Transformations 2

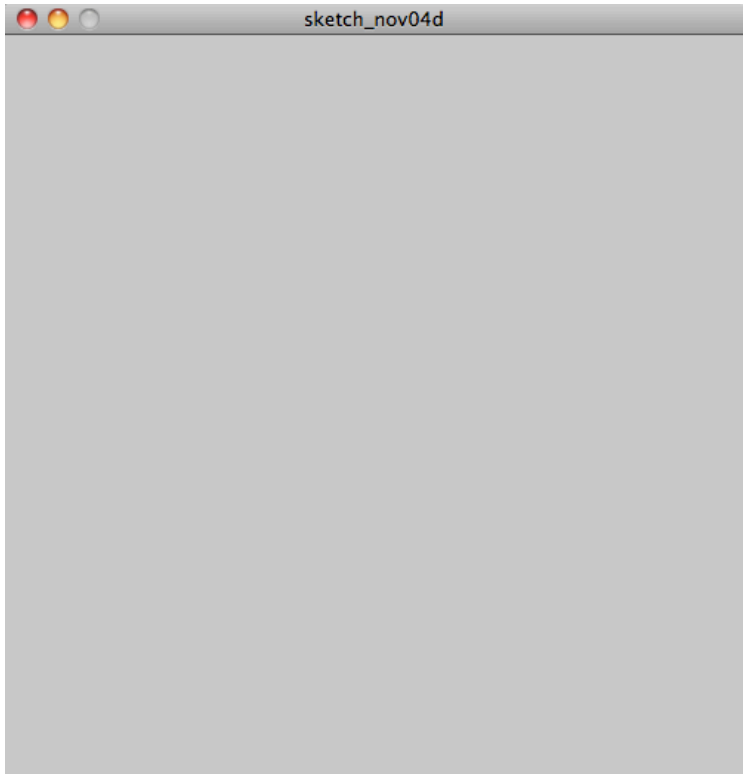
CS110

Transformations Reviewed

We can think of the Processing window as being a field of pixels on which we draw.

How do we know where processing will draw the ellipse?

```
size(500,500);
ellipse(250,250,200,200);
```

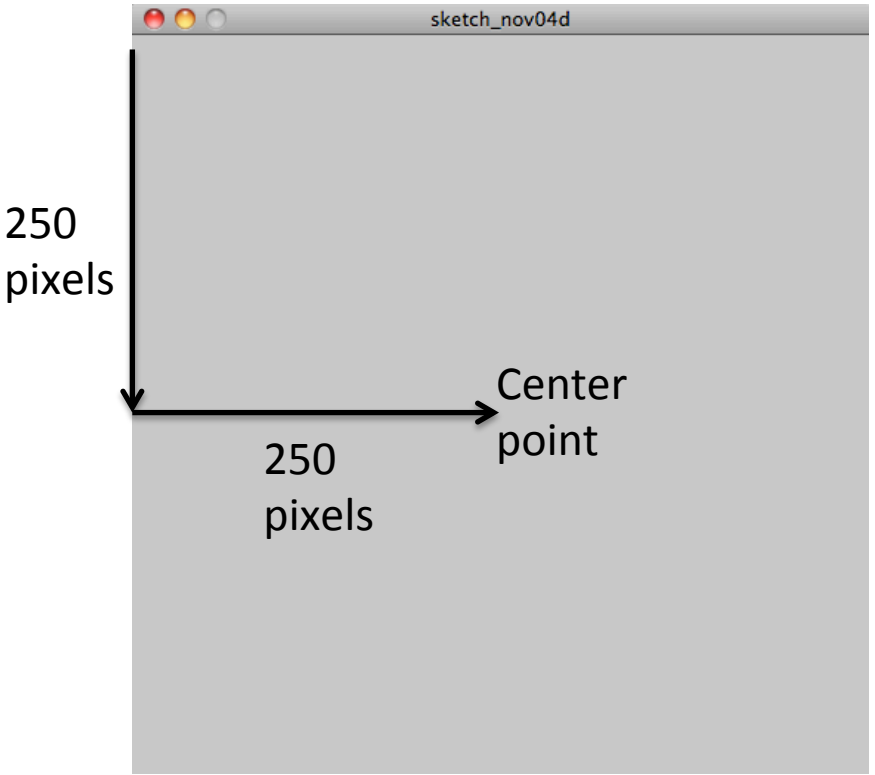


Transformations Reviewed

How we've done things thus far:

```
size(500,500);
ellipse(250,250,200,200);
```

Center pixel

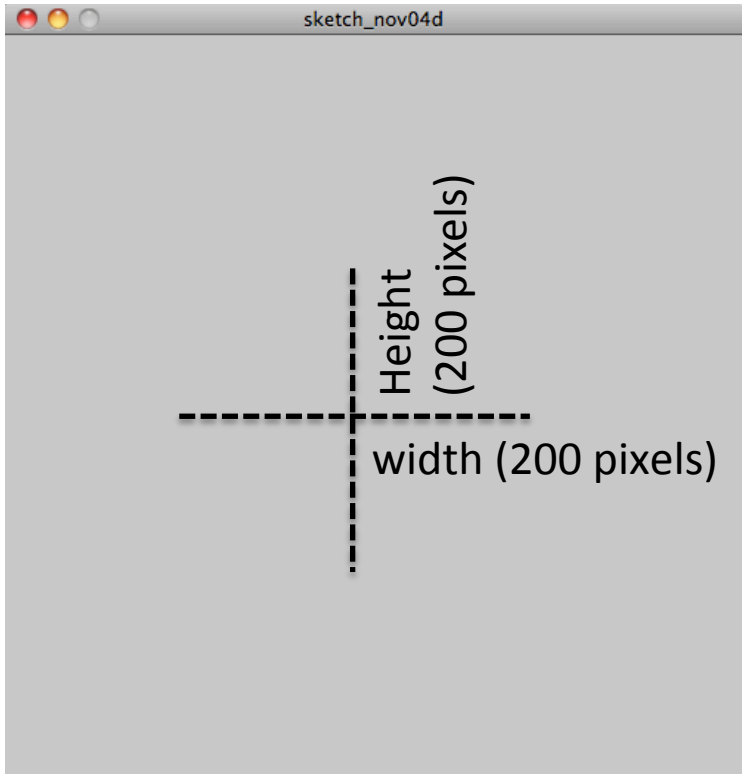


Transformations Reviewed

How we've done things thus far:

```
size(500,500);
ellipse(250,250,200,200);
```

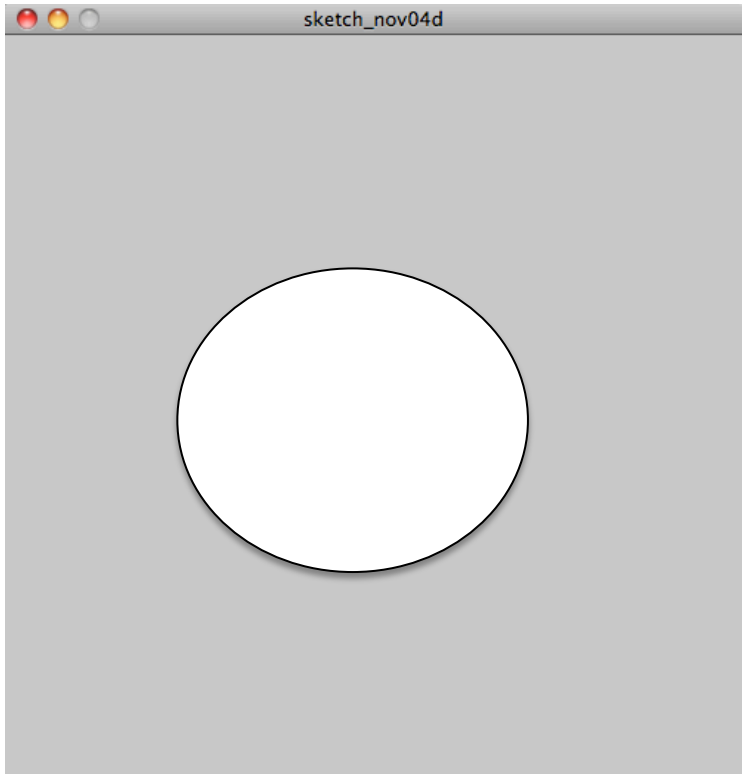
Width and
height in pixels



Transformations Reviewed

How we've done things thus far:

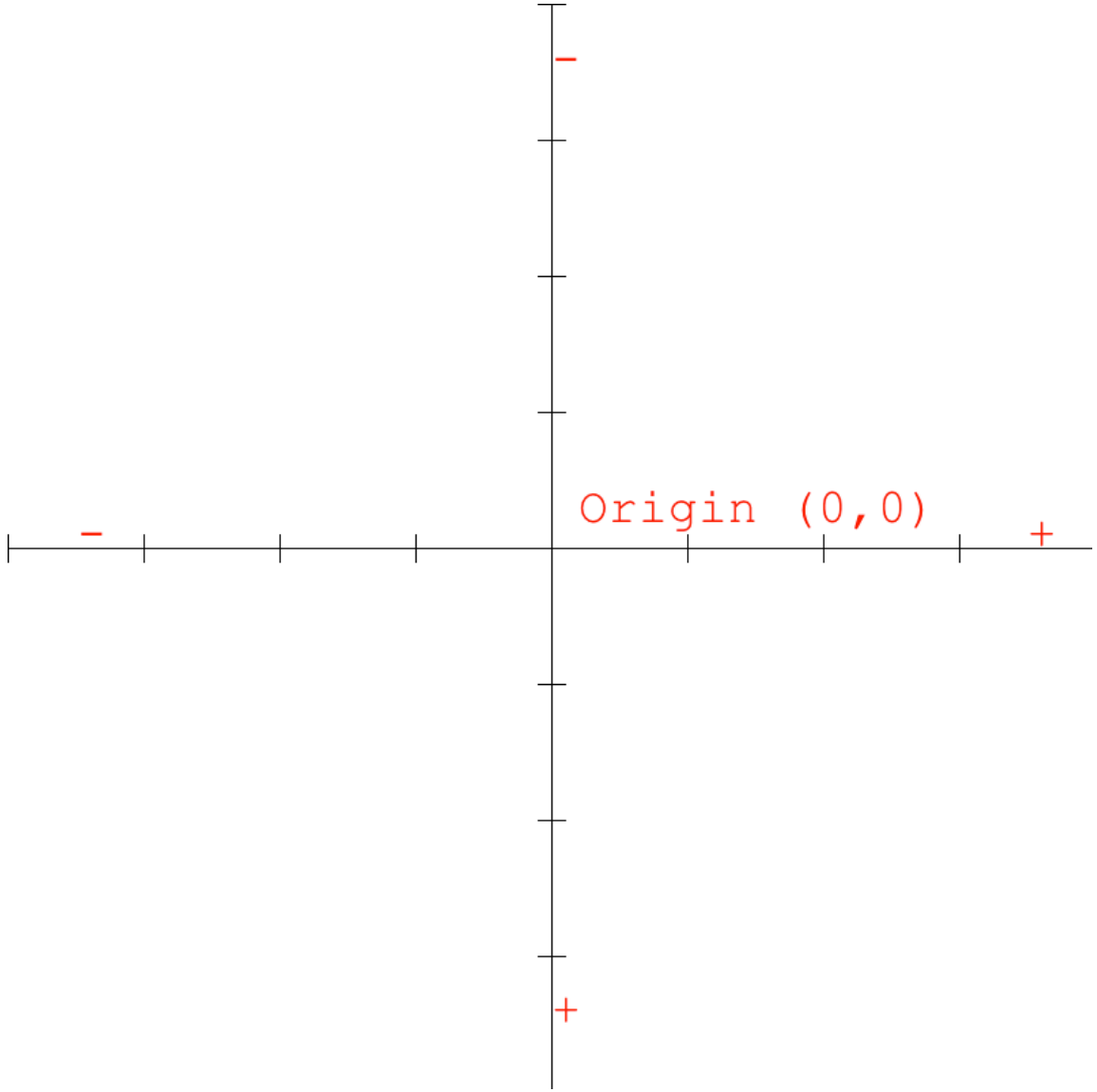
```
size(500,500);
ellipse(250,250,200,200);
```



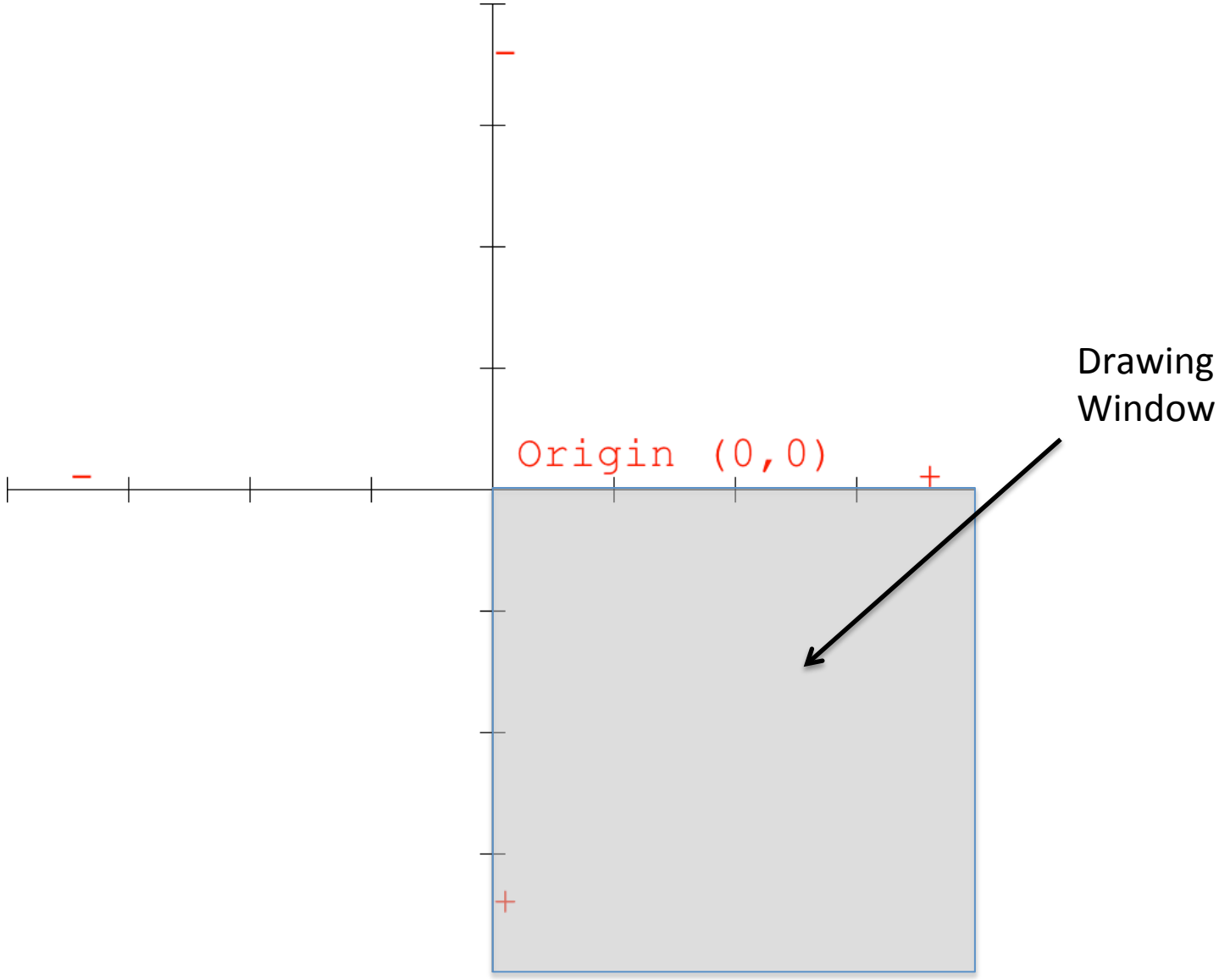
Separating the Display Window from the Coordinate System

- We are used to thinking of the arguments passed to drawing functions as specifying which **pixels** to draw the object at
- Transformations introduce the idea of a coordinate system that is **not necessarily the same as pixel positions** within the window

