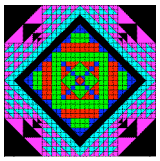
PictureWorld

A world of fruitful methods

Friday, September 21, 2007



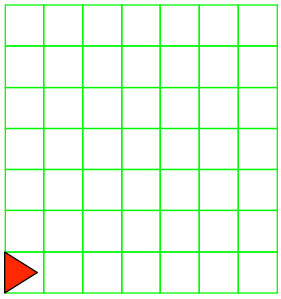
CS111 Computer Programming

Department of Computer Science
Wellesley College

Buggles and BuggleWorld

Primitives

Simple values: integers, booleans
Black-box objects: buggles, points, colors
Black-box methods: forward(), left()



Means of Combination

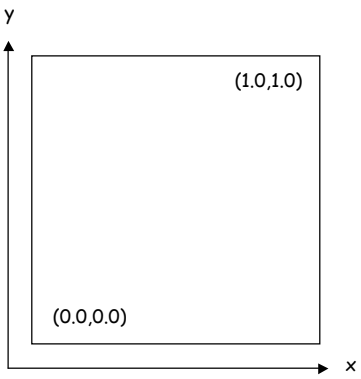
Arithmetic on numbers: 1 + 2
Instance variable reference: p.x
Class variable reference: Color.red
Void method invocation: becky.forward()
Fruitful method invocation: becky.getColor()
Constructor method invocation: new Location(1,2)
Sequences of statements:
bob.forward(3); bob.left();

Means of abstraction

Creating our own methods: buildDogHouse(), buildStair()
Creating our own classes: PuppyBuggle, StairBuggle

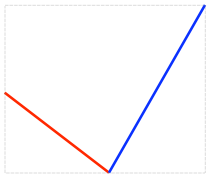
PictureWorld

- A world for studying (1) fruitful methods and (2) the notion that complex structures can be built from simple primitives using powerful means of combination and means of abstraction.
- Each picture exists within the unit square, and understands one method: how to stretch itself to fill a given rectangle on the screen.
- PictureWorld's GUI is much simpler than BuggleWorld's.



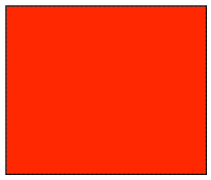
Some "Primitive" Pictures

bp
(blue patch)



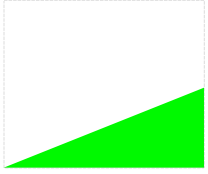
mark

rp
(red patch)



leaves

gw
(green
wedge)



empty

Adding Pictures to a PictureWorld

```
public class SimplePictureWorld extends PictureWorld {

  public void initializePictureChoices() {

    // Create new "primitive" pictures
    // (they're not really primitive, as we'll see later)
    Picture bp = this.patch(Color.blue); // blue patch
    Picture rp = this.patch(Color.red); // red patch
    Picture mark = this.checkmark(Color.red, Color.blue); // red/blue check
    Picture gw = this.wedge(Color.green); // green wedge
    Picture leaves = this.twoLeaves(Color.green); // green leaves

    // Add pictures to the menu
    this.addPictureChoice("blue patch", bp);
    this.addPictureChoice("red patch", rp);
    this.addPictureChoice("mark", mark);
    this.addPictureChoice("green wedge", gw);
    this.addPictureChoice("leaves", leaves);

    // Notes:
    // 1. "this." is optional; can omit it!
    // 2. Can always use Picture expression in place of name.
    // For example:
    //   addPictureChoice("mark", checkMark(Color.red, Color.blue))
  }
  ...
}
```

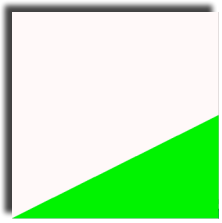

PictureWorld contract

```
// Automatically invoked when a PictureWorld window is created
public void initializePictureChoices();

// Adds name to the menu and associates it with pic
public void addPictureChoice(String name, Picture pic);

public Picture empty();  // Returns an empty picture
```

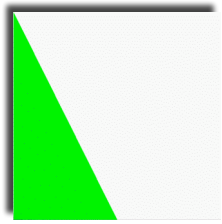
But wait! There are more …

Rotating Pictures

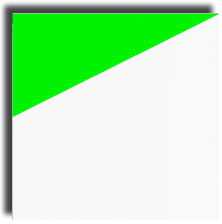
```
public Picture clockwise90(Picture p)  // Returns p rotated 90° clockwise
public Picture clockwise180(Picture p) // Returns p rotated 180° clockwise
public Picture clockwise270(Picture p) // Returns p rotated 270° clockwise
```



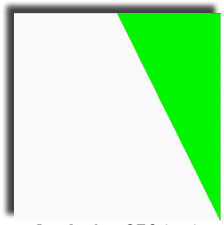
gw



clockwise90(gw)



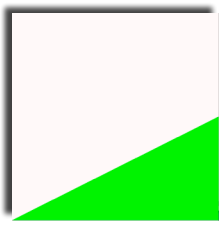
clockwise180(gw)



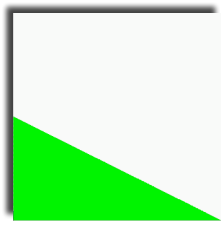
clockwise270(gw)

Flipping Pictures

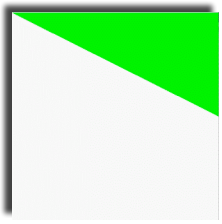
```
public Picture flipHorizontally(Picture p) // Returns p flipped across vert axis
public Picture flipVertically(Picture p) // Returns p flipped across horiz axis
public Picture flipDiagonally(Picture p) // Returns p flipped acros diag axis
```



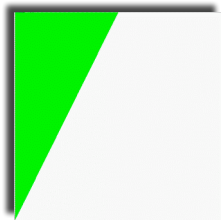
gw



flipHorizontally(gw)



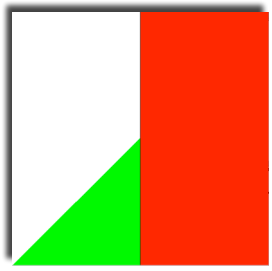
flipVertically(gw)



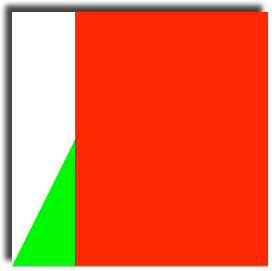
flipDiagonally(gw)

Putting one picture beside another

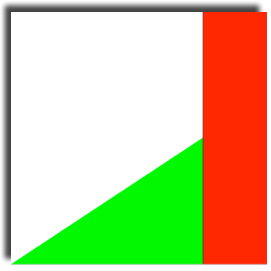
```
// Returns picture resulting from putting p1 beside p2
public Picture beside(Picture p1, Picture p2)

// Returns picture resulting from putting p1 beside p2,
// where p1 uses the specified fraction of the rectangle.
public Picture beside(Picture p1, Picture p2, double fraction)
```



beside(gw,rp)



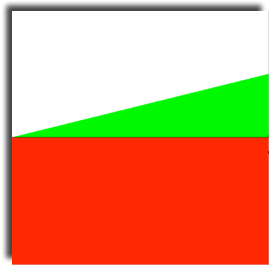
beside(gw,rp,0.25)



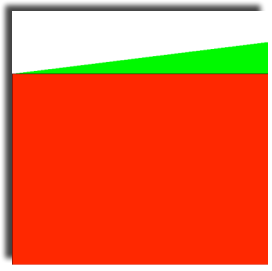
beside(gw,rp,0.75)

