which serve as prototypes

Some Prototype-based languages

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

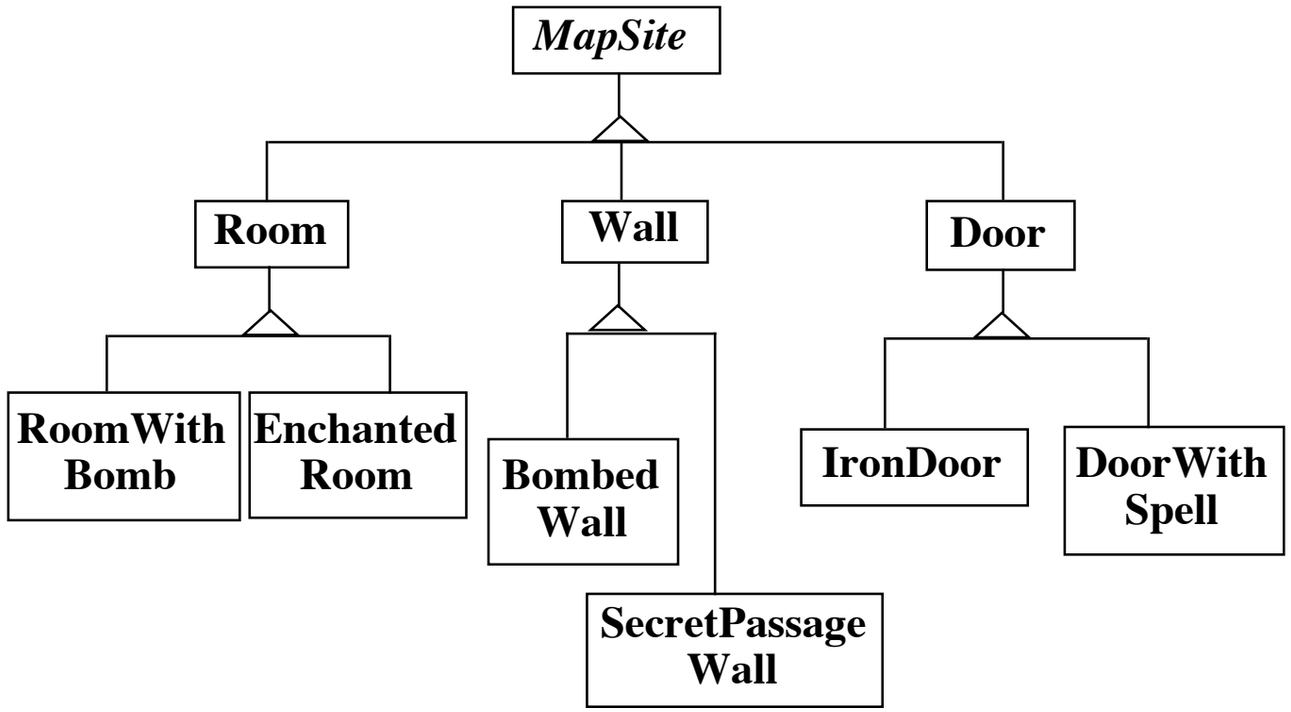
Factory Method

Factory Method

A template method for creating objects

```
public class Example {
    protected Bar bar() { return new Bar(); }

    public void foo() {
        blah
        Bar soap = bar();
        blah;
    }
```

Maze Game Example



Maze Game Example

```
class MazeGame{
    public Maze makeMaze() { return new Maze(); }
    public Room makeRoom(int n ) { return new Room( n ); }
    public Wall makeWall() { return new Wall(); }
    public Door makeDoor() { return new Door(); }

    public Maze CreateMaze(){
        Maze aMaze = makeMaze();
        Room r1 = makeRoom( 1 );
        Room r2 = makeRoom( 2 );
        Door theDoor = makeDoor( r1, r2);

        aMaze.addRoom( r1 );
        aMaze.addRoom( r2 );
        etc

        return aMaze;
        }
}
```

```
class BombedMazeGame extends MazeGame {

    public Room makeRoom(int n )  {
        return new RoomWithABomb( n );
    }

    public Wall makeWall() {
        return new BombedWall();
    }
}
```

Implementation Variation

```
class Hershey {

    public Candy makeChocolateStuff( CandyType id ) {
        if ( id == MarsBars ) return new MarsBars();
        if ( id == M&Ms ) return new M&Ms();
        if ( id == SpecialRich ) return new SpecialRich();

        return new PureChocolate();
    }

class GenericBrand extends Hershey {
    public Candy makeChocolateStuff( CandyType id ) {
        if ( id == M&Ms ) return new Flupps();
        if ( id == Milk ) return new MilkChocolate();
        return super.makeChocolateStuff(id);
    }
}
```

Using C++ Templates

```
template <class ChocolateType>
class Hershey
        {
        public:
                virtual Candy* makeChocolateStuff( );
        }

template <class ChocolateType>
Candy*
Hershey<ChocolateType>::makeChocolateStuff( )
        {
        return new ChocolateType;
        }

Hershey<SpecialRich> theBest;
```

SmallTalk Variant

Return the class, caller creates an object

```
chocolateStuff
        ^SpecialRich
```

```
some code
candy := (self chocolateStuff) new
mode code
```

Use Factory Method When

A class can't anticipate the class of objects it must create

A class wants its subclasses to specify the objects it creates

You want to localize the knowledge of which help classes is used in a class

But when is this?

CS 580 Example - Testing a Server

```
public class SDWitterServer {
    public void run(int port) throws IOException {
        ServerSocket input = new ServerSocket( port );

        while (true) {
            Socket client = input.accept();
            processRequest(
                client.getInputStream(),
                client.getOutputStream());
            client.close();
        }
    }

    void processRequest(InputStream in,OutputStream out) {
        do a bunch of stuff
    }

    etc.
```


This code requires us to send/receive data over the network, which at times is not convenient in unit tests.

Using Factory Method

```
public class SDWitterServer {
    public void run(int port) throws IOException {
        ServerSocket input = this.serverSocket( port );

        while (true) {
            Socket client = input.accept();
            processRequest(
                client.getInputStream(),
                client.getOutputStream());
            client.close();
        }
    }

    ServerSocket serverSocket( int port) {
        return new ServerSocket(port);
    }

    etc.
```

TestServer

```
public class TestServer extends SDWitterServer {
    MockServerSocket testSocket;

    ServerSocket serverSocket( int port) {
        return testSocket;
    }
}
```

Other than using a different type of socket it performs the operations as the parent class

```
public class Tests extends Testcase {
    public void testLogin() {
        TestServer server = new TestServer();
        server.testSocket = new MockServerSocket("client command to login");
        server.run();
        assertTrue(server.testSocket.serverResponse() = "the correct response here");
    }
}
```


The situation is more complex than shown here. I simplified it to avoid details that might confuse people.

MockServerSocket

Returns a fake (Mock) client connection

Fakes client connection

- Does not use network
- Contains fixed requests
- Records server responses