The Coordinate System

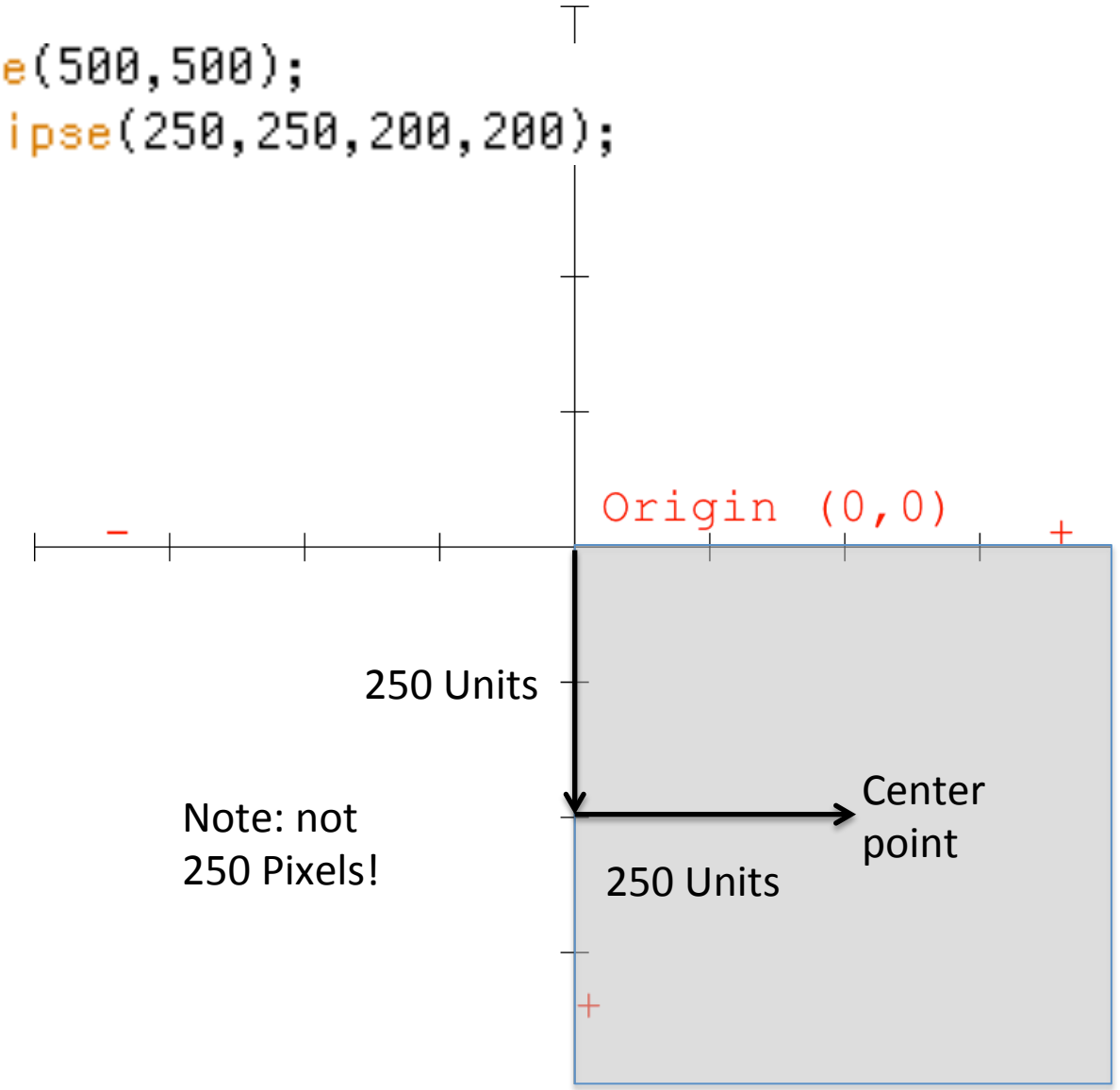


Initial Alignment of Main Window



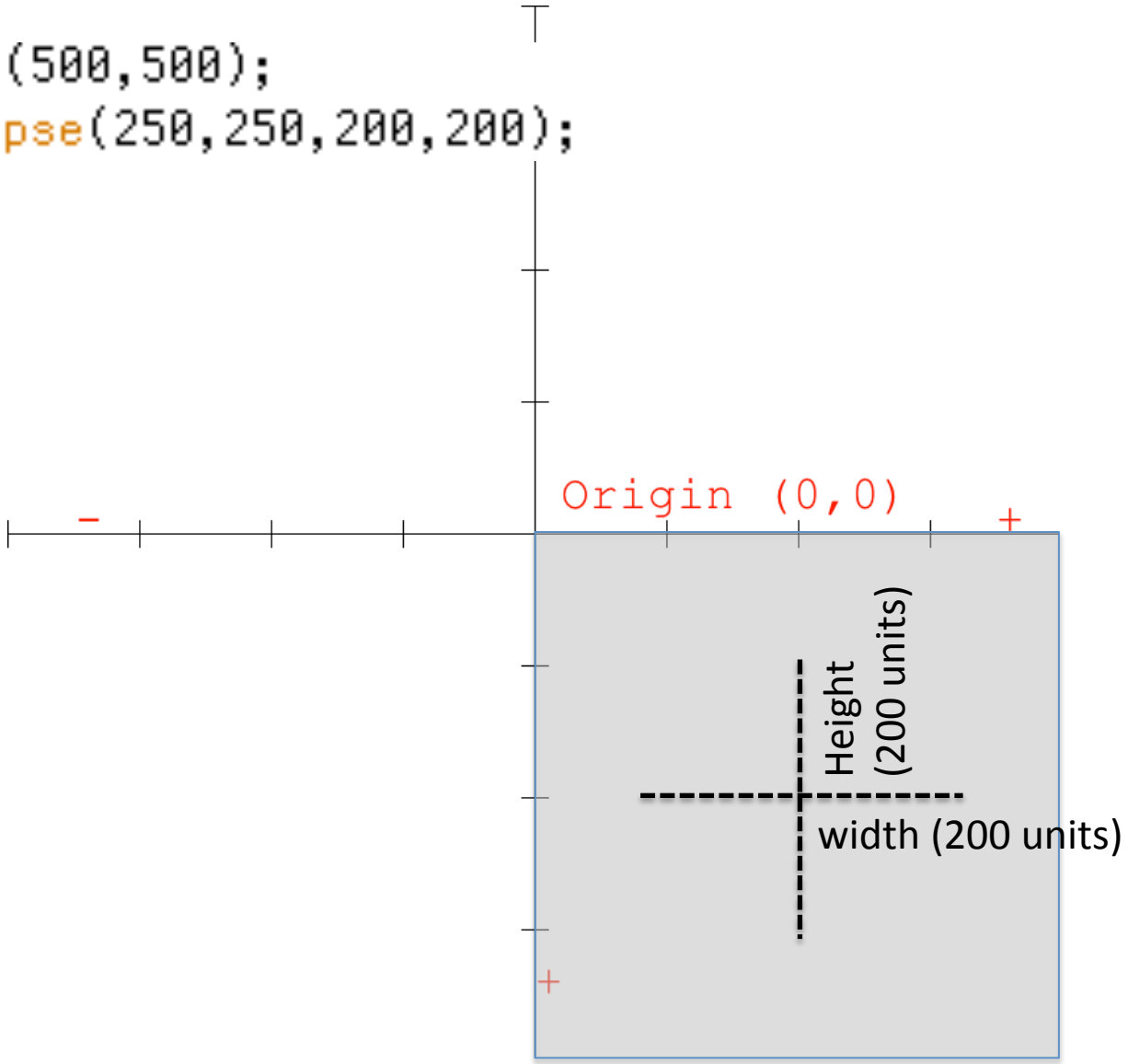
A Simple Example Revisited

```
size(500,500);
ellipse(250,250,200,200);
```



A Simple Example Revisited

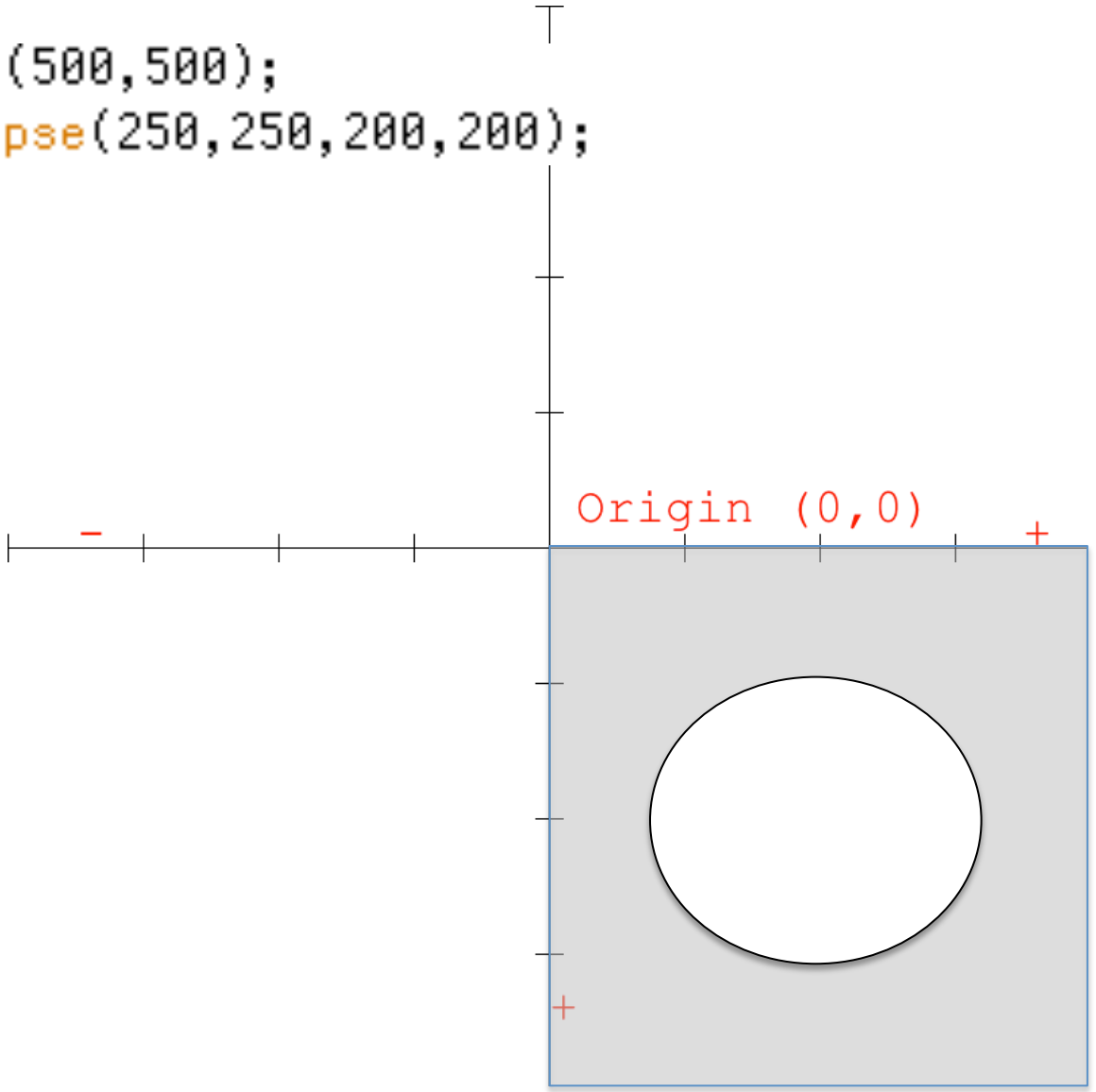
```
size(500,500);
ellipse(250,250,200,200);
```



Note: not
200 Pixels!

A Simple Example Revisited

```
size(500,500);
ellipse(250,250,200,200);
```

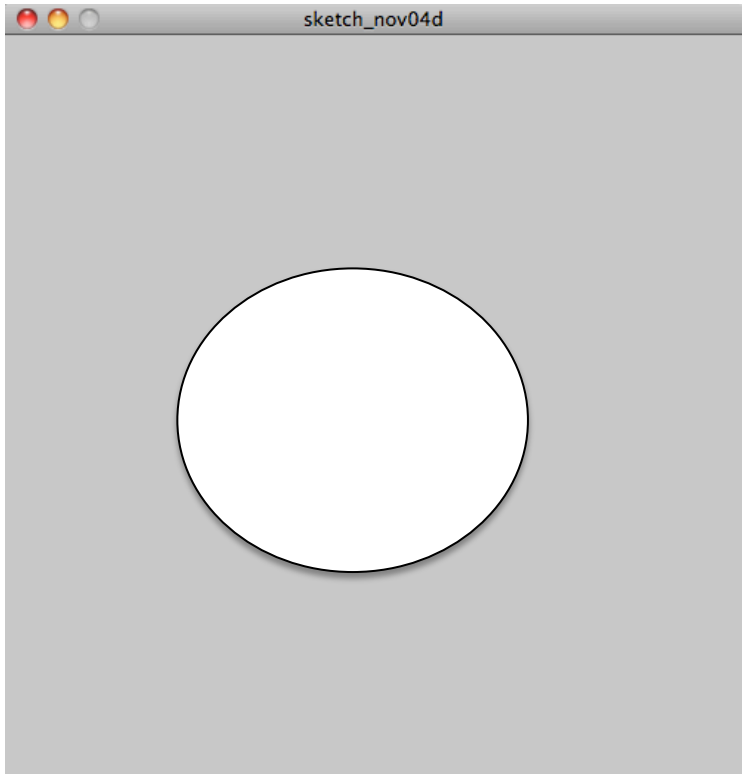


A Simple Example Revisited

```
size(500,500);
ellipse(250,250,200,200);
```

Once we have computed the shape in the coordinate system, all we do is transfer it to the main window!

Once the shape is transferred, its appearance is not affected by subsequent transformations



So What are Transformations?

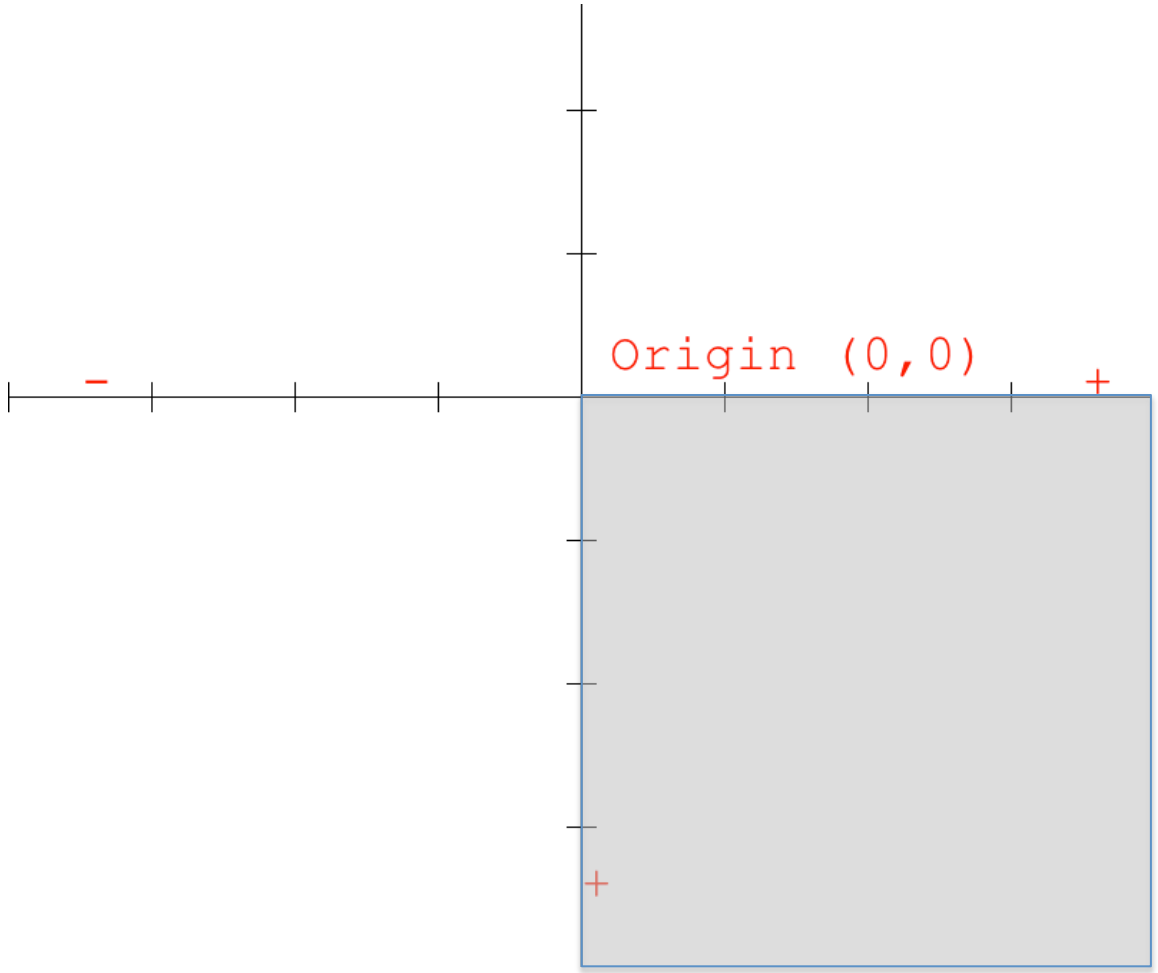
Transformations simply move the coordinate system without moving the processing window!

Three main operations:

- translate()
- scale()
- rotate()

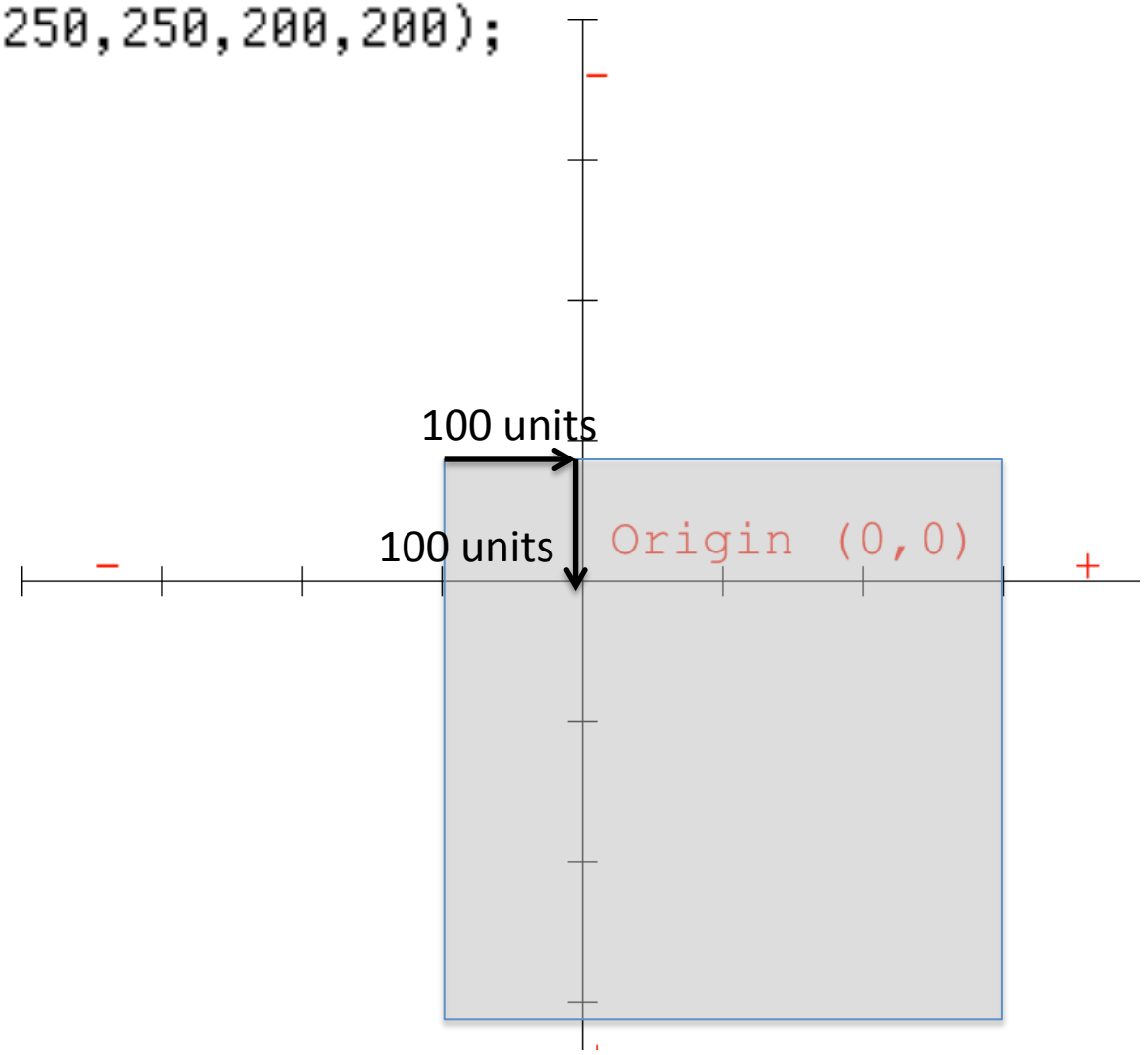
Translate

```
size(500,500);
translate(100,100);
ellipse(250,250,200,200);
```



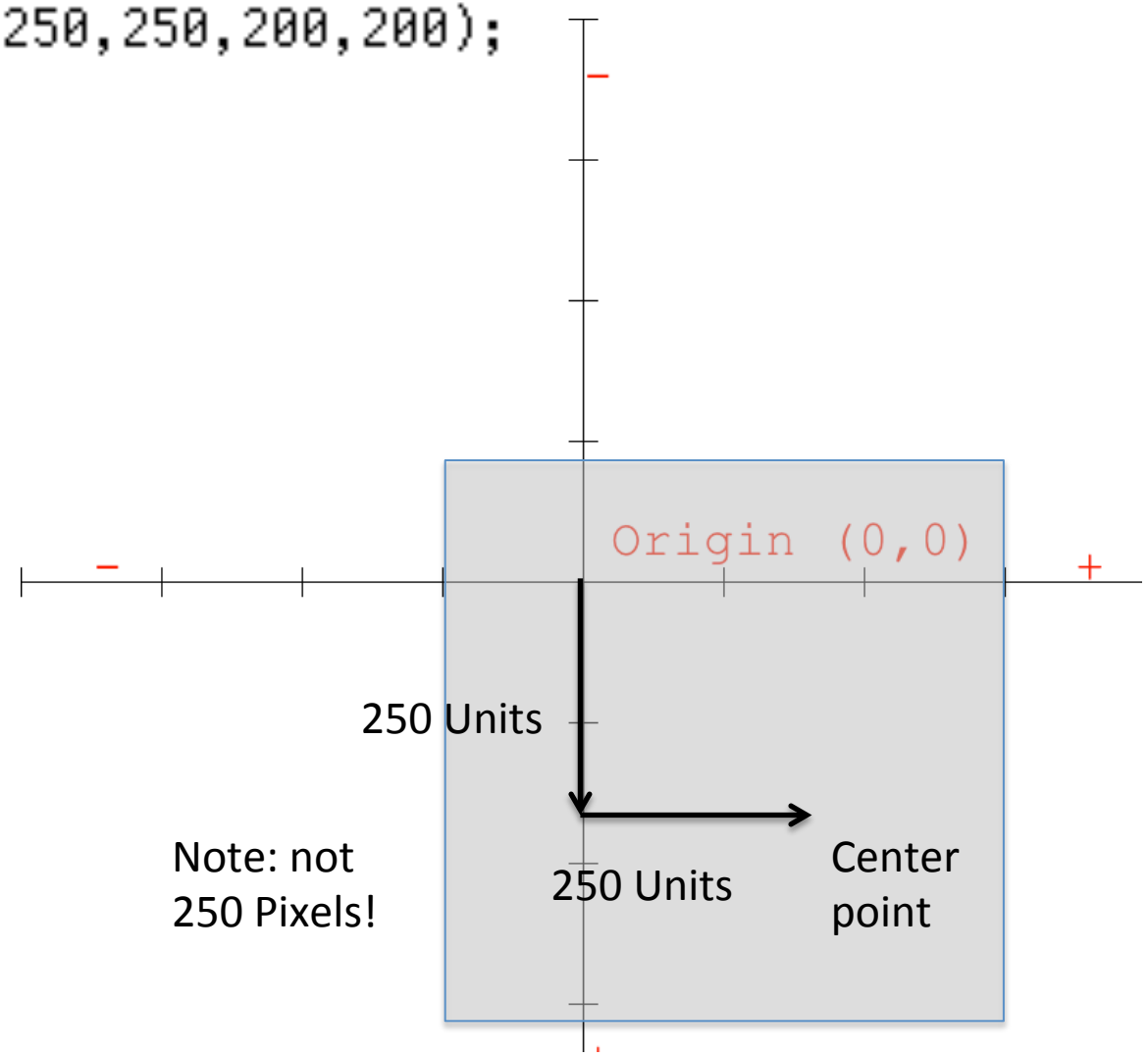
Translate

```
size(500,500);
translate(100,100);
ellipse(250,250,200,200);
```