Putting one picture above another

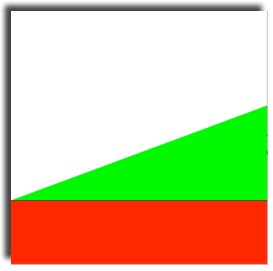
```
// Returns picture resulting from putting p1 above p2
public Picture above(Picture p1, Picture p2)

// Returns picture resulting from putting p1 above p2,
// where p1 uses the specified fraction of rectangle.
public Picture above(Picture p1, Picture p2, double fraction)
```



above(gw,rp)



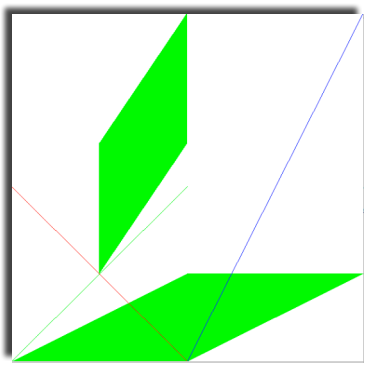
above(gw,rp,0.25)



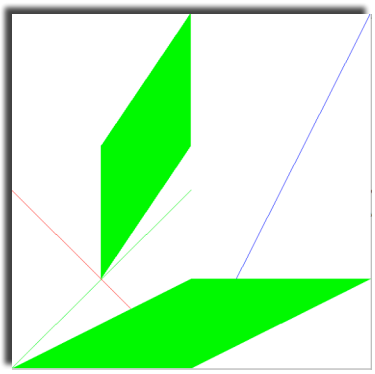
above(gw,rp,0.75)

Putting one picture over another

```
// Returns picture resulting from overlaying p1 on top of p2
public Picture overlay(Picture p1, Picture p2)
```



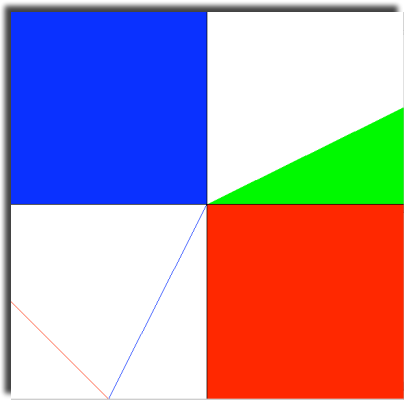
overlay(mark,leaves)



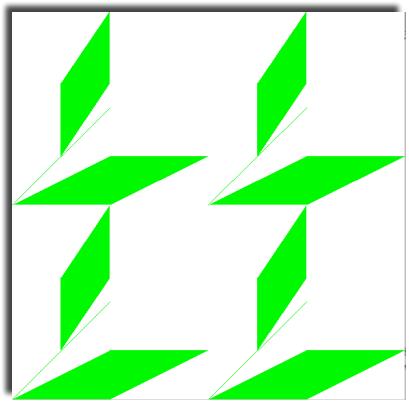
overlay(leaves,mark)

Combining Four Pictures

```
public Picture fourPics(Picture p1, Picture p2, Picture p3, Picture p4) {
    return above(beside(p1,p2), beside(p3,p4));
}

public Picture fourSame(Picture p) {
    return fourPics(p, p, p, p);
}
```



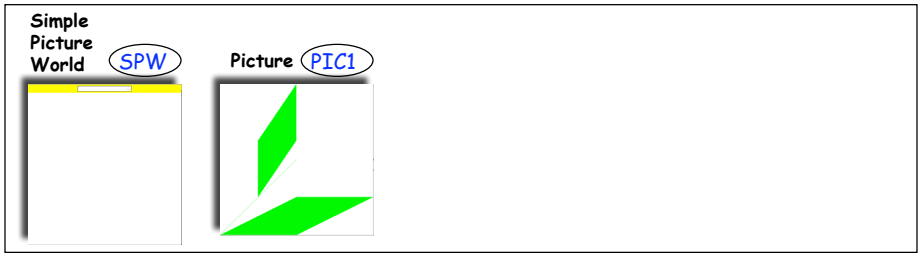
fourPics(bp,gw,mark,rp)



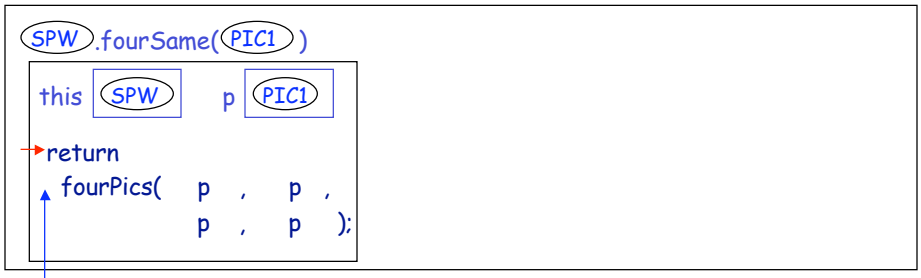
fourSame(leaves)

PictureWorld JEM Example: fourSame(leaves)

Object Land



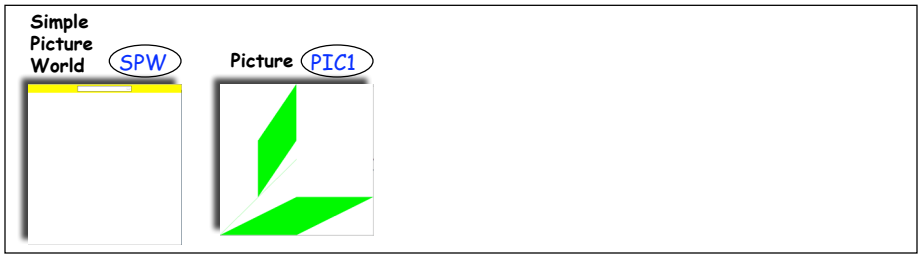
Execution Land



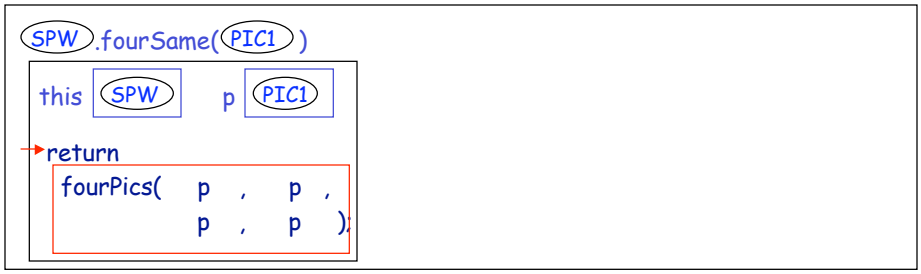
To save space, we omit "this." from all PictureWorld method invocations.