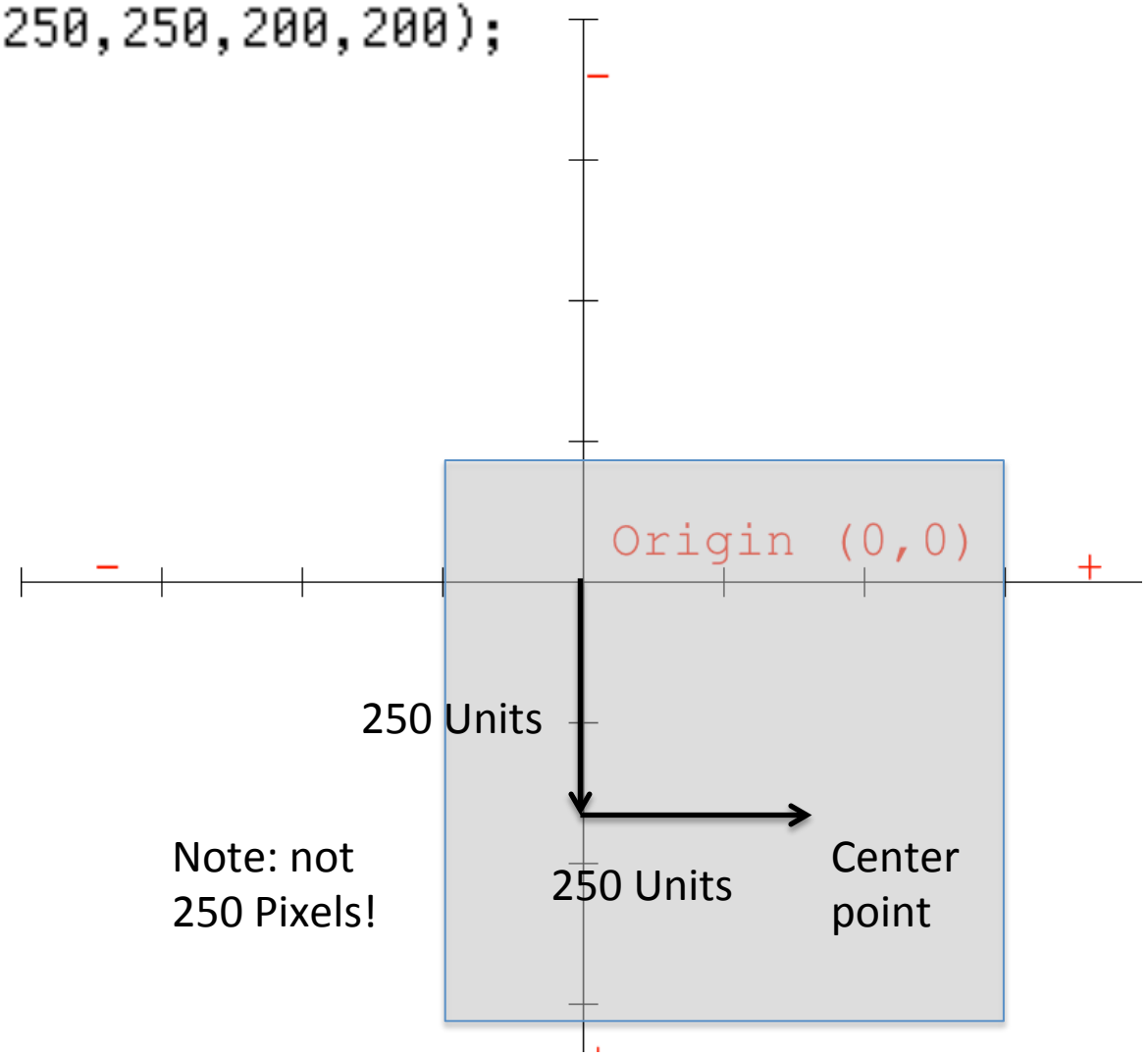
Translate

```
size(500,500);
translate(100,100);
ellipse(250,250,200,200);
```



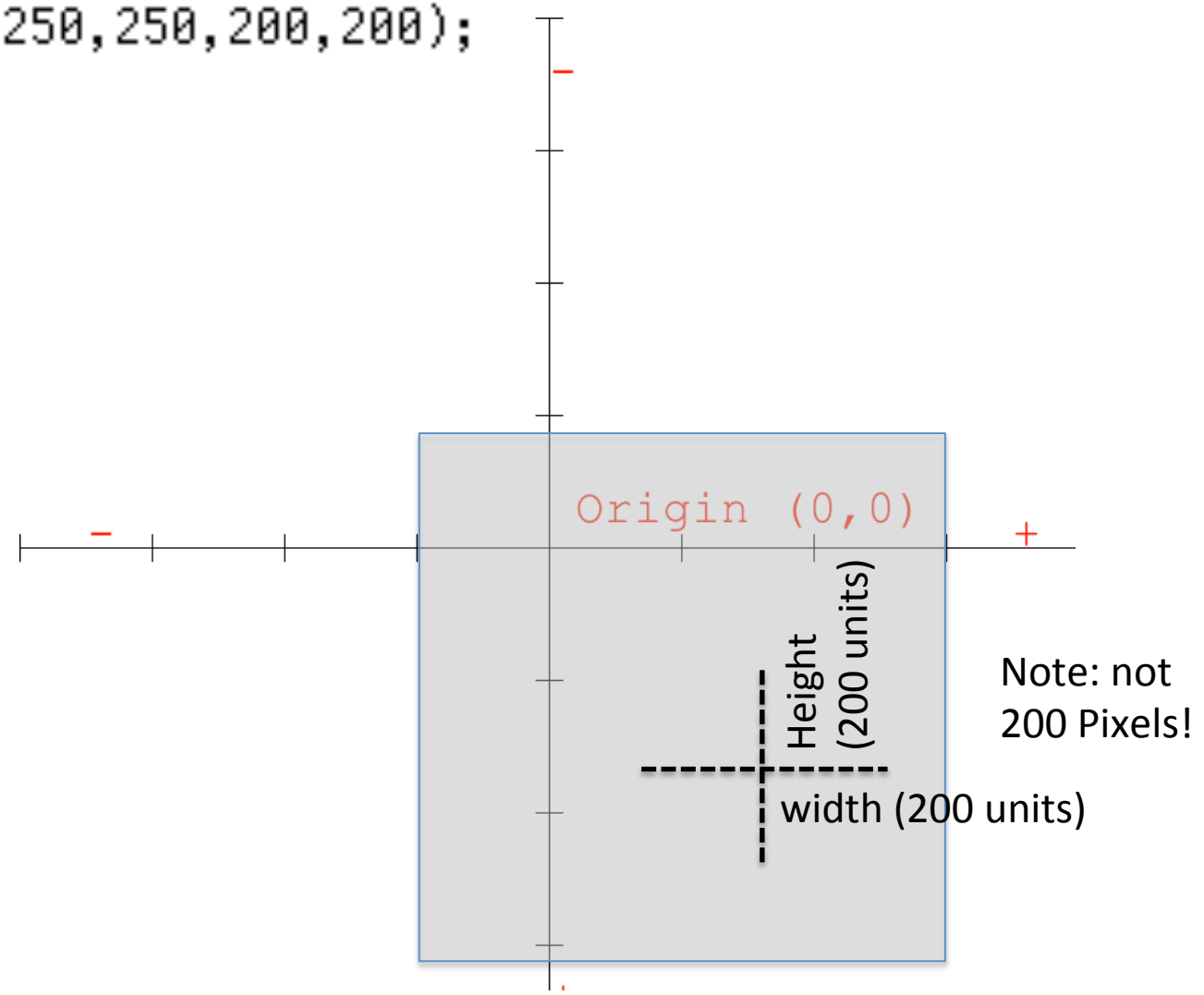
Translate

```
size(500,500);
translate(100,100);
ellipse(250,250,200,200);
```



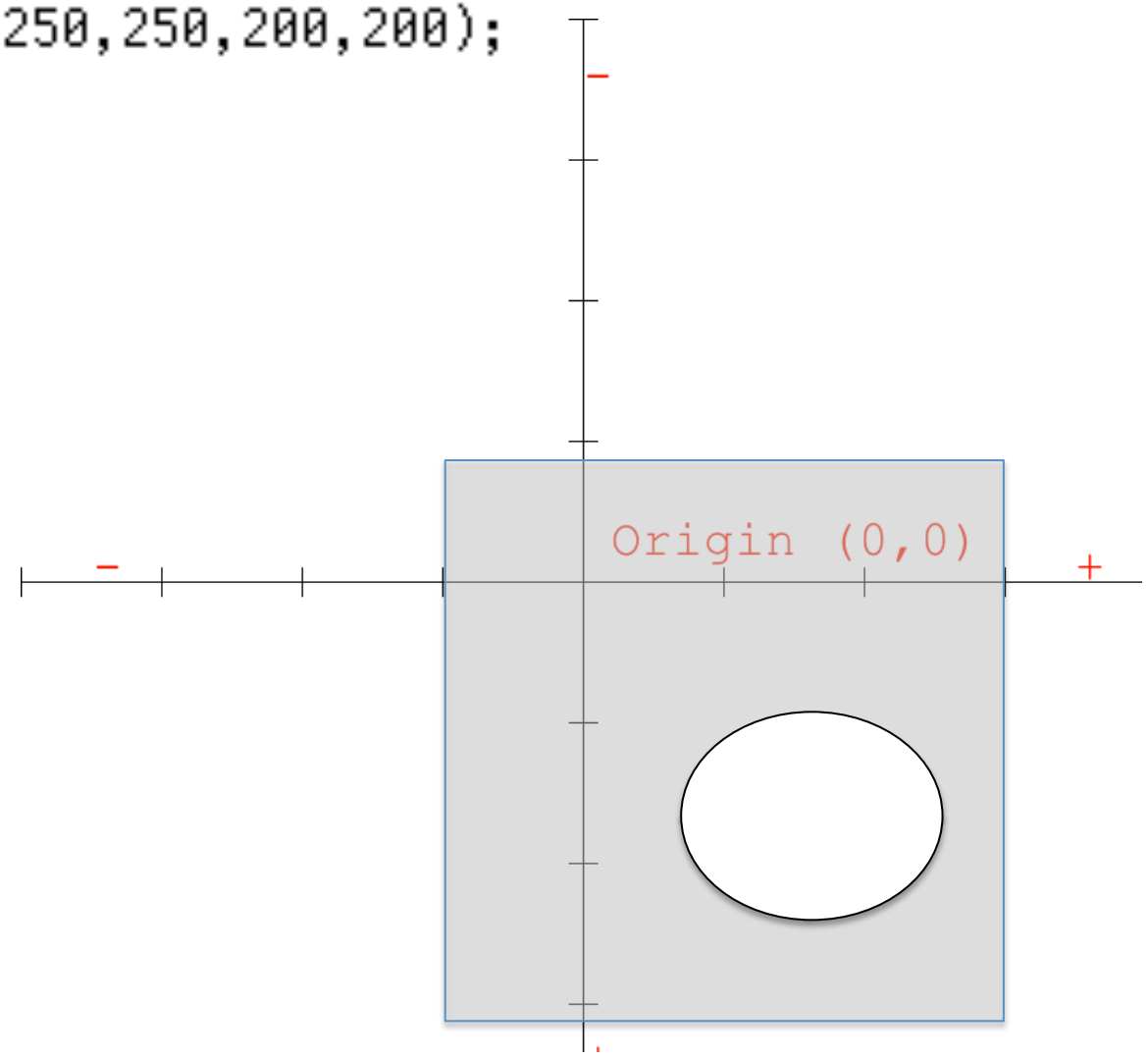
Translate

```
size(500,500);
translate(100,100);
ellipse(250,250,200,200);
```



Translate

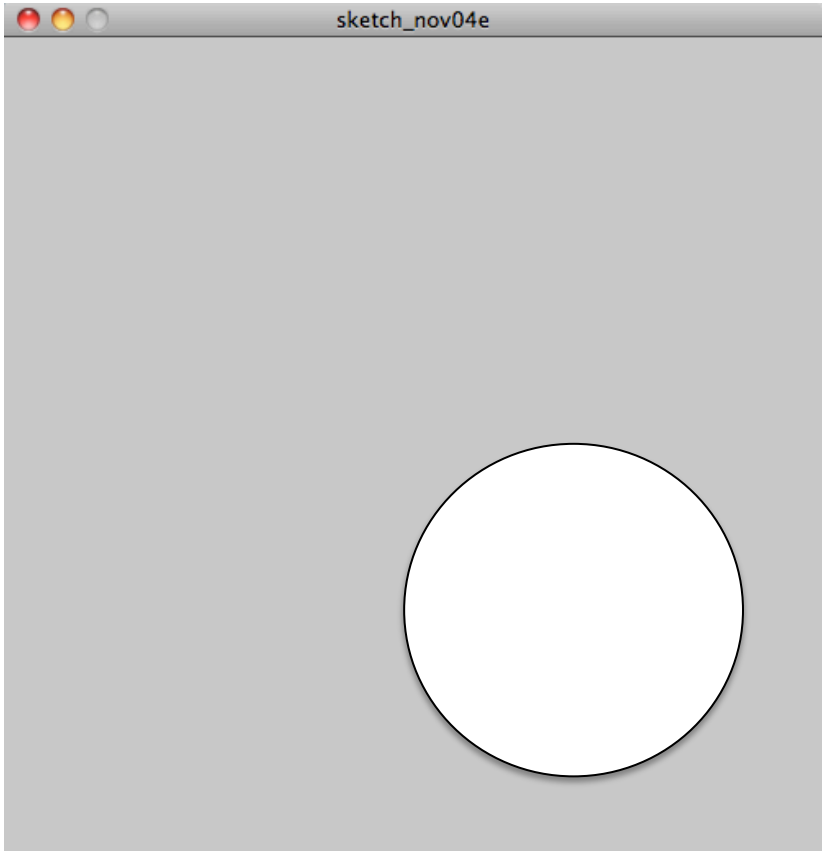
```
size(500,500);
translate(100,100);
ellipse(250,250,200,200);
```



Translate

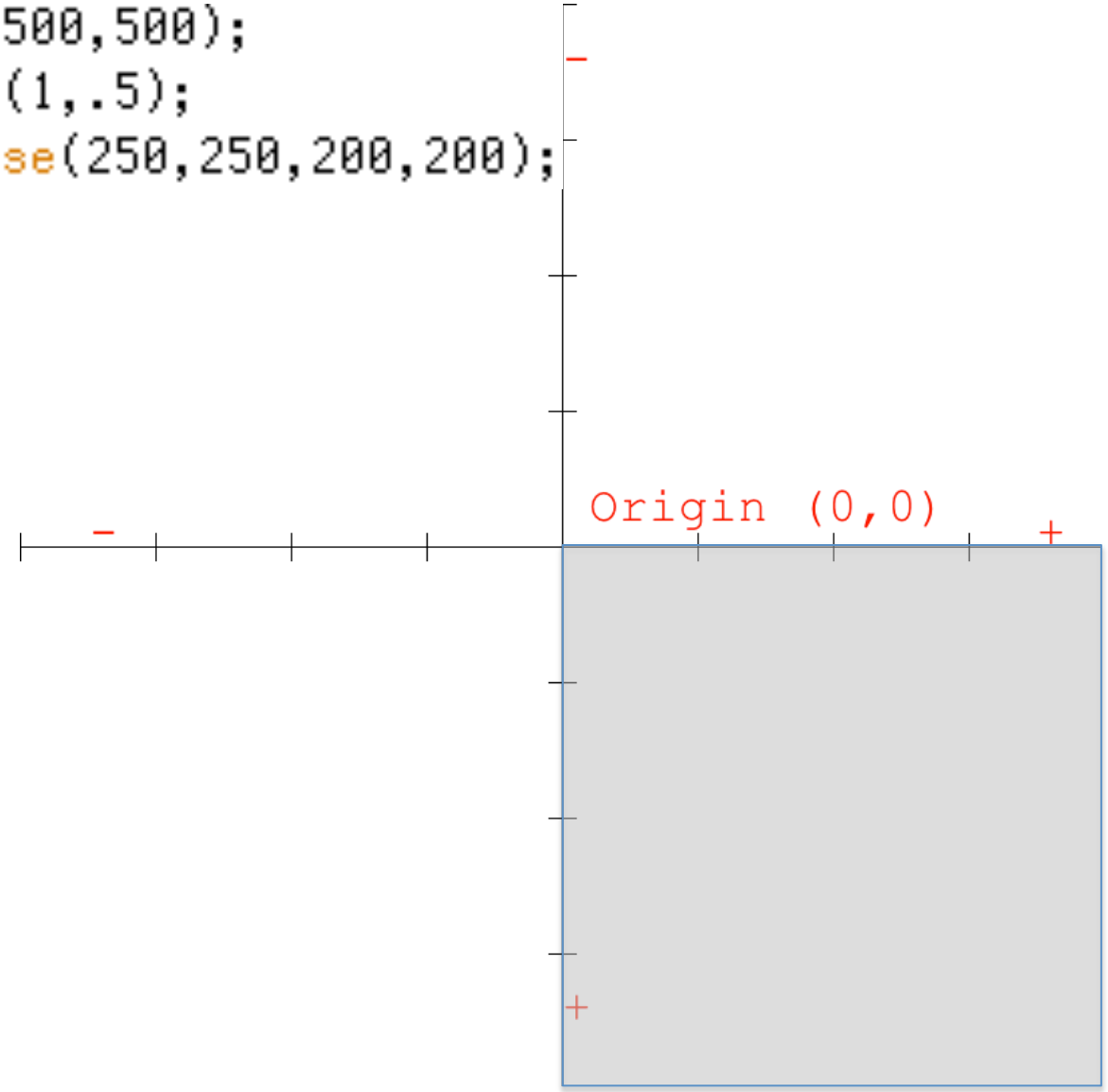
```
size(500,500);
translate(100,100);
ellipse(250,250,200,200);
```

Once we have computed the shape in the coordinate system, all we do is transfer it to the main window!



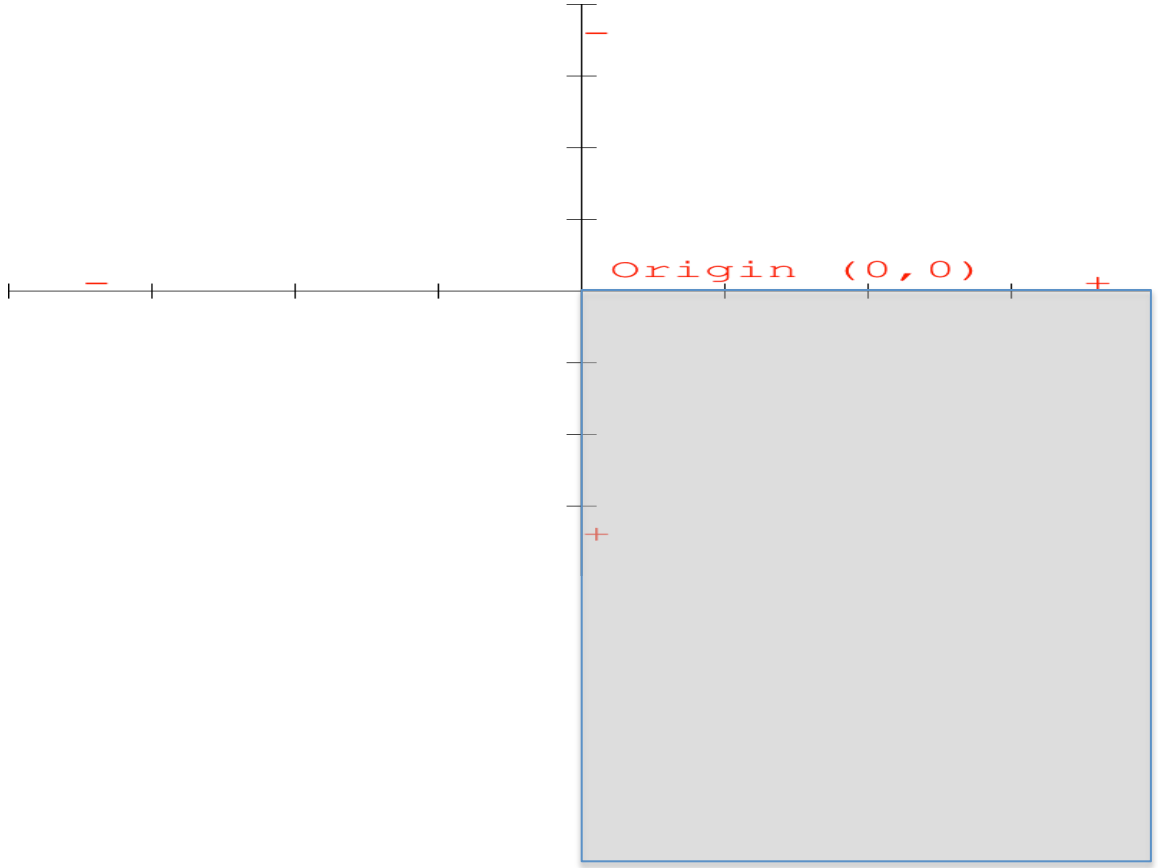
Scale

```
size(500,500);
scale(1,.5);
ellipse(250,250,200,200);
```



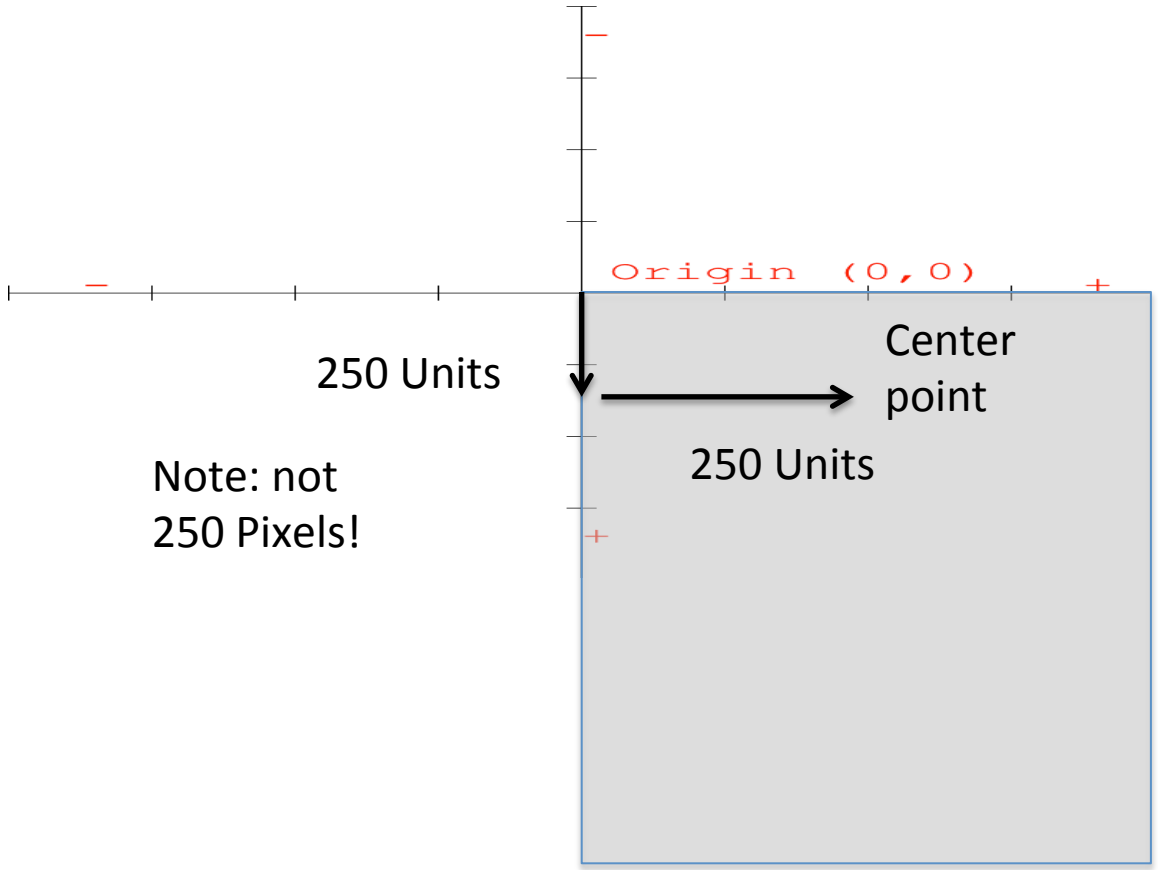
Scale

```
size(500,500);
scale(1,.5);
ellipse(250,250,200,200);
```



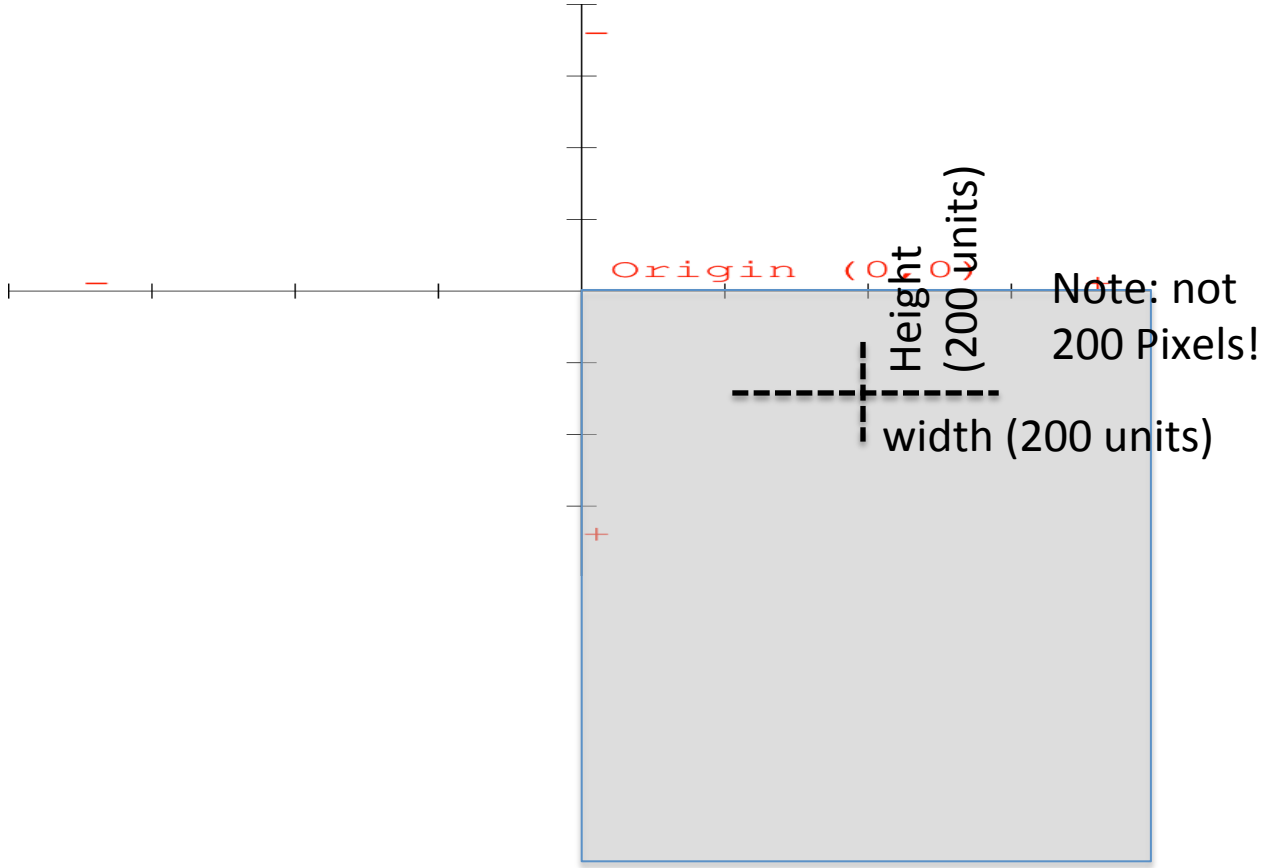
Scale

```
size(500,500);
scale(1,.5);
ellipse(250,250,200,200);
```



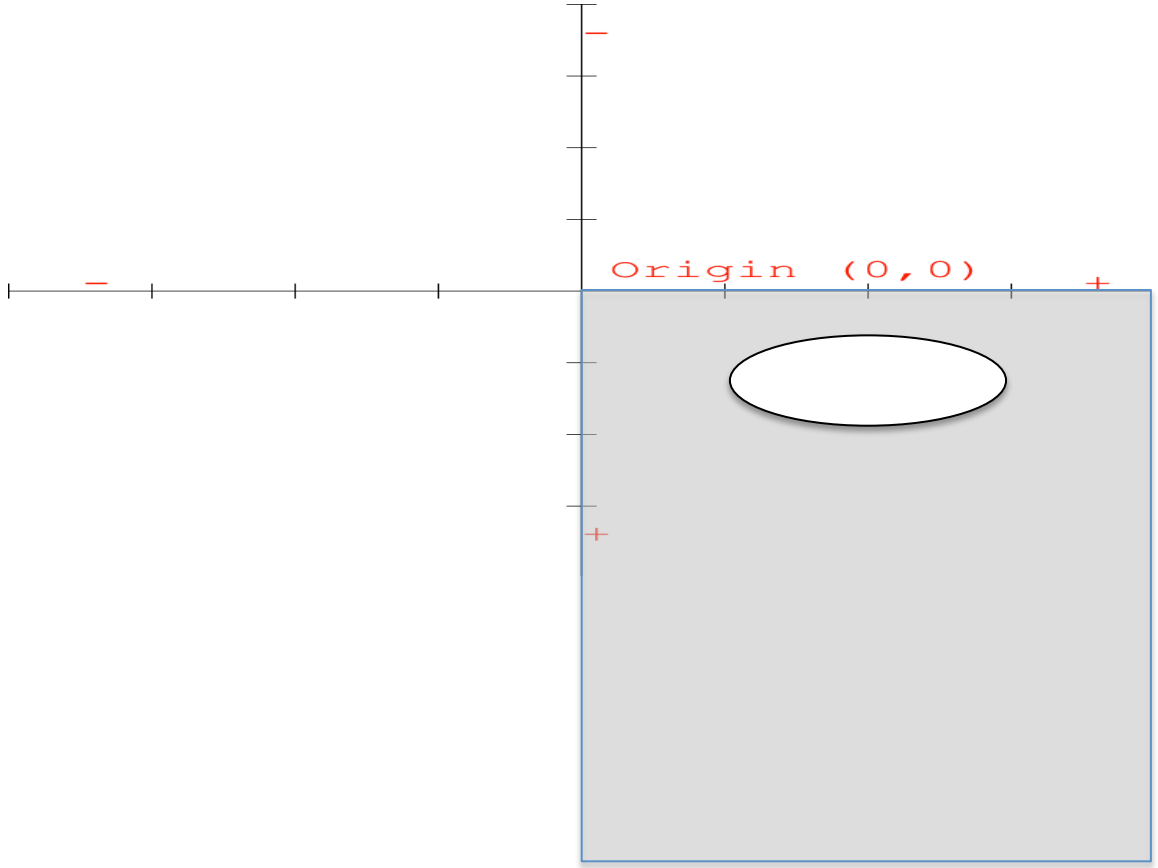
Scale

```
size(500,500);
scale(1,.5);
ellipse(250,250,200,200);
```



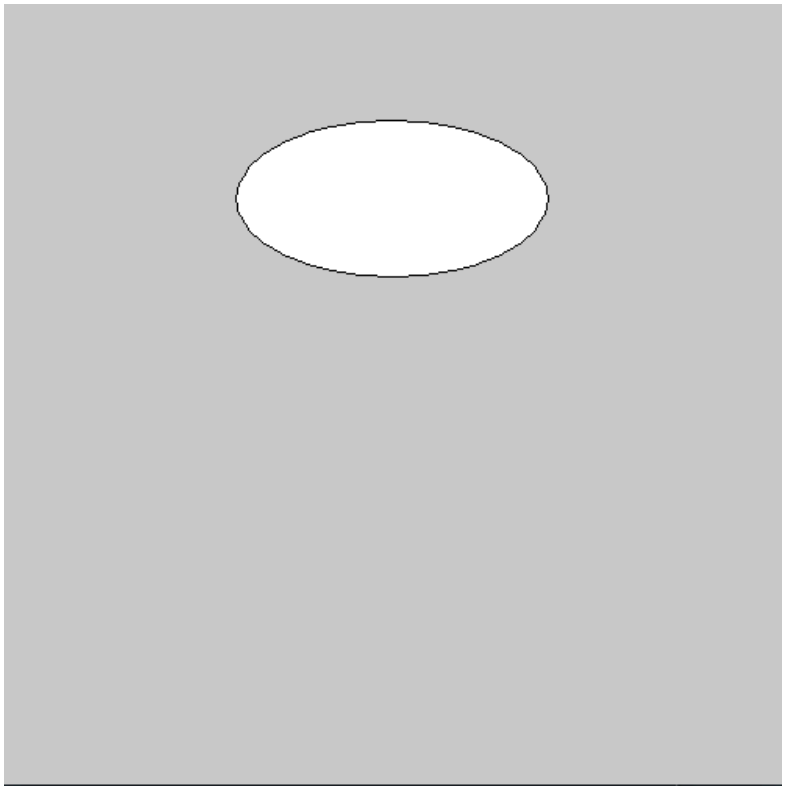
Scale

```
size(500,500);
scale(1,.5);
ellipse(250,250,200,200);
```



Scale

```
size(500,500);
scale(1,.5);
ellipse(250,250,200,200);
```

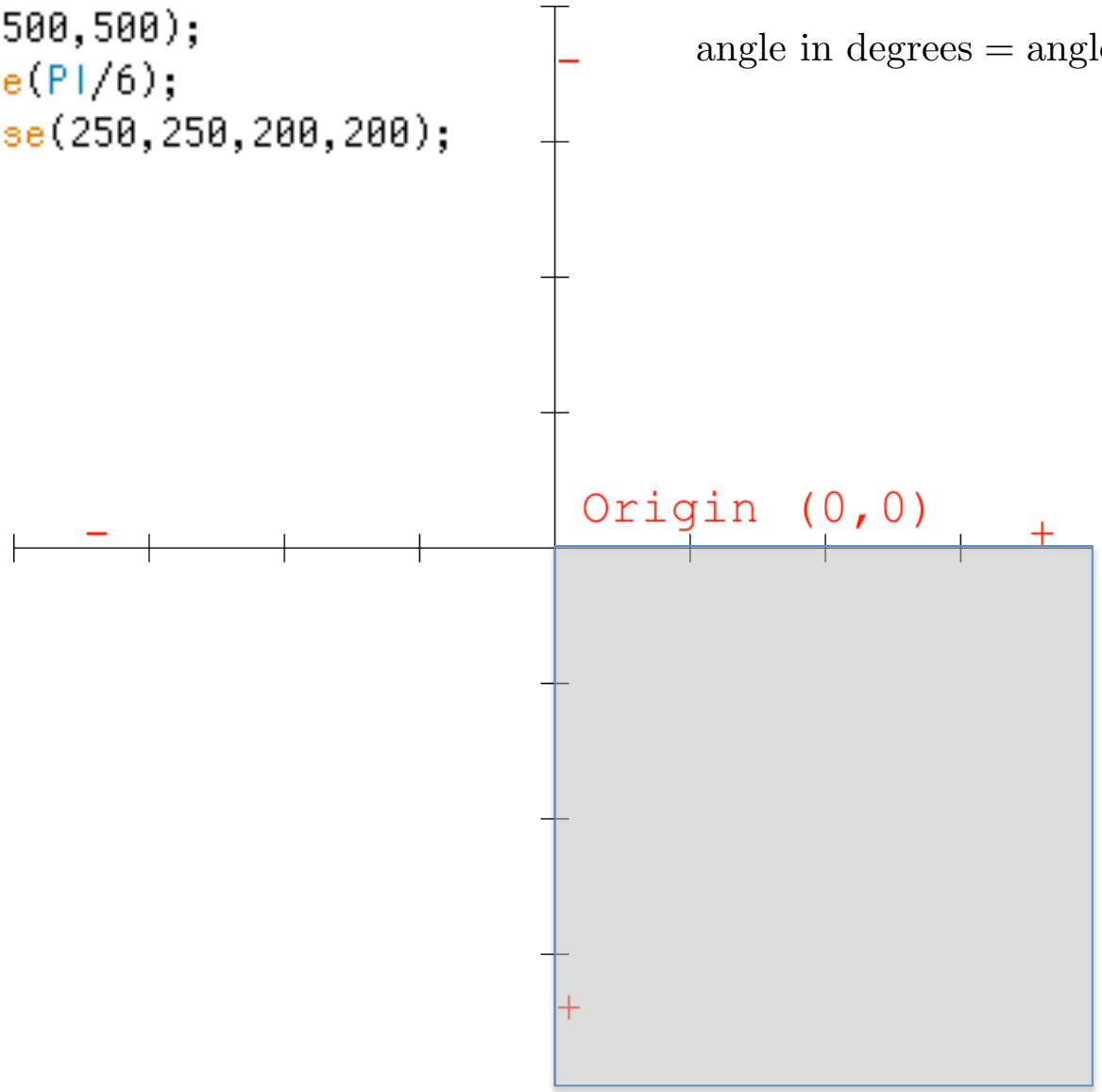


Once we have computed the shape in the coordinate system, all we do is transfer it to the main window!