Begin Evaluating the fourPics() Expression

Object Land

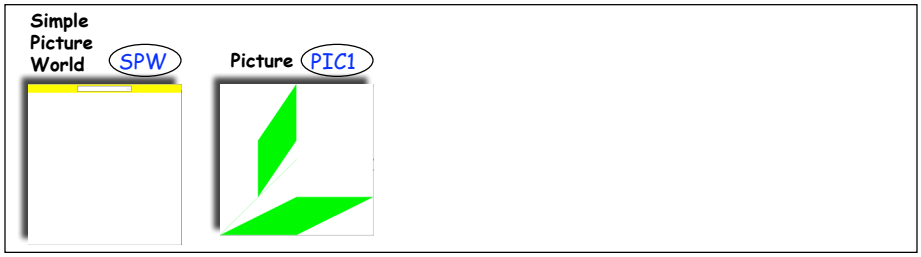


Execution Land

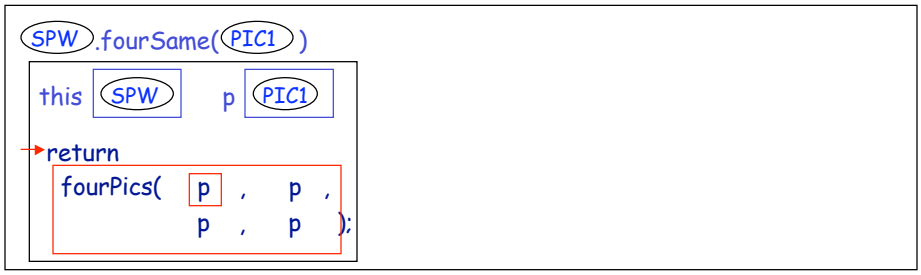


Evaluate the First Argument of fourPics()

Object Land

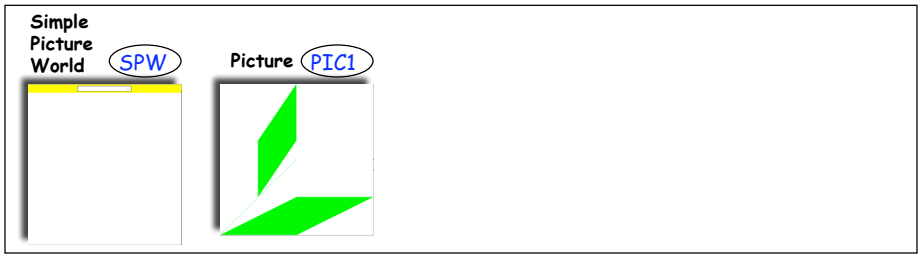


Execution Land

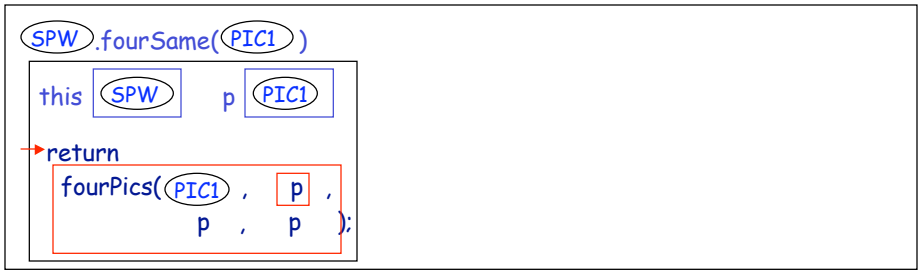


Evaluate the Second Argument of fourPics()

Object Land

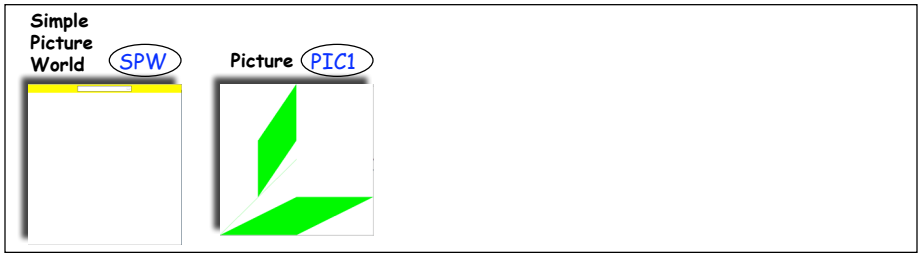


Execution Land

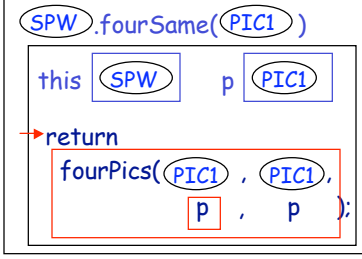


Evaluate the Third Argument of fourPics()

Object Land

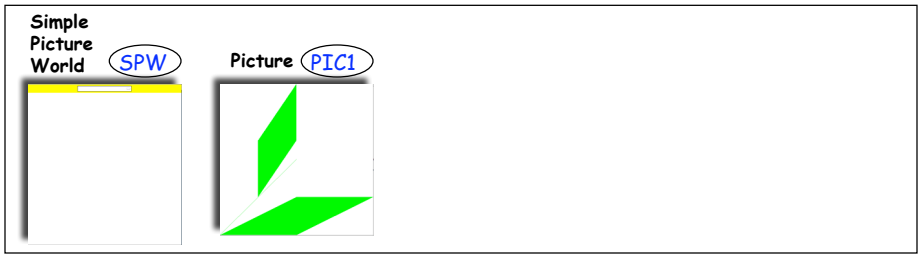


Execution Land

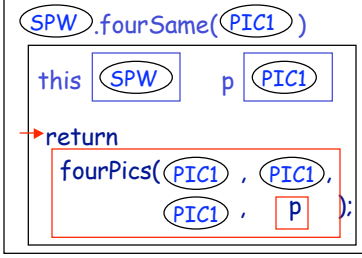


Evaluate the Fourth Argument of fourPics()