Rotate

```
size(500,500);
rotate(PI/6);
ellipse(250,250,200,200);
```

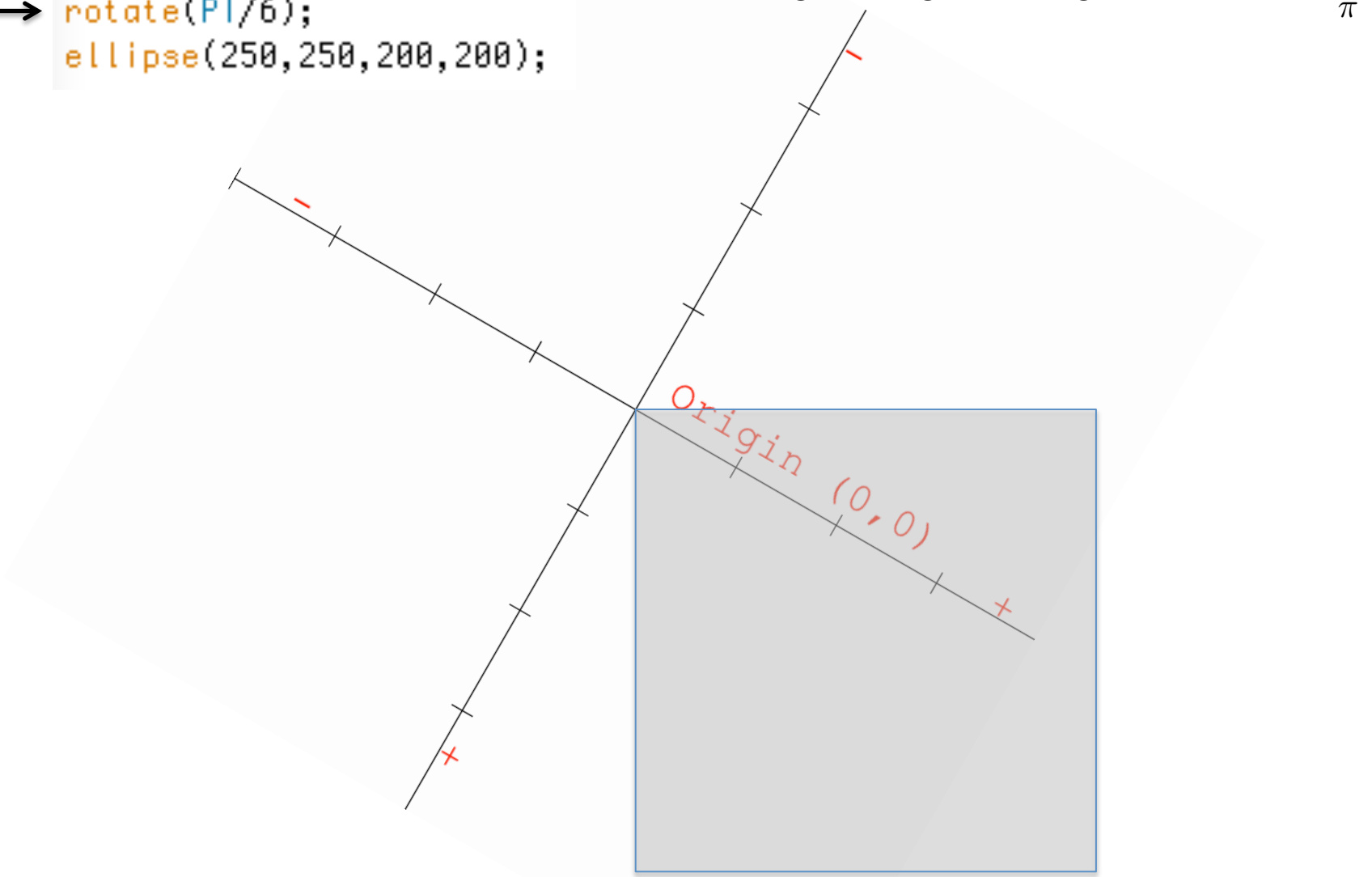
$$\text{angle in degrees} = \text{angle in radians} \times \frac{180}{\pi}$$



Rotate

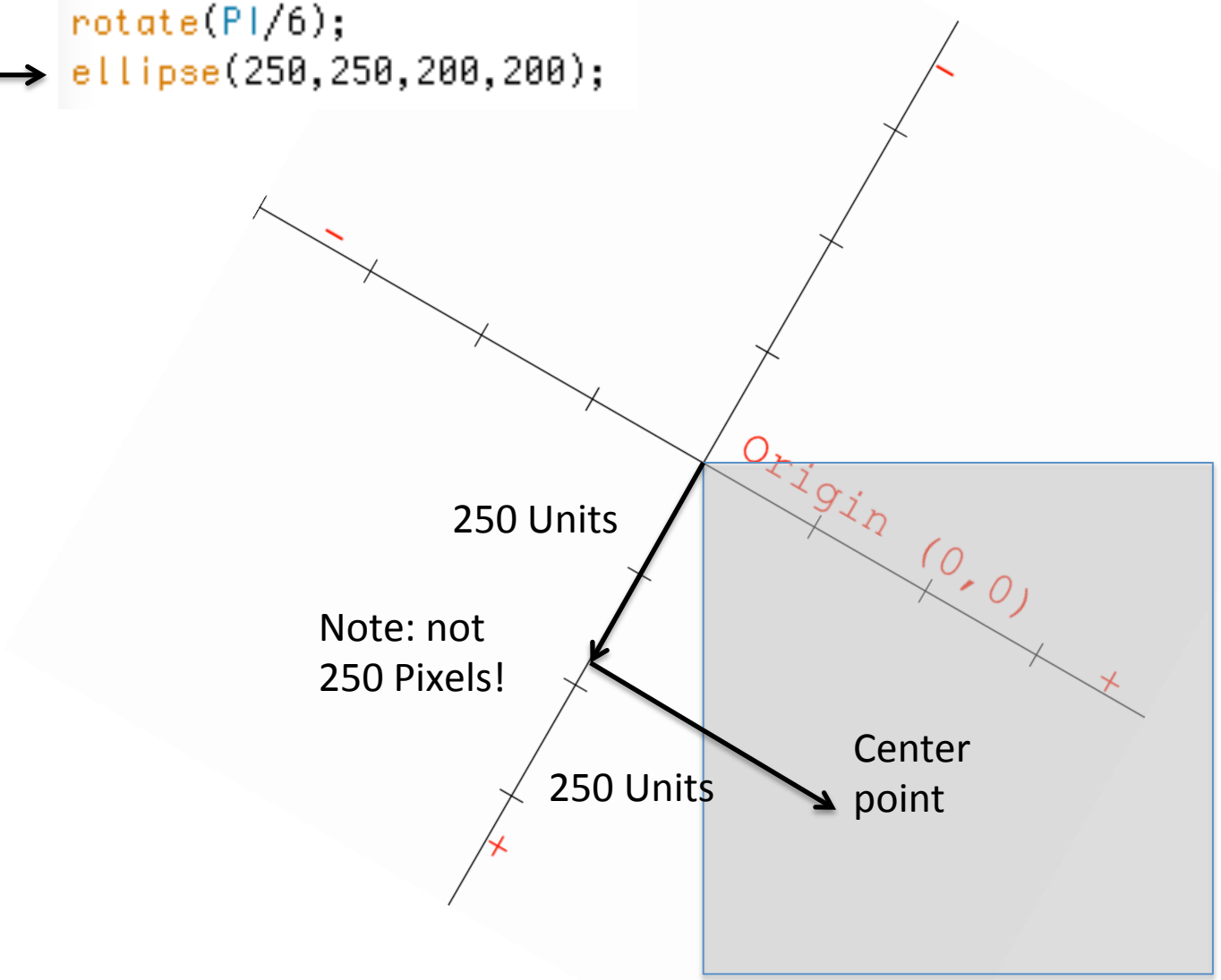
```
size(500,500);
rotate(PI/6);
ellipse(250,250,200,200);
```

$$\text{angle in degrees} = \text{angle in radians} \times \frac{180}{\pi}$$



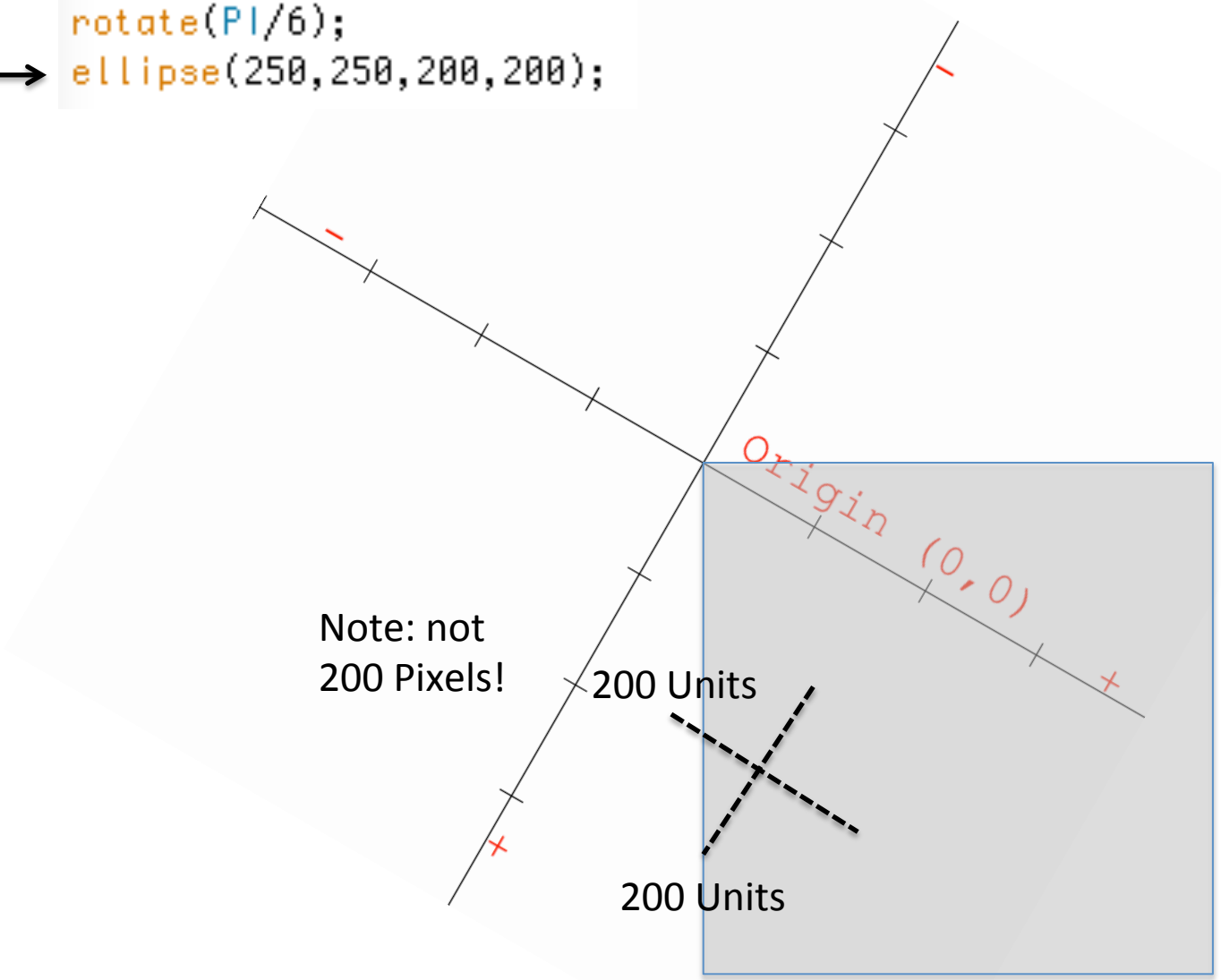
Rotate

```
size(500,500);
rotate(PI/6);
ellipse(250,250,200,200);
```



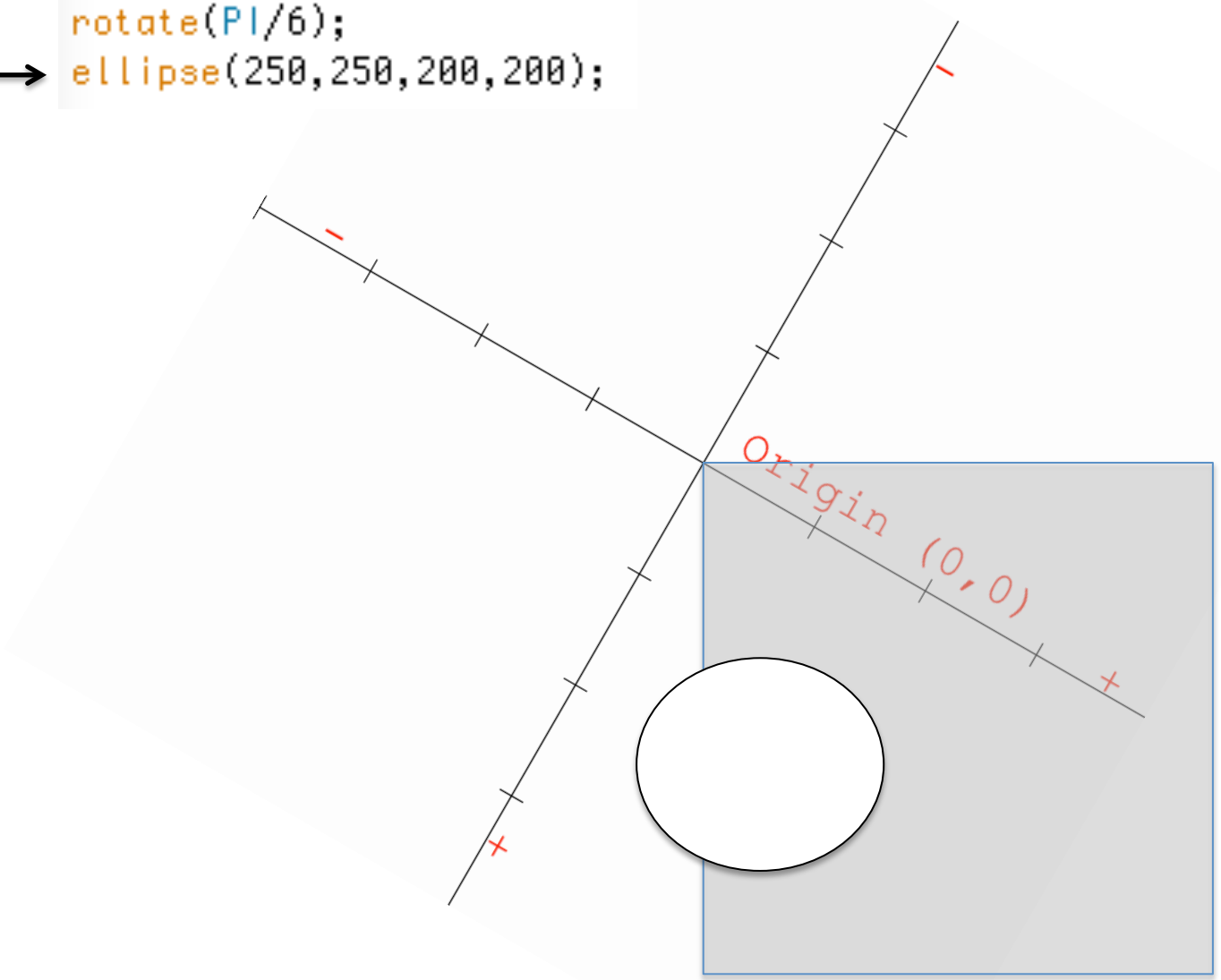
Rotate

```
size(500,500);
rotate(PI/6);
ellipse(250,250,200,200);
```



Rotate

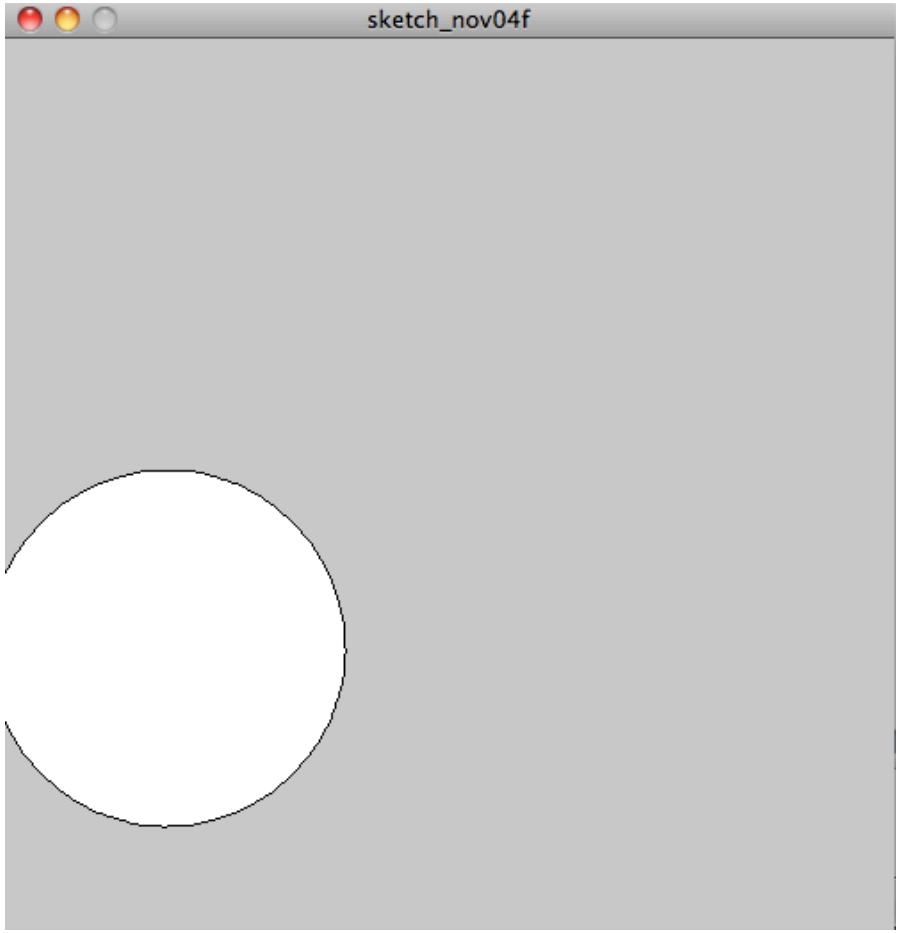
```
size(500,500);
rotate(PI/6);
ellipse(250,250,200,200);
```



Scale

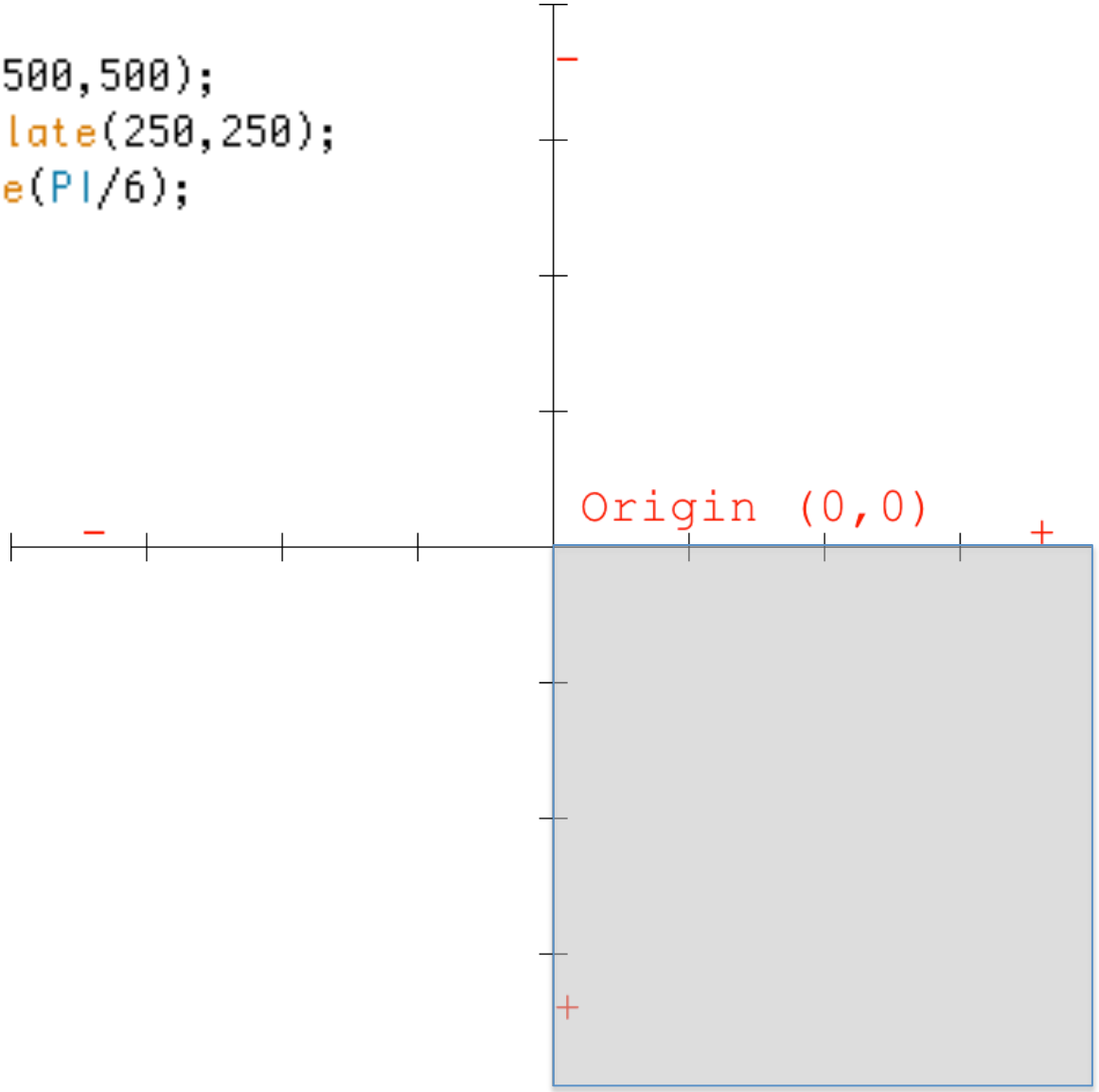
```
size(500,500);
rotate(PI/6);
ellipse(250,250,200,200);
```

Once we have computed the shape in the coordinate system, all we do is transfer it to the main window!



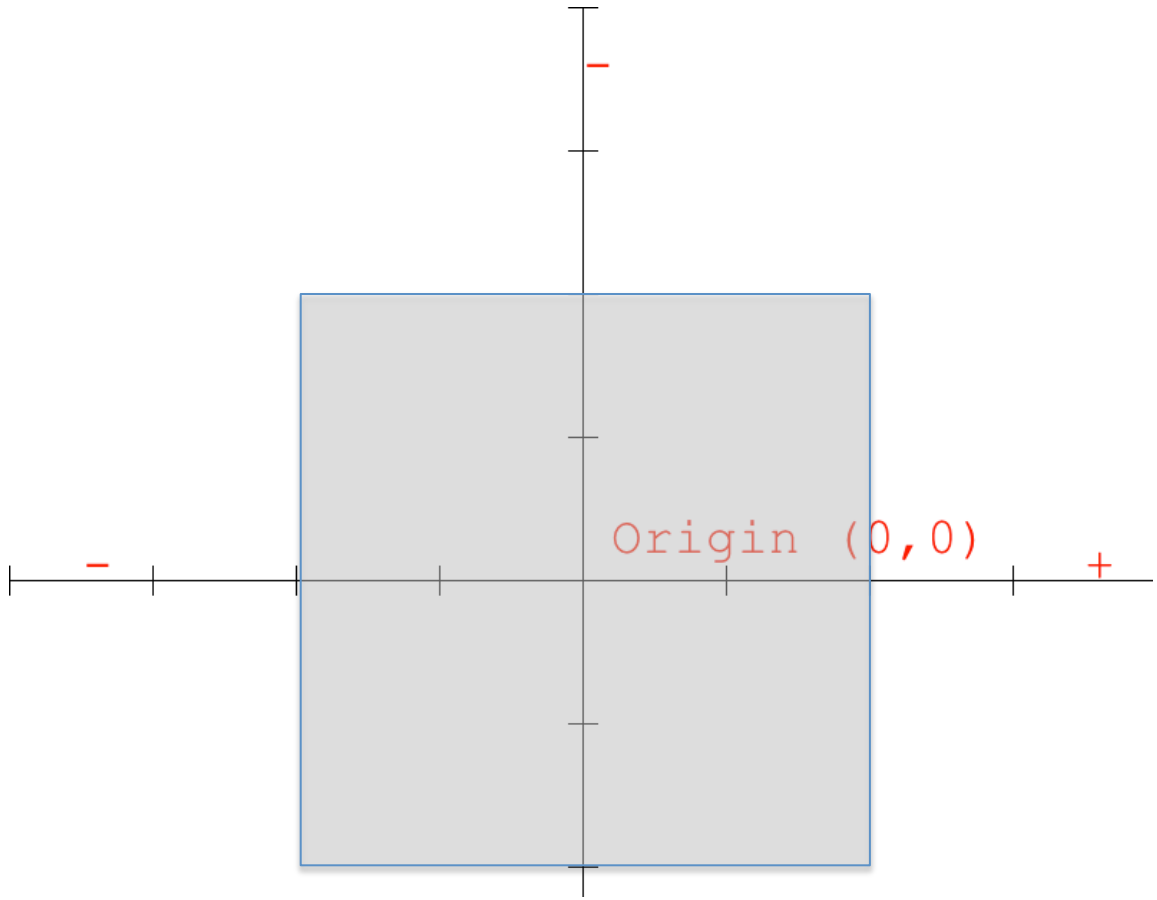
Combining Transformations

```
size(500,500);
translate(250,250);
rotate(PI/6);
```



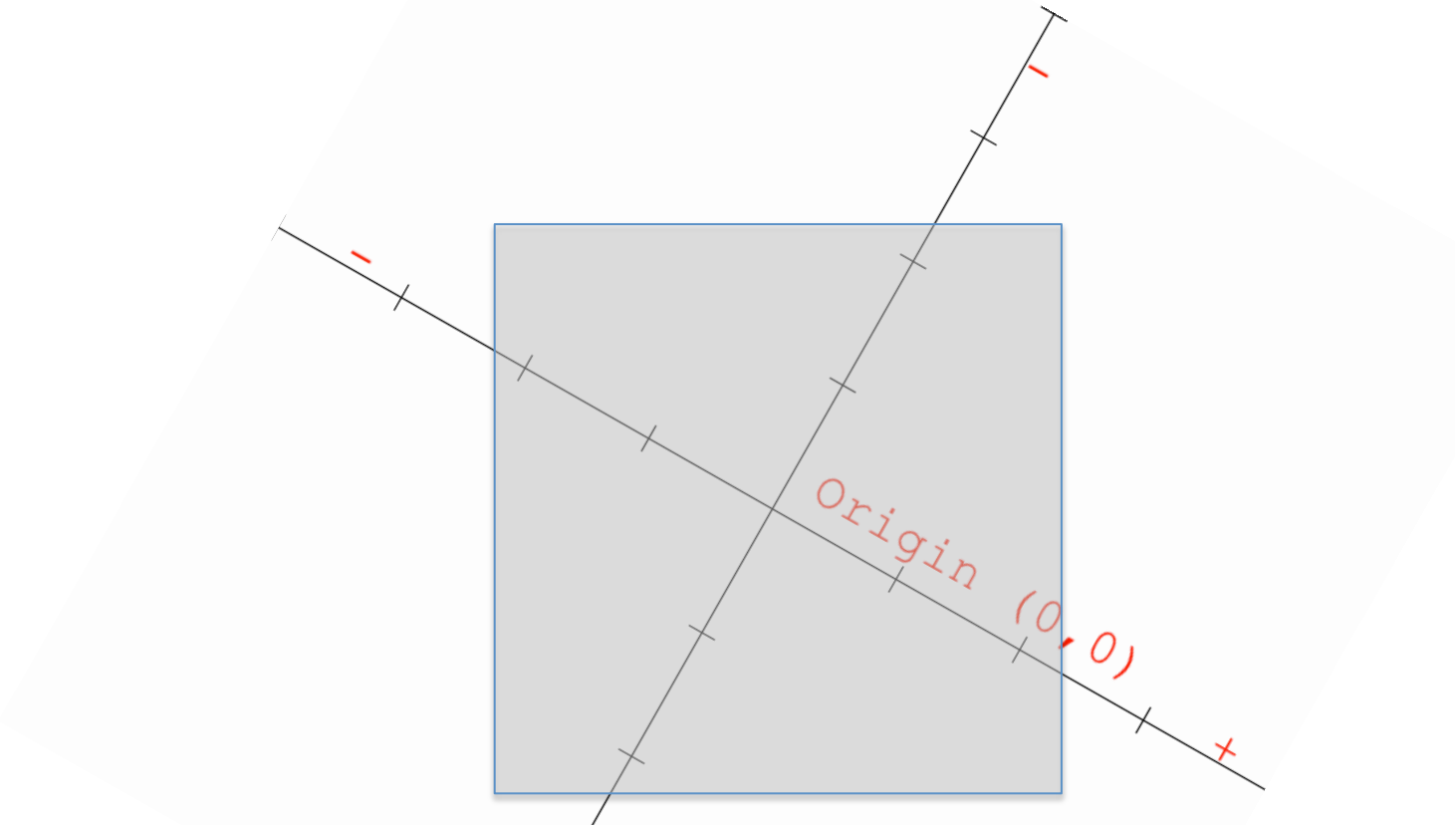
Combining Transformations

```
size(500,500);
translate(250,250);
rotate(PI/6);
```



Combining Transformations

```
size(500,500);
translate(250,250);
rotate(PI/6);
```



Is this the same as the previous example?

```
size(500,500);
rotate(PI/6);
translate(250,250);
```

Transformations and the draw loop

- All transformations are reset each time the draw loop is called
- We will see another way to undo transformations in a few minutes

Ball With Eye Example Revisited

Ball With Eye Code

```
Ball[] balls = new Ball[10];

void setup() {
  size(500, 500);
  fill(255, 0, 0);
  smooth();
  ellipseMode(CENTER);

  // Create all new Ball objects
  for (int i = 0; i < balls.length; i++) {
    balls[i] = new Ball();
  }
}

void draw() {
  background(255);
  for (int i = 0; i < balls.length; i++) {
    balls[i].update();
    balls[i].display();
  }
}
```

Ball With Eye Code

```
void display() {
  fill(c);
  translate(sx, sy);
  if (vx < 0) {
    scale(-1, 1);
  }

  // draw the body of the ball
  ellipse(0, 0, d, d);

  // drawing code cut for brevity

  if (vx < 0) {
    scale(-1, 1);
  }
  translate(-sx,-sy);
}
```

```
class Ball {
  // Fields
  float ay = 0.2;      // y acceleration (gravity)
  float sx;    // x position
  float sy;    // y position
  float vx;    // x velocity
  float vy;    // y velocity
  float d;
  color c;
}
```

pushMatrix() and popMatrix()

Undoing transformations manually is annoying

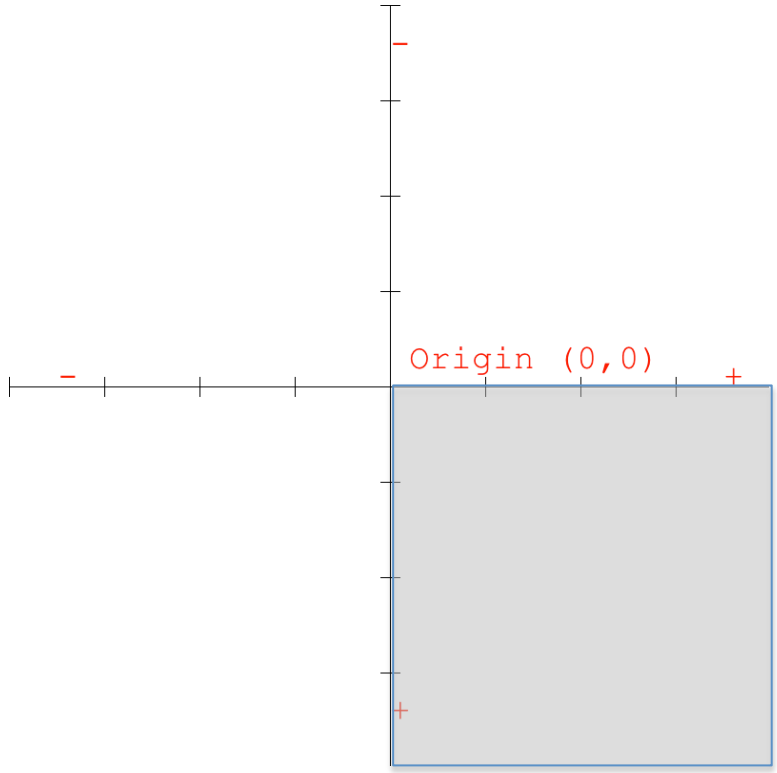
Alternative:

pushMatrix(): save the current coordinate system

popMatrix(): revert to the most recently saved coordinate system

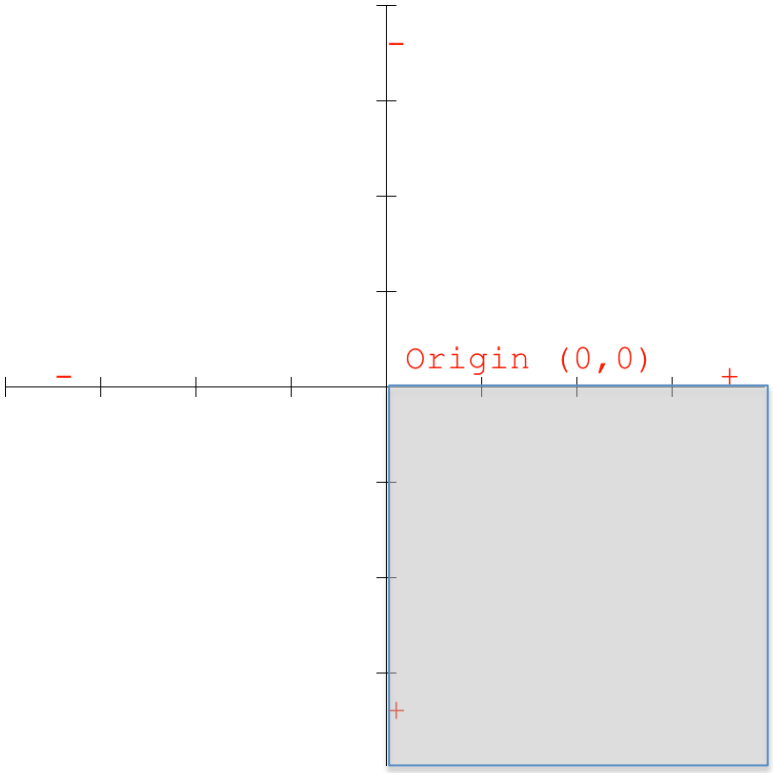
Push and Pop Matrix Example

```
size(500,500);
pushMatrix();
translate(250,250);
pushMatrix();
rotate(PI/6);
popMatrix();
popMatrix();
```

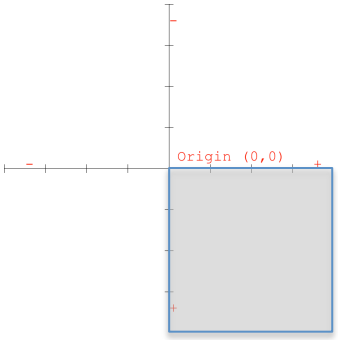


Push and Pop Matrix Example

```
size(500,500);
pushMatrix();
translate(250,250);
pushMatrix();
rotate(PI/6);
popMatrix();
popMatrix();
```

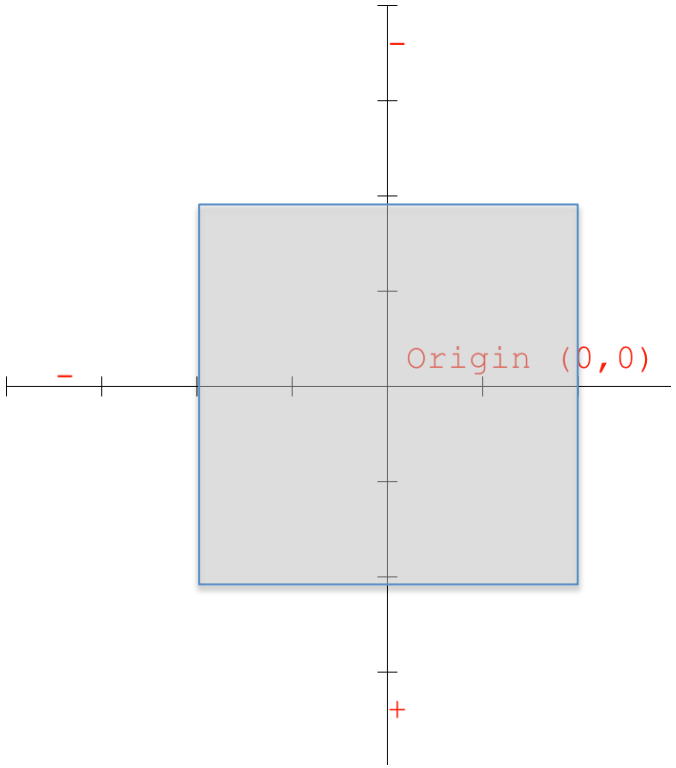


Saved Coordinate Systems:

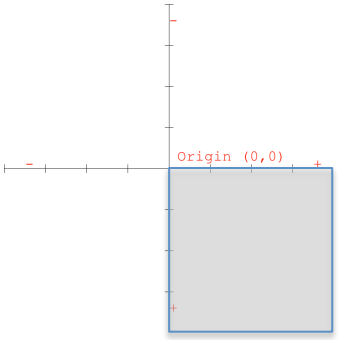


Push and Pop Matrix Example

```
size(500,500);
pushMatrix();
translate(250,250);
pushMatrix();
rotate(PI/6);
popMatrix();
popMatrix();
```

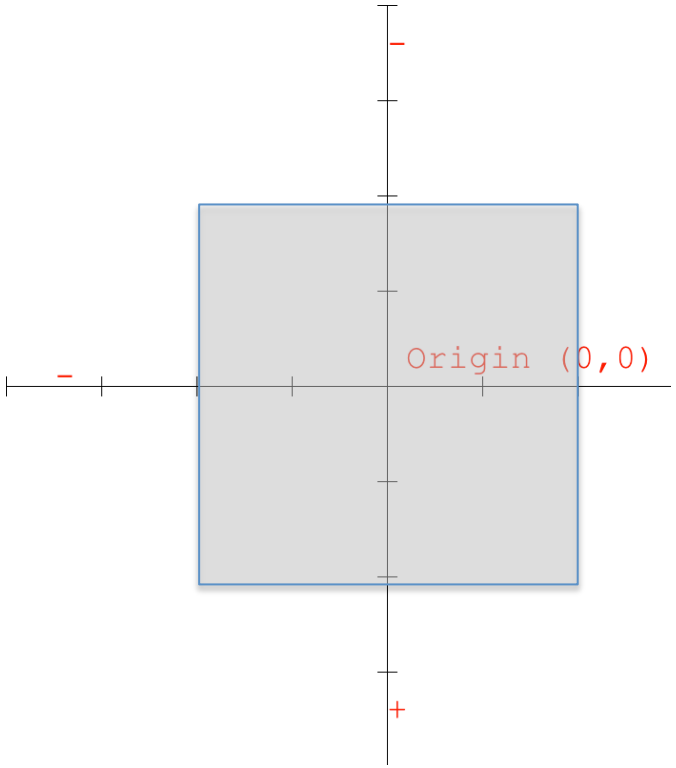


Saved Coordinate Systems:

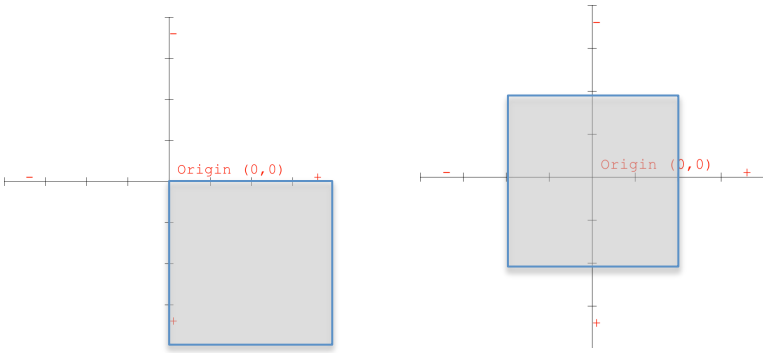


Push and Pop Matrix Example

```
size(500,500);
pushMatrix();
translate(250,250);
pushMatrix();
rotate(PI/6);
popMatrix();
popMatrix();
```