Object Land

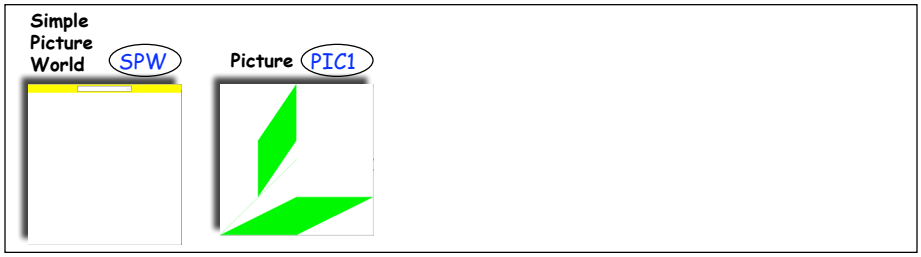


Execution Land

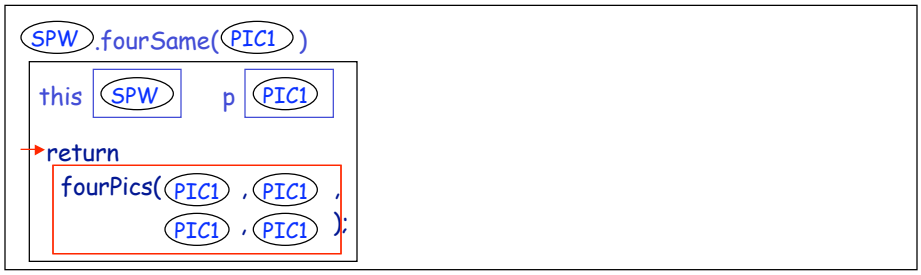


Invoke the fourPics() Method on Its Arguments

Object Land

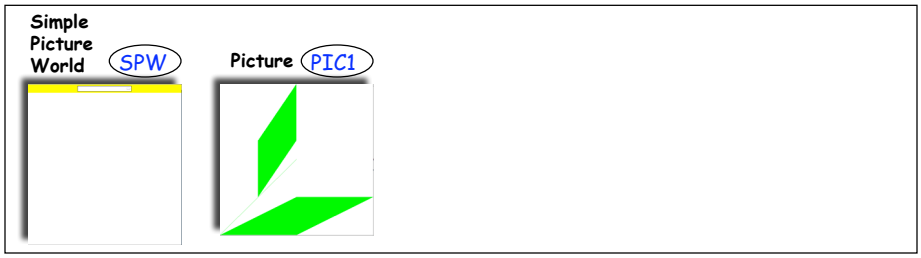


Execution Land

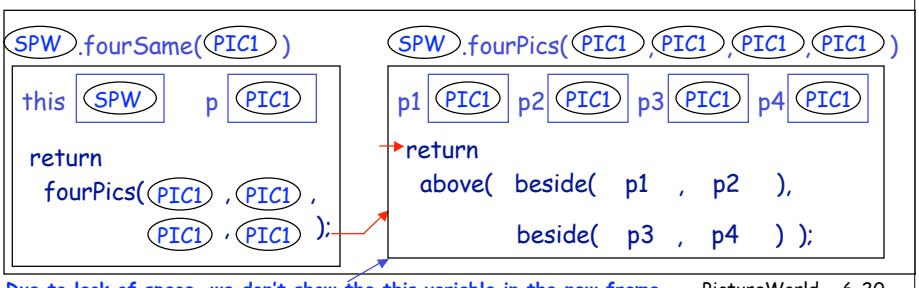


Create an Execution Frame for the fourPics() Invocation

Object Land

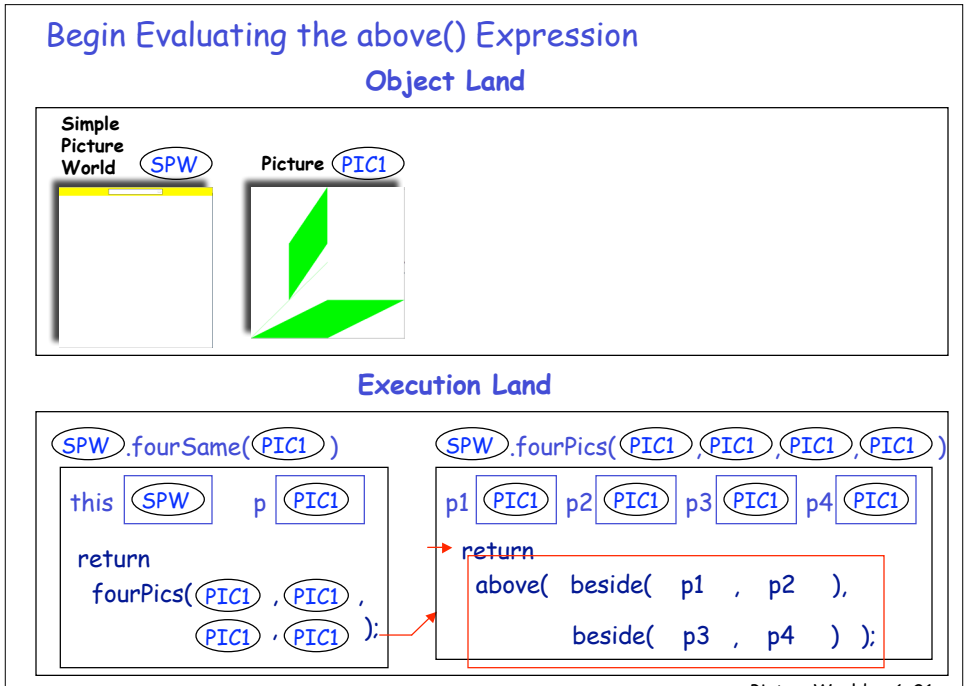


Execution Land

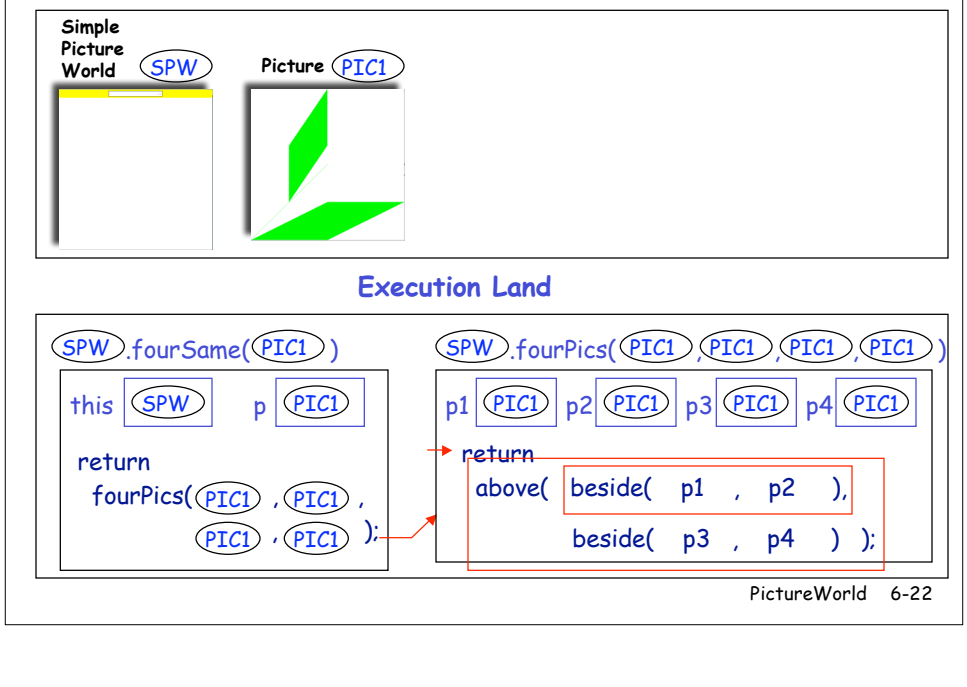


Due to lack of space, we don't show the this variable in the new frame

Begin Evaluating the above() Expression

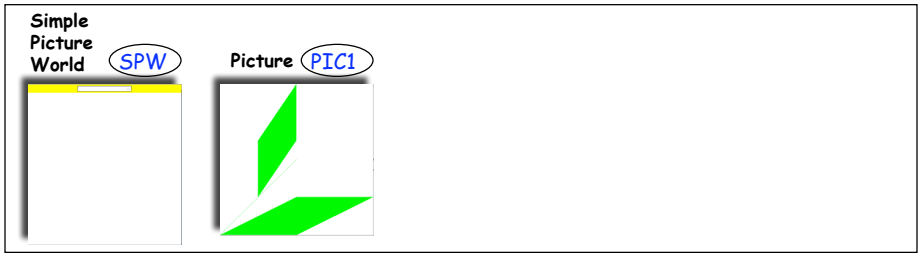


Begin Evaluating the first argument of above()

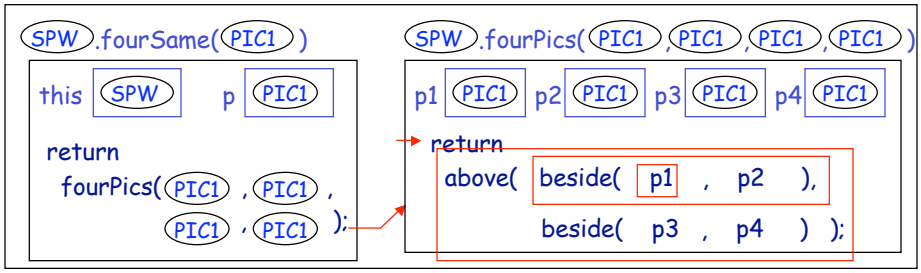


Evaluate the first argument of the first beside()