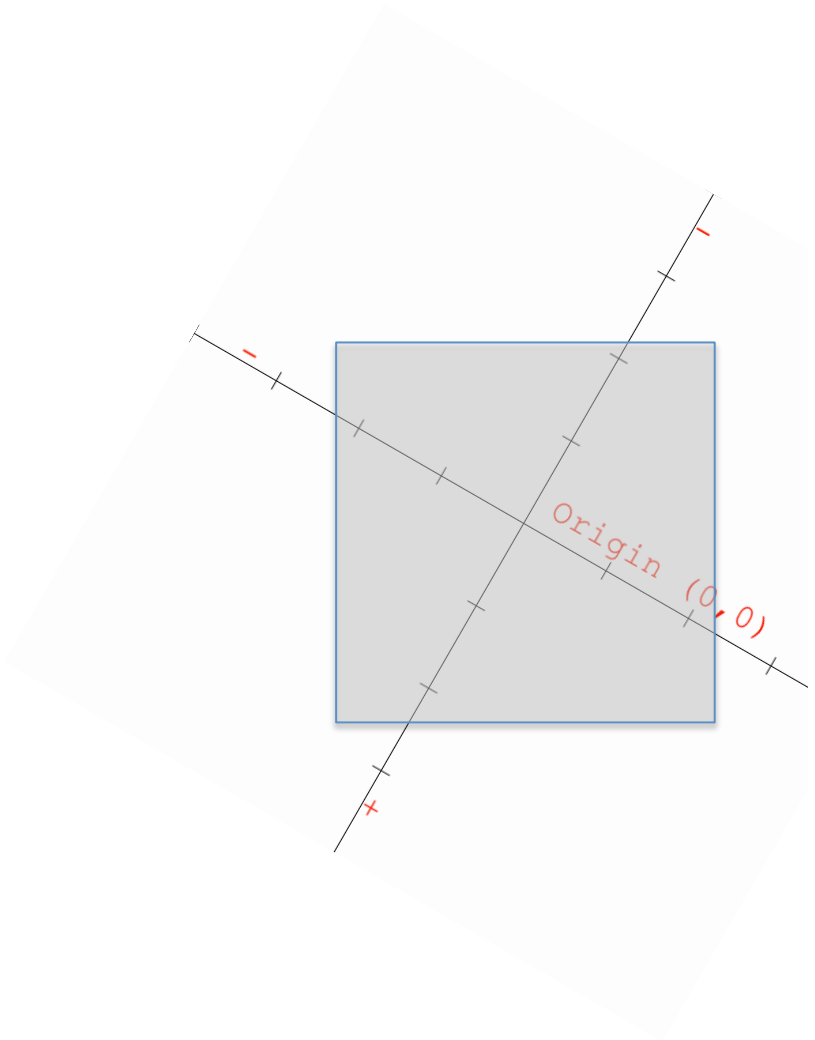


Saved Coordinate Systems:

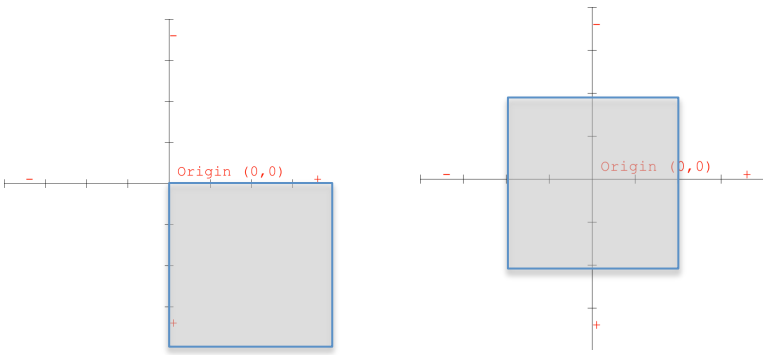


Push and Pop Matrix Example

```
size(500,500);
pushMatrix();
translate(250,250);
pushMatrix();
rotate(PI/6);
popMatrix();
popMatrix();
```

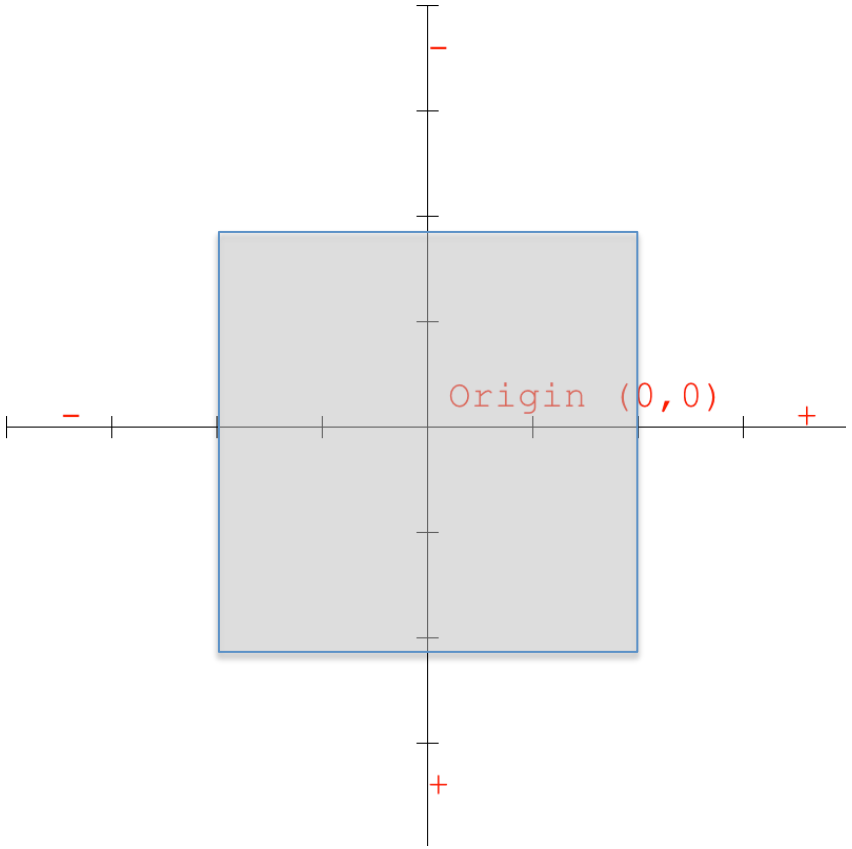


Saved Coordinate Systems:

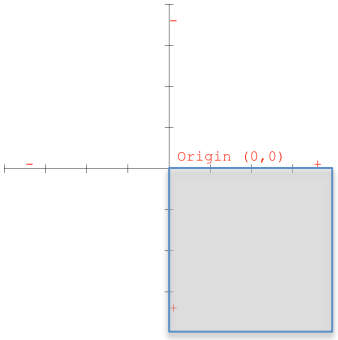


Push and Pop Matrix Example

```
size(500,500);
pushMatrix();
translate(250,250);
pushMatrix();
rotate(PI/6);
popMatrix();
popMatrix();
```

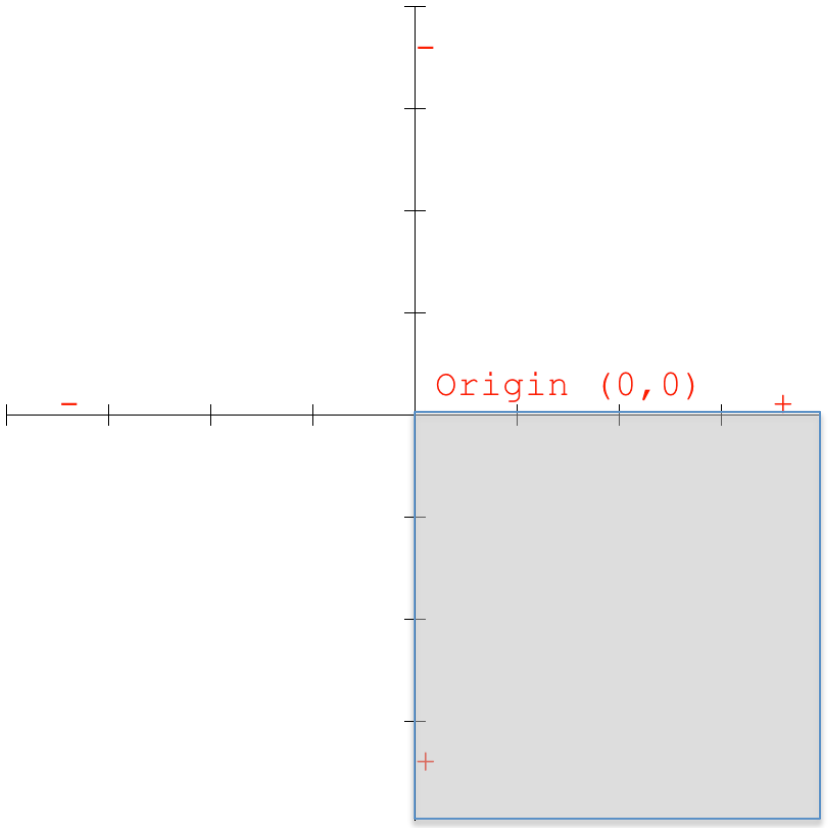


Saved Coordinate Systems:



Push and Pop Matrix Example

```
size(500,500);
pushMatrix();
translate(250,250);
pushMatrix();
rotate(PI/6);
popMatrix();
popMatrix();
```



Saved Coordinate Systems:

Advertisement the Next Computer Science Course: Data Structures

- Data structures is all about how to organize data in the computer in order to perform interesting computation
- The data structure we store the coordinate systems is called a stack

Last in first out structure
Always take the top plate
(unless you are a magician)

Advertisement Part 2

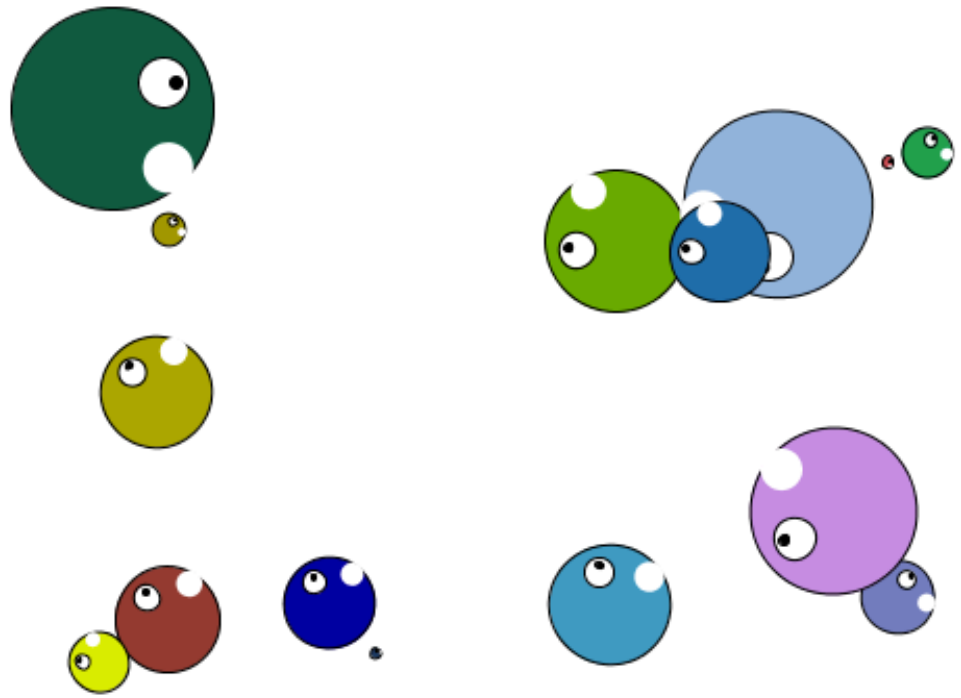
Where does the matrix part come in?!?!?

How Can We Modify The Ball Code?

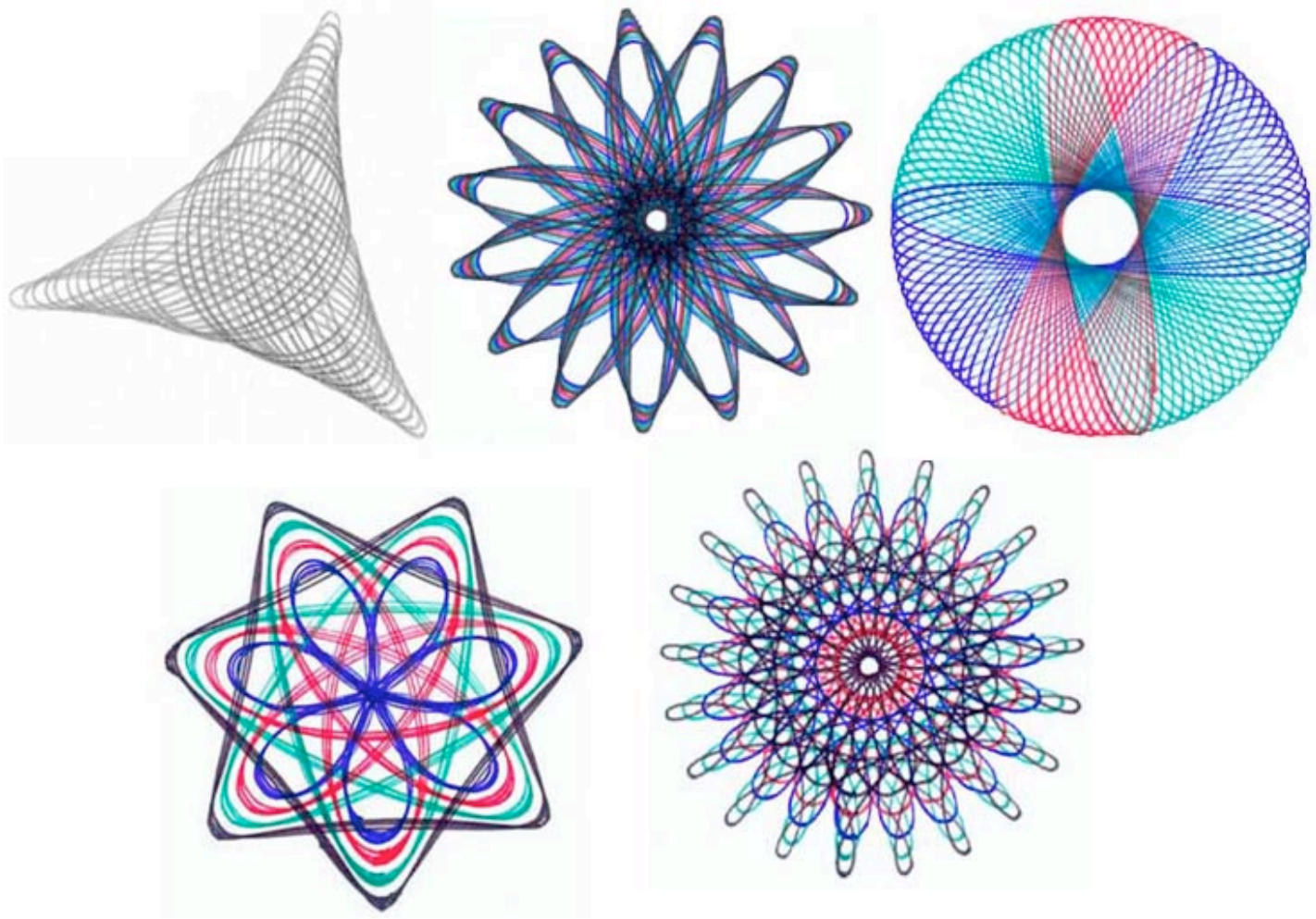
```
void display() {
  fill(c);
  translate(sx, sy);
  if (vx < 0) {
    scale(-1, 1);
  }

  // draw the body of the ball
  ellipse(0, 0, d, d);

  // drawing code cut for brevity

  if (vx < 0) {
    scale(-1, 1);
  }
  translate(-sx,-sy);
}
```

```
class Ball {
  // Fields
  float ay = 0.2;      // y acceleration (gravity)
  float sx;    // x position
  float sy;    // y position
  float vx;    // x velocity
  float vy;    // y velocity
  float d;
  color c;
}
```