Object Land

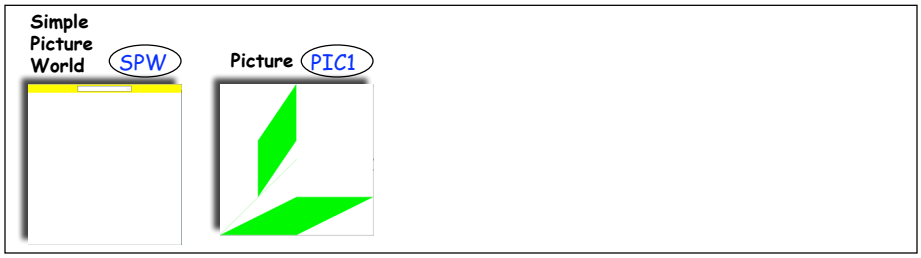


Execution Land

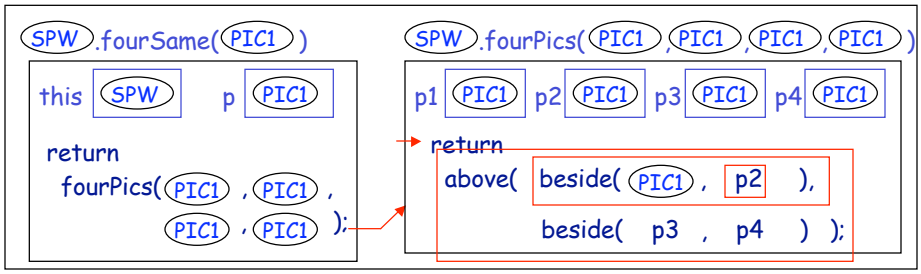


Evaluate the second argument of the first beside()