Rotating Ball Example

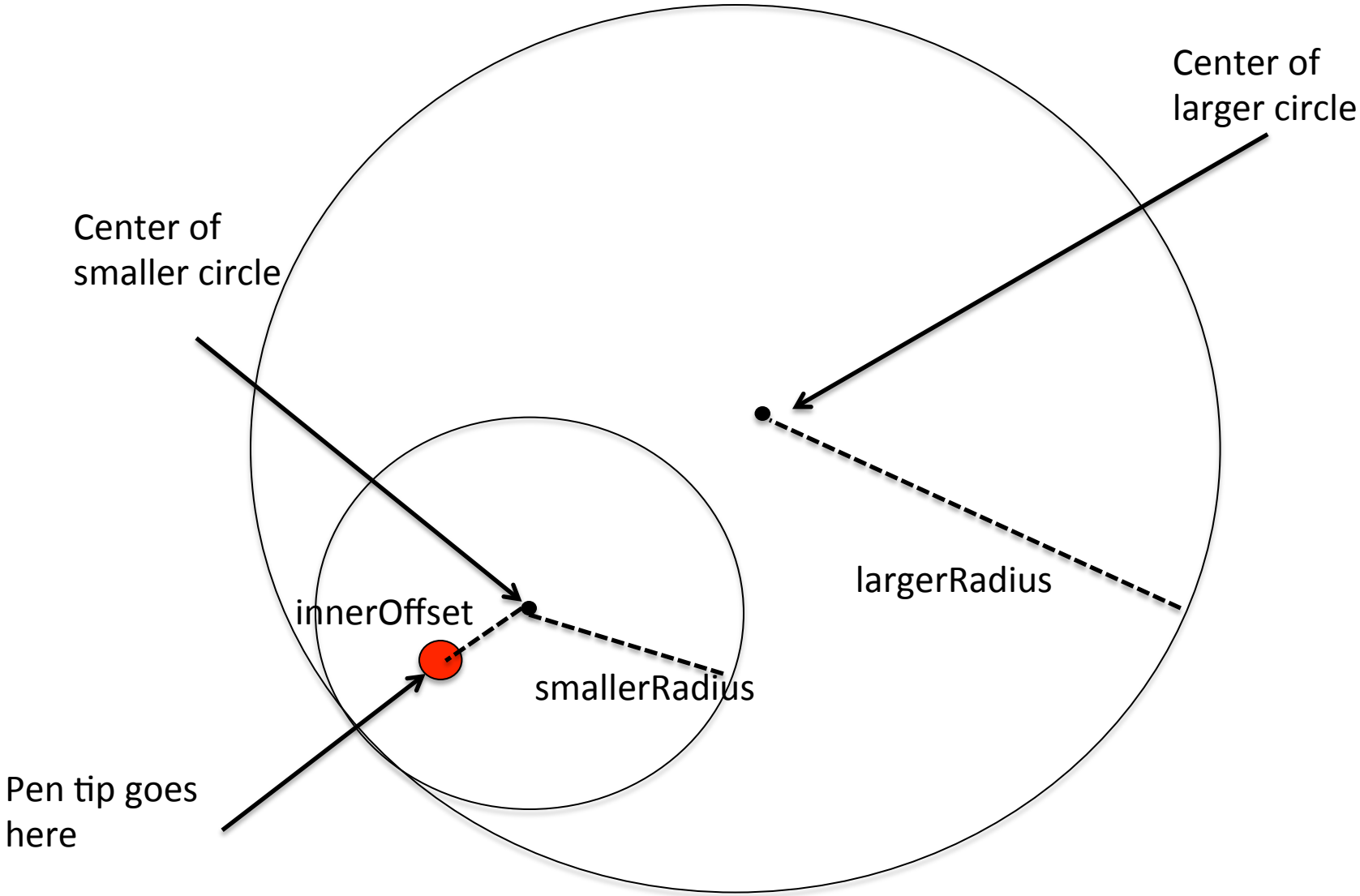


Spirograph

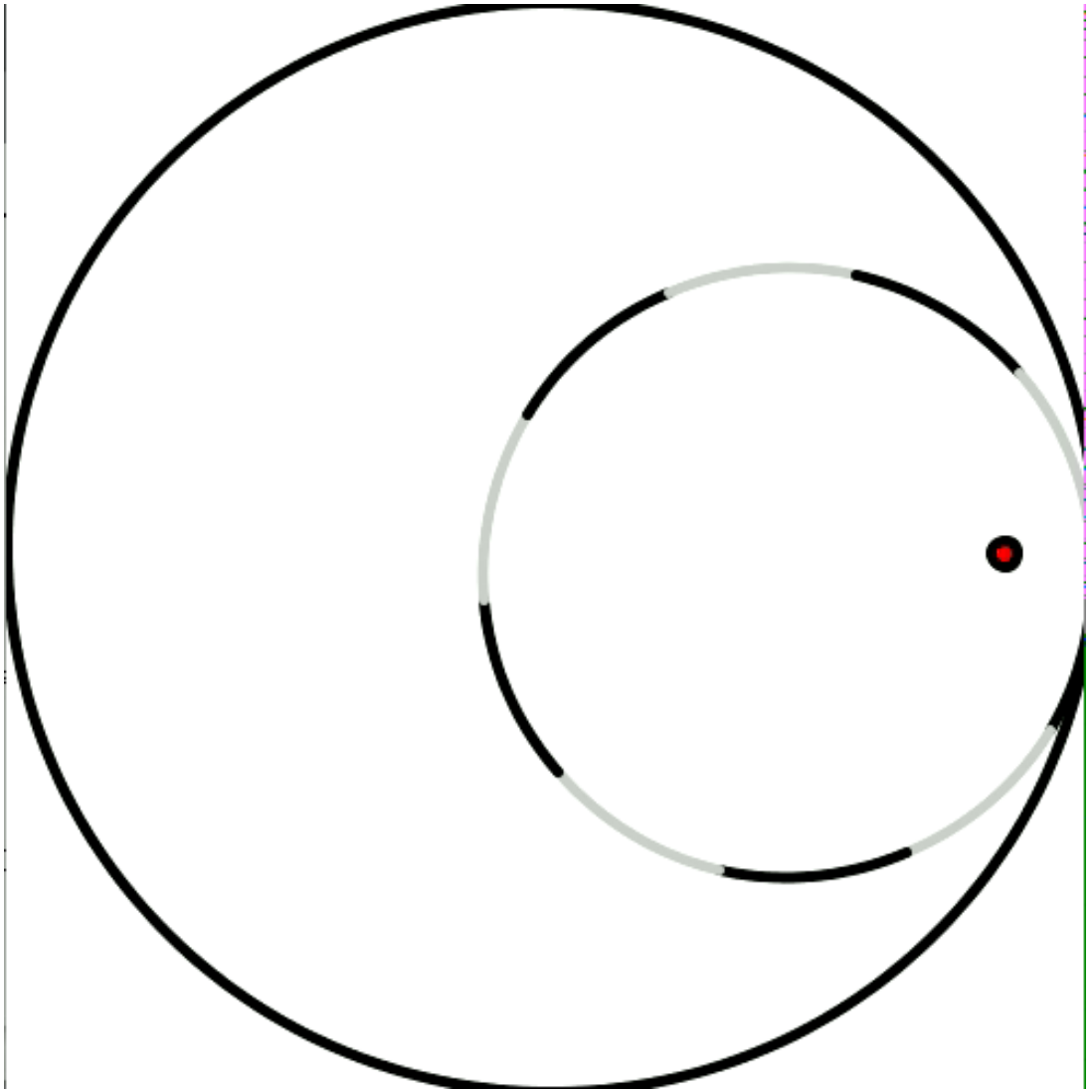


http://www.youtube.com/watch?v=LbvmKzf_wr4

Spirograph Mechanism



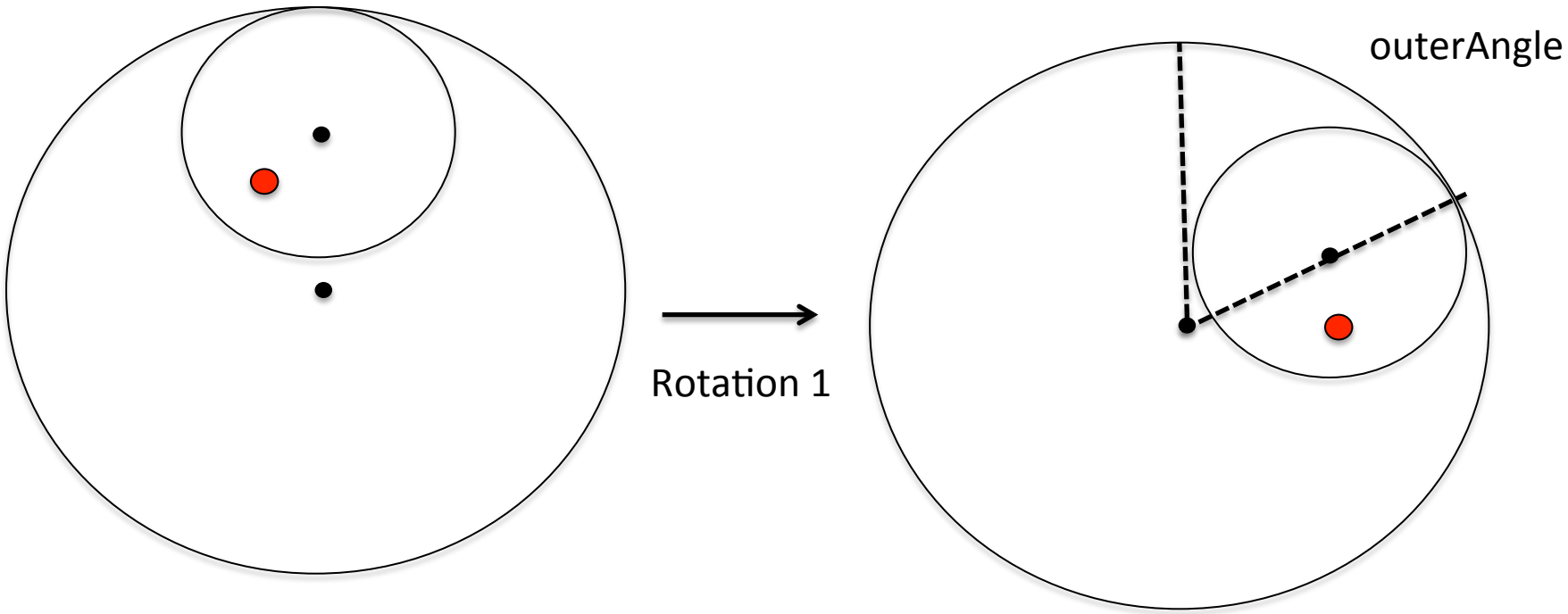
Spirograph Example



Spirograph Motion

The motion of the pen-tip can be decomposed into two rotations

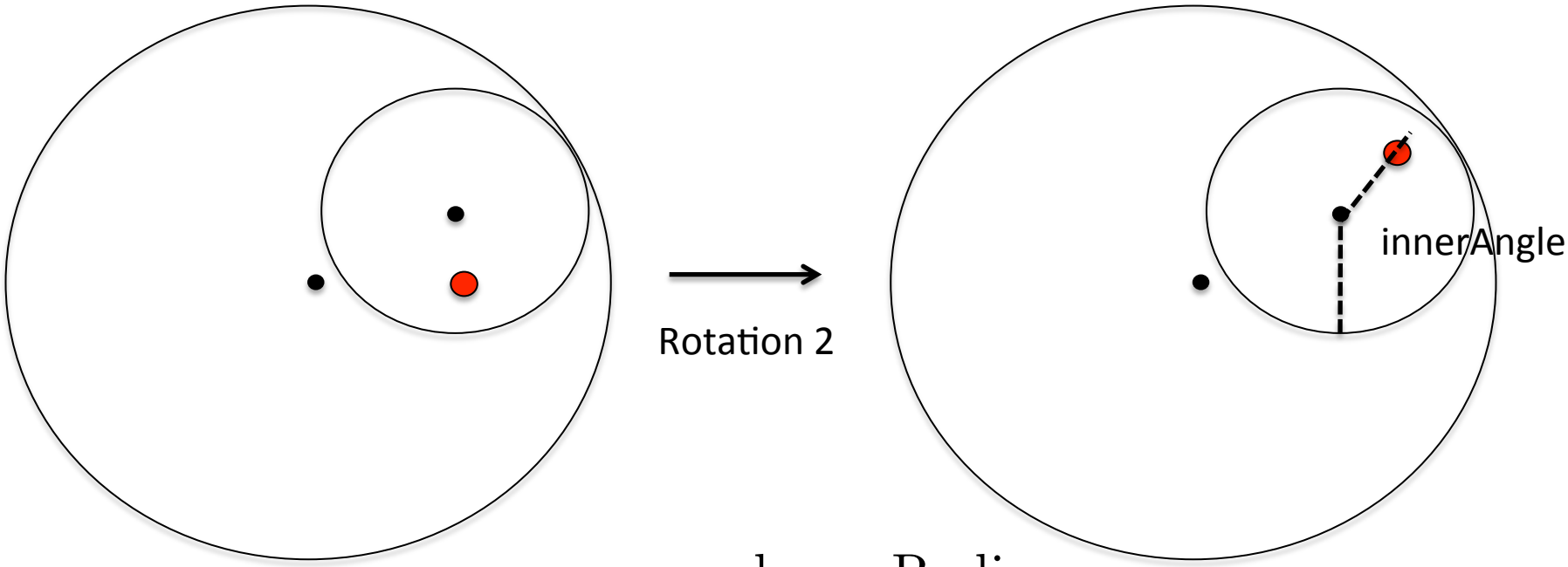
Rotation 1: rotation around the center of the larger circle



Spirograph Motion

The motion of the pen-tip can be decomposed into two rotations

Rotation 2: rotation around the center of smaller



$$\text{innerAngle} = -\text{outeAngler} \times \frac{\text{largerRadius}}{\text{smallerRadius}}$$

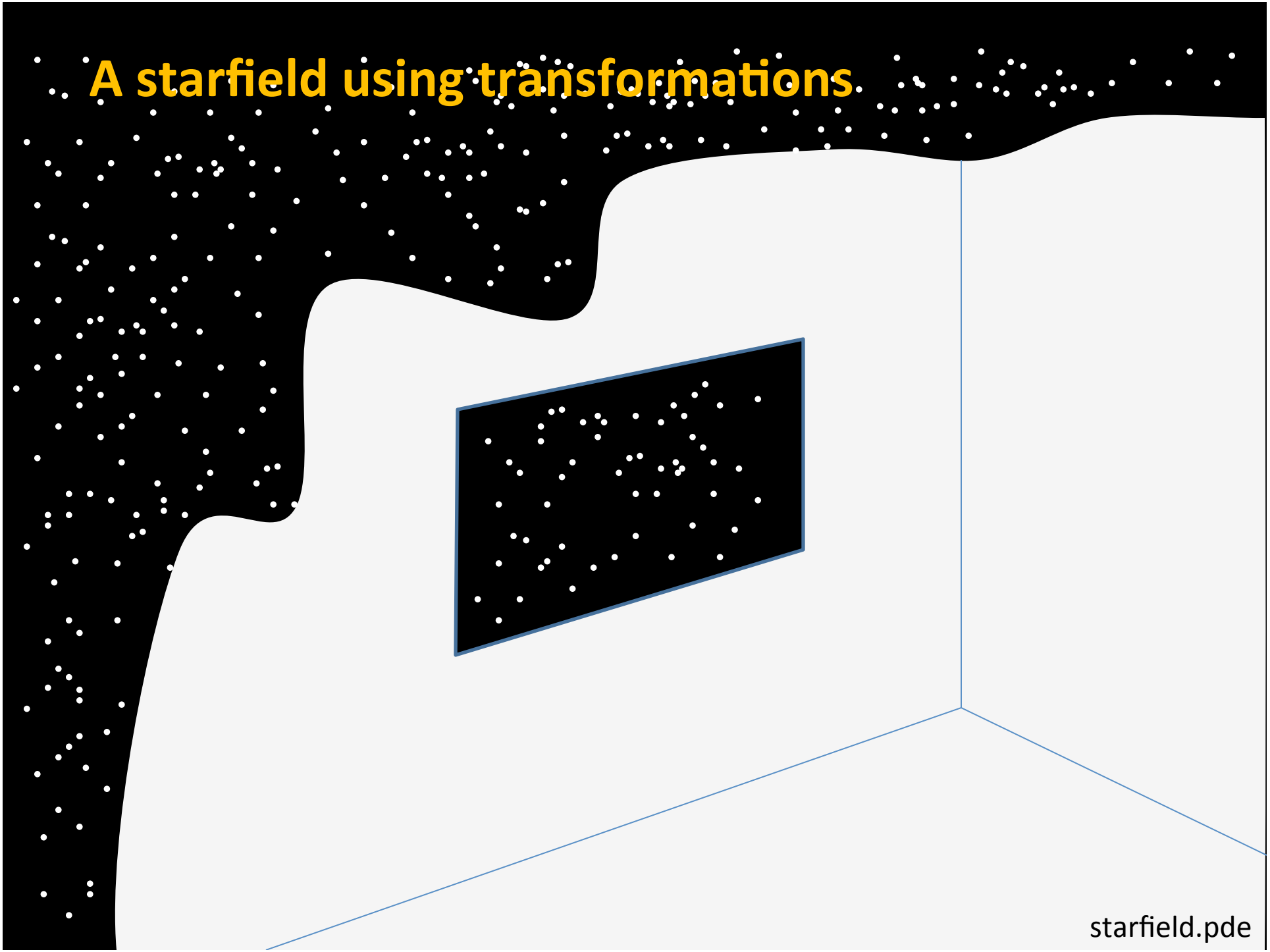
Spirograph Code Starter

```
float smallerRadius;
float largerRadius;
float innerOffset = 100;
float outerAngle = 0;
float dOuterAngle = .01;
float innerAngle = 0;
color penColor = color(255, 0, 0);

void setup() {
  size(500, 500);
  smooth();
  background(255);
  largerRadius = width/2.0;
  smallerRadius = width*7.0/25.0;
  frameRate(1000);
}

void mouseClicked() {
  // choose a new random pen color, inner circle size, and inner offset
  penColor = color(random(0, 255), random(0, 255), random(0, 255));
  smallerRadius = random(0, largerRadius);
  innerOffset = random(0, smallerRadius);
}
```

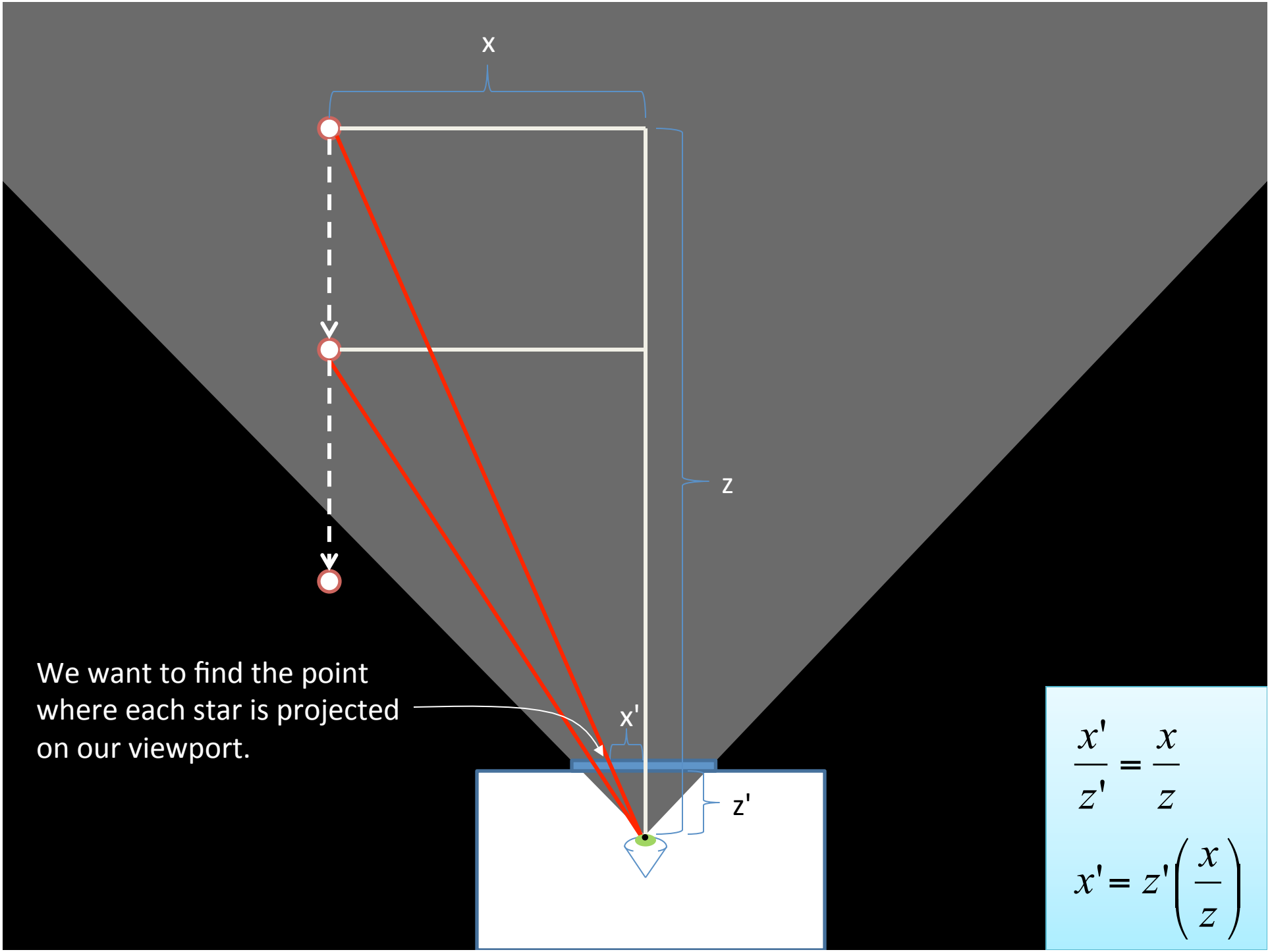
Example: Rotated Polygons

```
void setup() {
  size(600, 600);
  smooth();
  noFill();
  translate(width/2,height/2);
  float numPentagons = 250;
  for (int i=0; i<numPentagons; i++) {
    rotate(random(0,PI/4));
    stroke(50-i, 50+i, 150+i, i);
    pentagon(numPentagons-i);
  }
}

void pentagon(float r) {
  beginShape();
  for (float theta=0; theta<TWO_PI; theta += TWO_PI/5) {
    vertex(cos(theta)*r, sin(theta)*r);
  }
  endShape(CLOSE);
}
```

A starfield using transformations



starfield.pde


x
z
We want to find the point
where each star is projected
on our viewport.
x'
z'
$\frac{x'}{z'} = \frac{x}{z}$
$x' = z'\left(\frac{x}{z}\right)$

```
class Star {
  // Star coordinates in 3D
  float x;
  float y;
  float z;

  Star() {
    x = random(-5000, 5000);
    y = random(-5000, 5000);
    z = random(0, 2000);
  }

  void update() {
    // Move star closer to viewport
    z-=10;

    // Reset star if it passes viewport
    if (z <= 0.0)
      reset();
  }

…
```

```
  void reset() {
     // Reset star to a position far away
     x = random(-5000, 5000);
     y = random(-5000, 5000);
     z = 2000.0;
   }

   void draw() {
     // Project star only viewport
     float offsetX = 100.0*(x/z);
     float offsetY = 100.0*(y/z);
     float scaleZ = 0.0001*(2000.0-z);

     // Draw this star
     pushMatrix();
     translate(offsetX, offsetY);
     scale(scaleZ);
     ellipse(0,0,20,20);
     popMatrix();
   }
}
```

```
// starfield

// Array of stars
Star[] stars = new Star[400];

void setup() {
  size(600, 600);
  smooth();
  stroke(255);
  strokeWeight(5);
  rectMode(CENTER);

  // Init all stars
  for (int i=0; i<stars.length; i++)
    stars[i] = new Star();
}

void draw() {
  background(0);

  // Draw all stars wrt center of screen
  translate(0.5*width, 0.5*height);

  // Update and draw all stars
  for (int i=0; i<stars.length; i++) {
    stars[i].update();
    stars[i].draw();
  }
}
```