Object Land

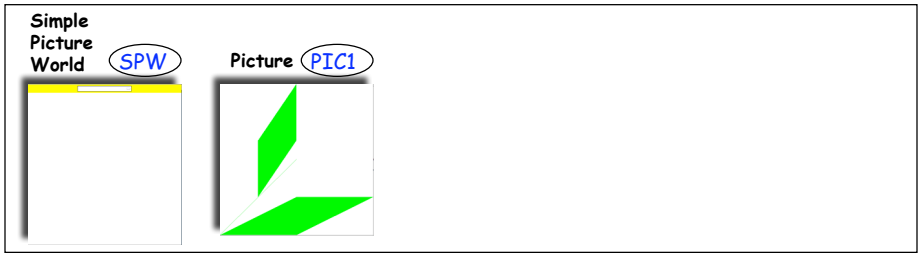


Execution Land

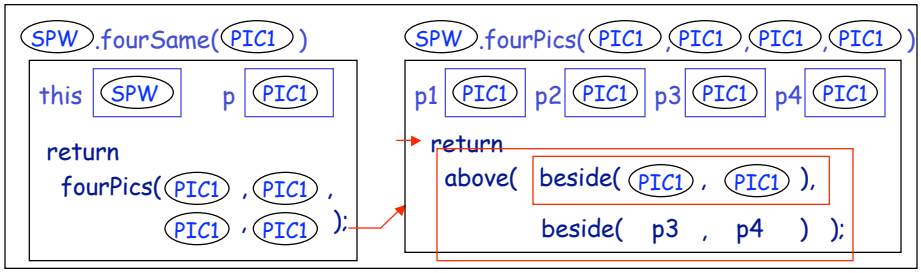


Invoke the First beside() method …

Object Land

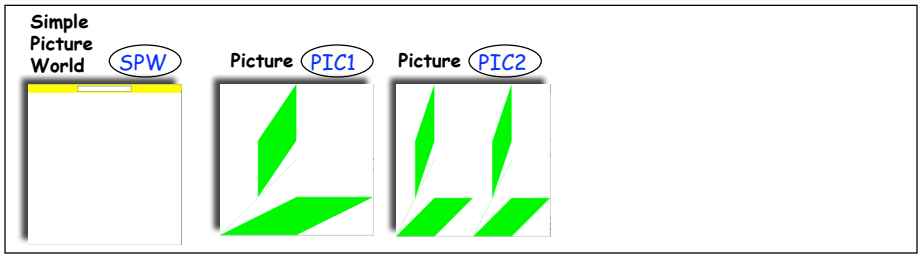


Execution Land

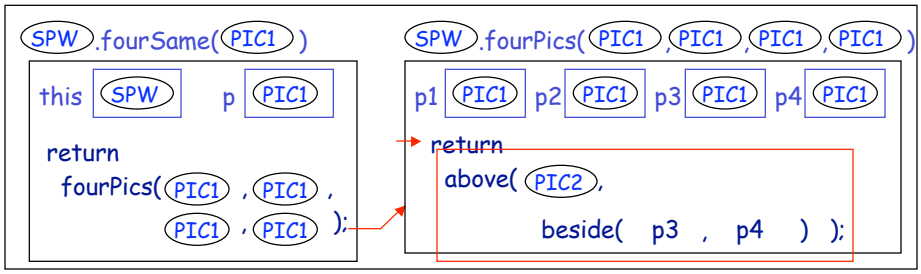


… Which Creates and Returns a New Picture

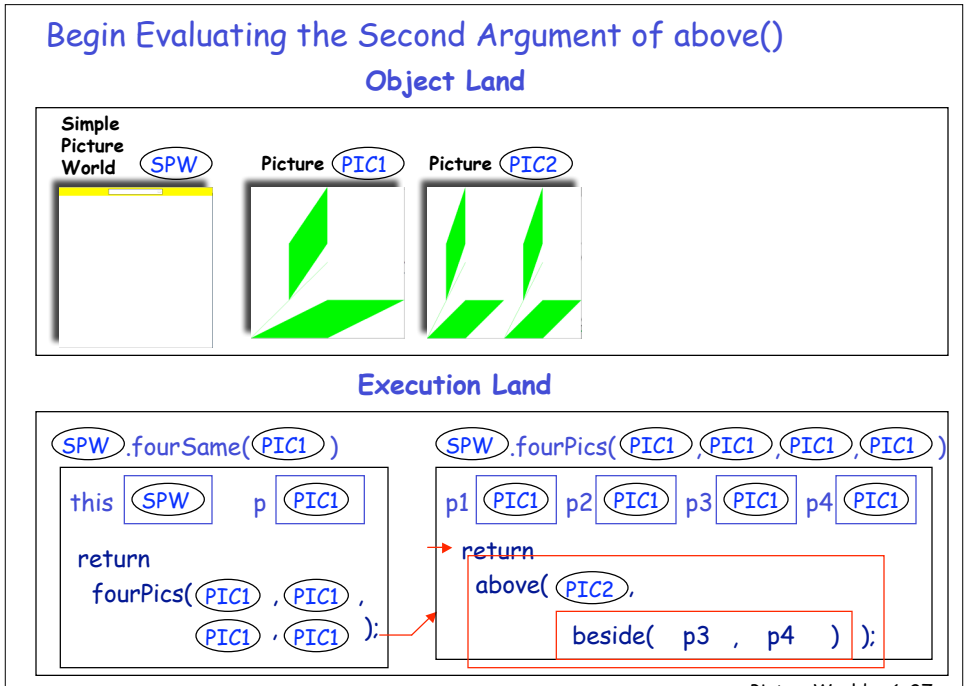
Object Land



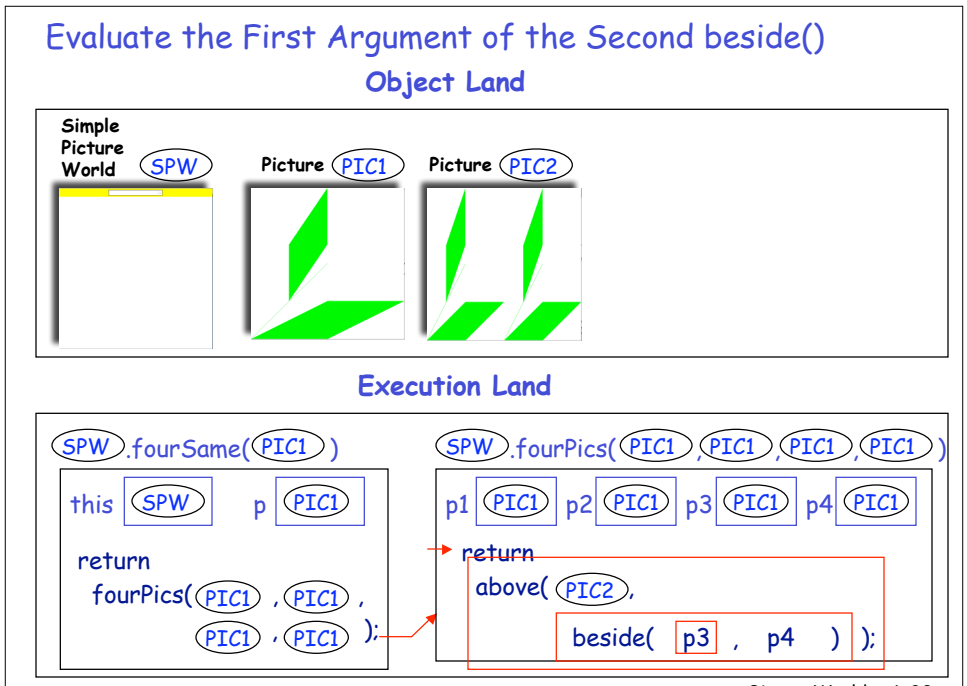
Execution Land



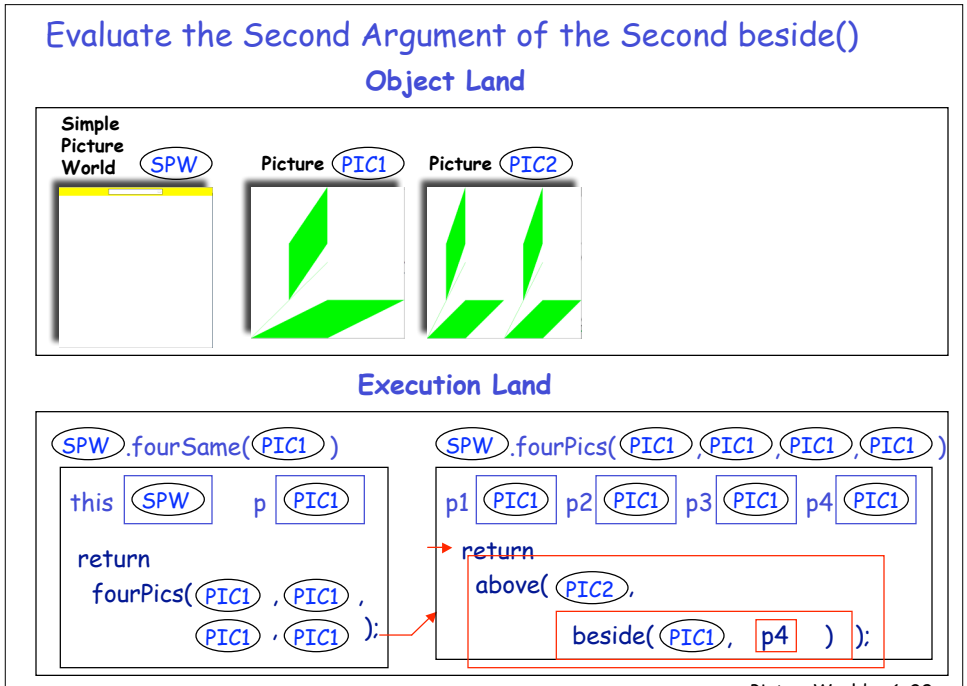
Begin Evaluating the Second Argument of above()



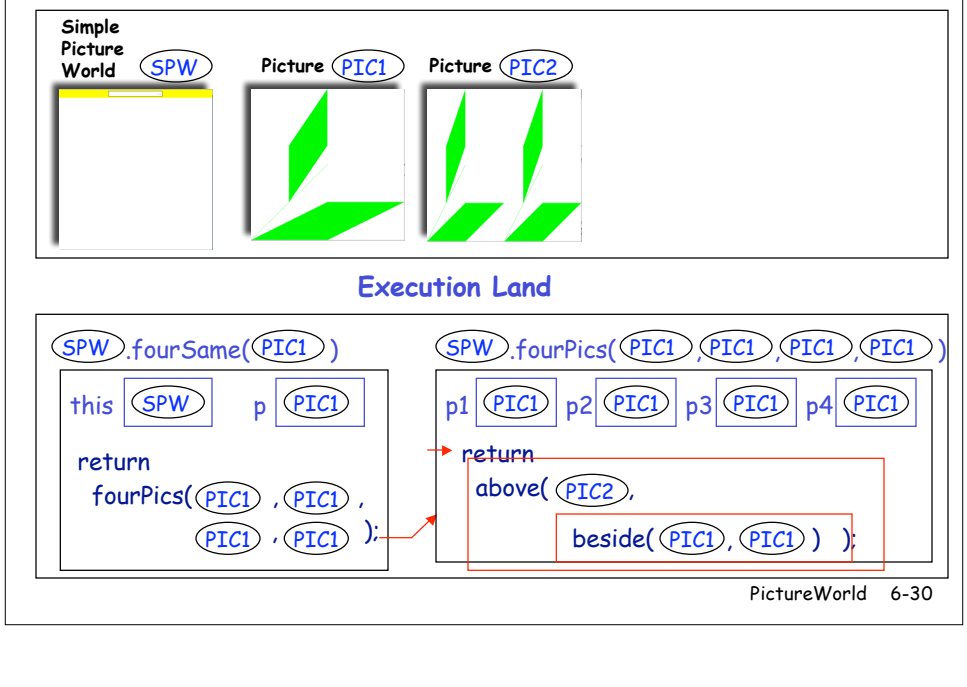
Evaluate the First Argument of the Second beside()



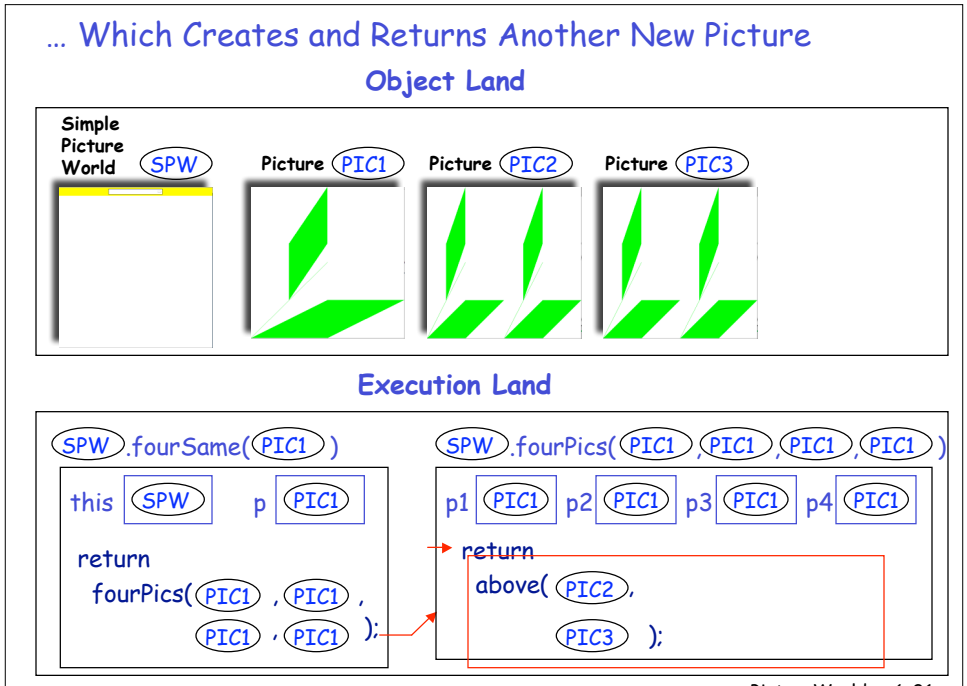
Evaluate the Second Argument of the Second beside()



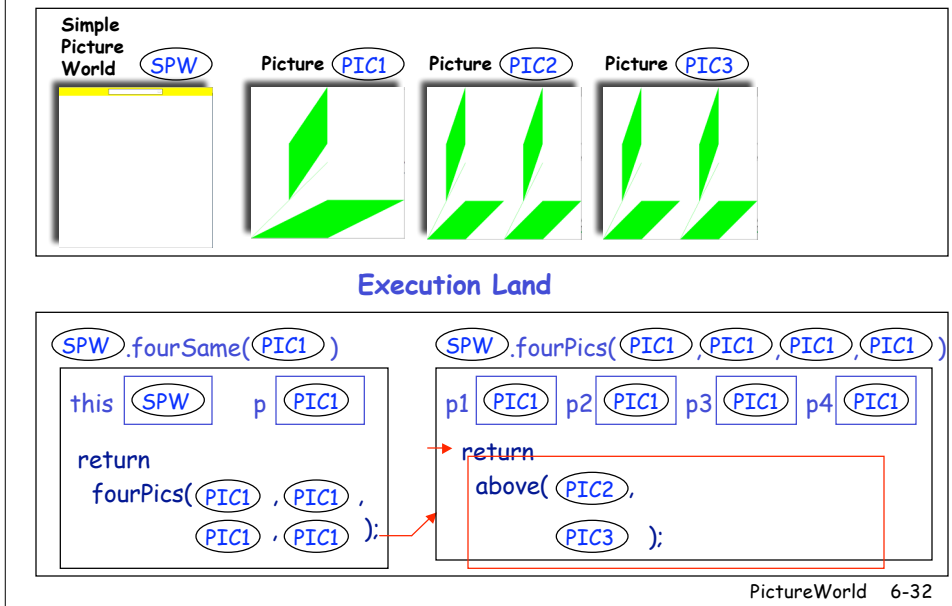
Invoke the Second beside() Method …



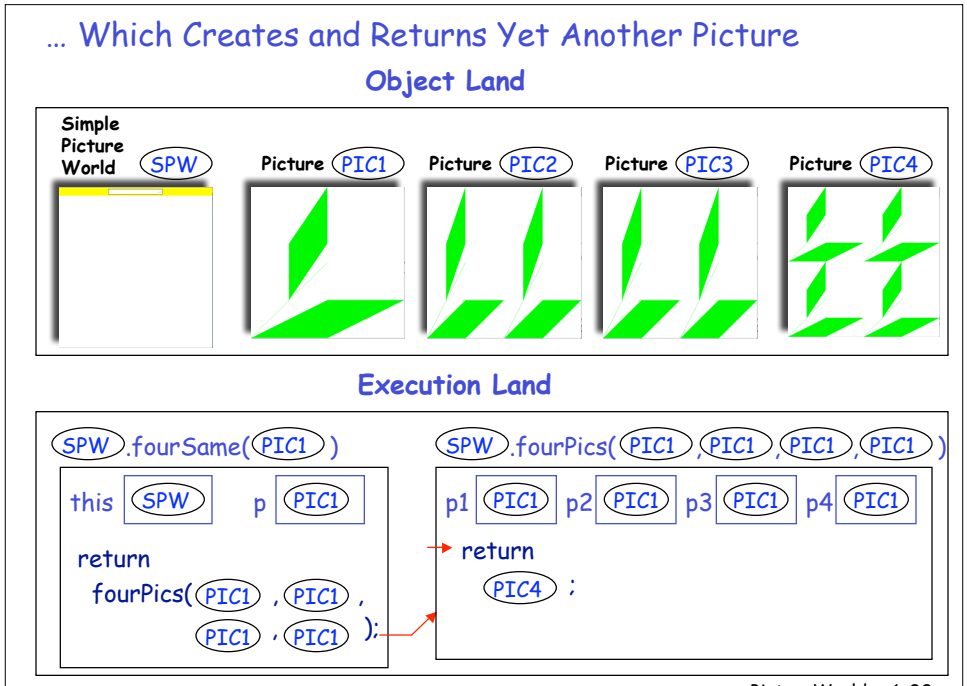
… Which Creates and Returns Another New Picture



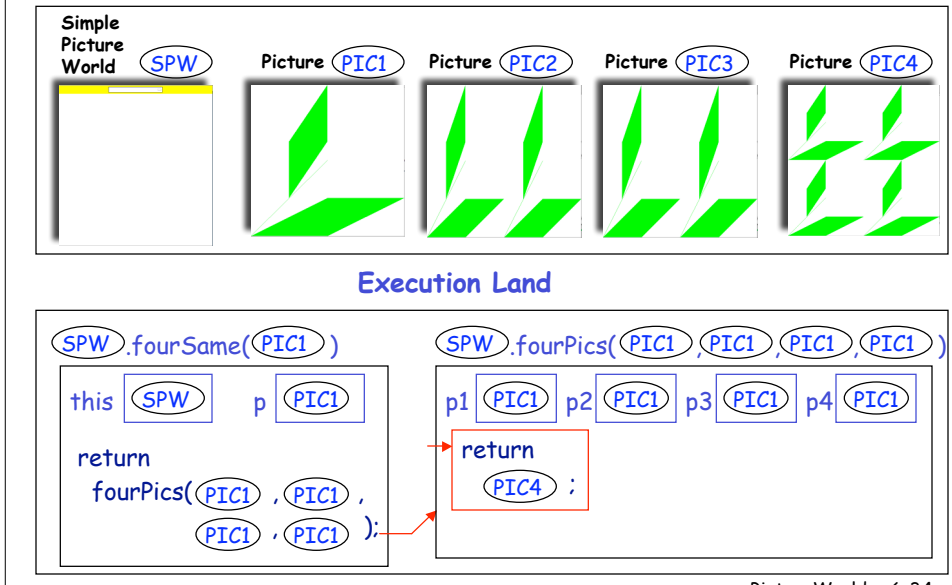
Now Invoke above() …



… Which Creates and Returns Yet Another Picture

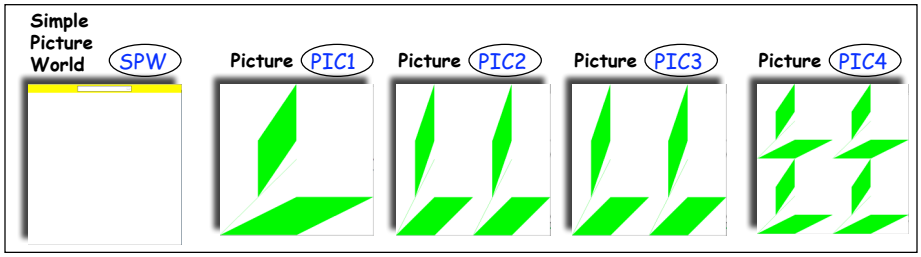


Return from the fourPics() Execution Frame …



… to the Place where fourPics() was Invoked

Object Land



Execution Land

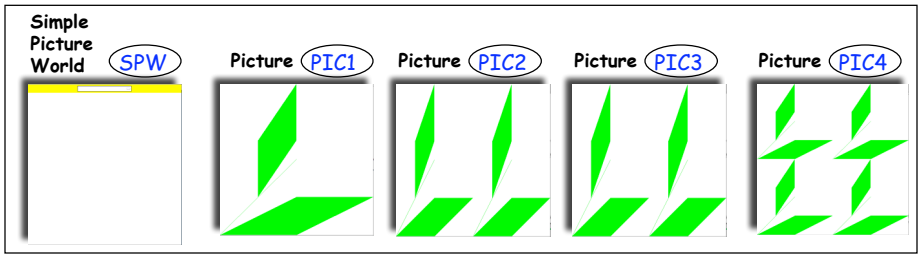
SPW.fourSame(PIC1)

this SPW p PIC1

return PIC4;

Finally, Return from the fourSame() Invocation Frame …

Object Land



Execution Land

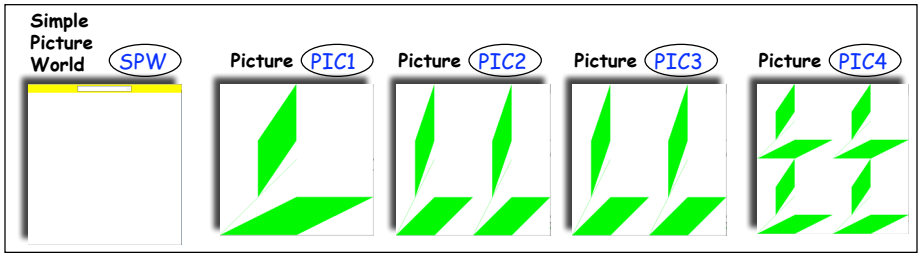
SPW.fourSame(PIC1)

this SPW p PIC1

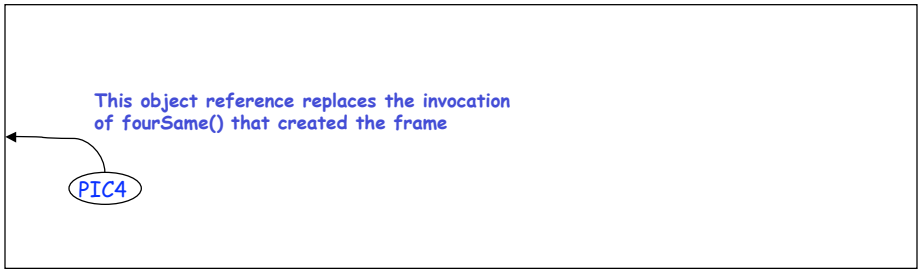
return PIC4;

… To the Place Where fourSame() was Invoked

Object Land

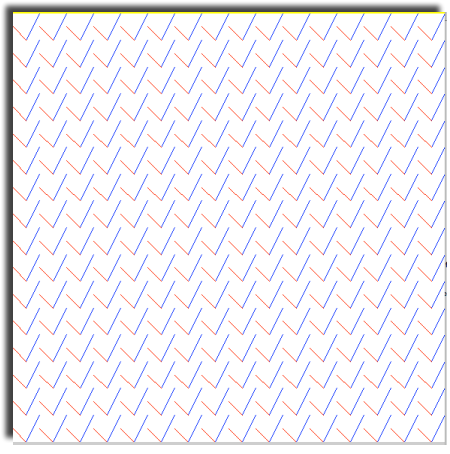


Execution Land

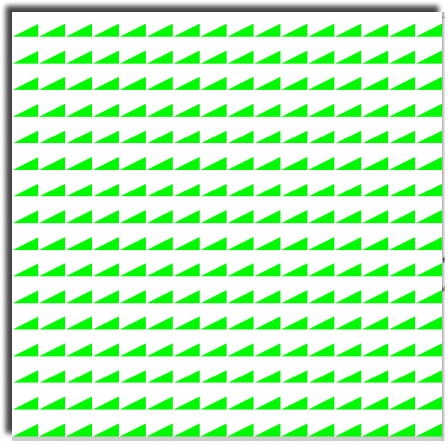


Repeated Tiling

```
public Picture tiling (Picture p) {
    return fourSame(fourSame(fourSame(fourSame(p))));
}
```



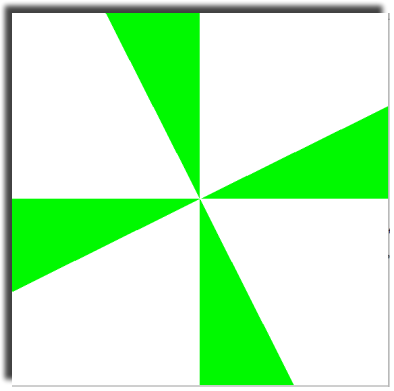
tiling(mark)



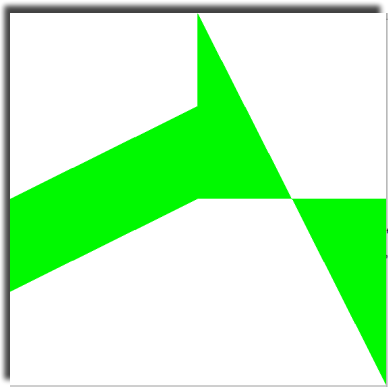
tiling(gw)

Rotation Combinators

```
public Picture rotations (Picture p) {
    return fourPics(clockwise270(p), p, clockwise180(p), clockwise90(p));
}

public Picture rotations2 (Picture p) {
    return fourPics(p, clockwise90(p), clockwise180(p), clockwise270(p));
}
```



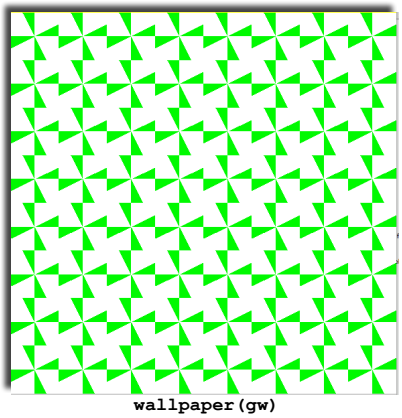
rotations(gw)



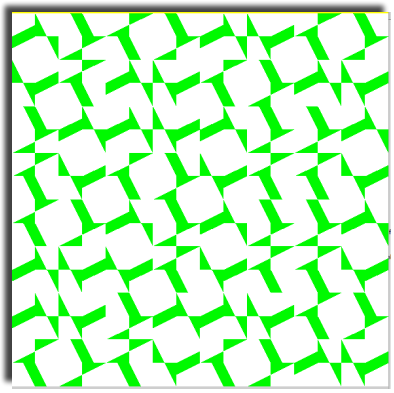
rotations2(gw)

A Simple Recipe for Complexity

```
public Picture wallpaper (Picture p) {
    return rotations(rotations(rotations(rotations(p))));
}

public Picture design (Picture p) {
    return rotations2(rotations2(rotations2(rotations2(p))));
}
```



wallpaper(gw)



design(gw)