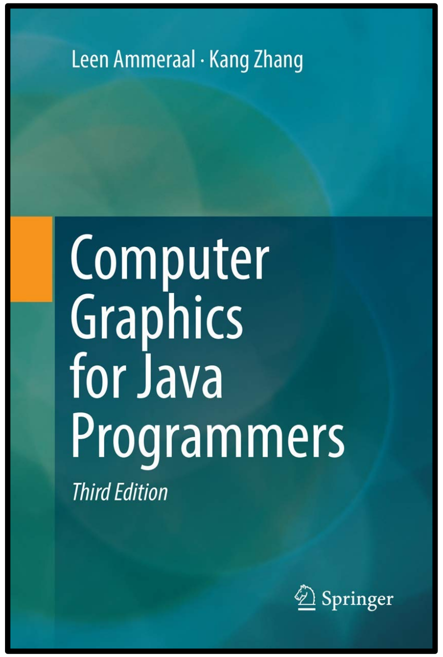
Computer Graphics
in Java and Scala

Part 1b

first see the **Scala** program translated into **Java**

then see the **Scala** program modified to produce a **more intricate drawing**



Leen Ammeraal · Kang Zhang

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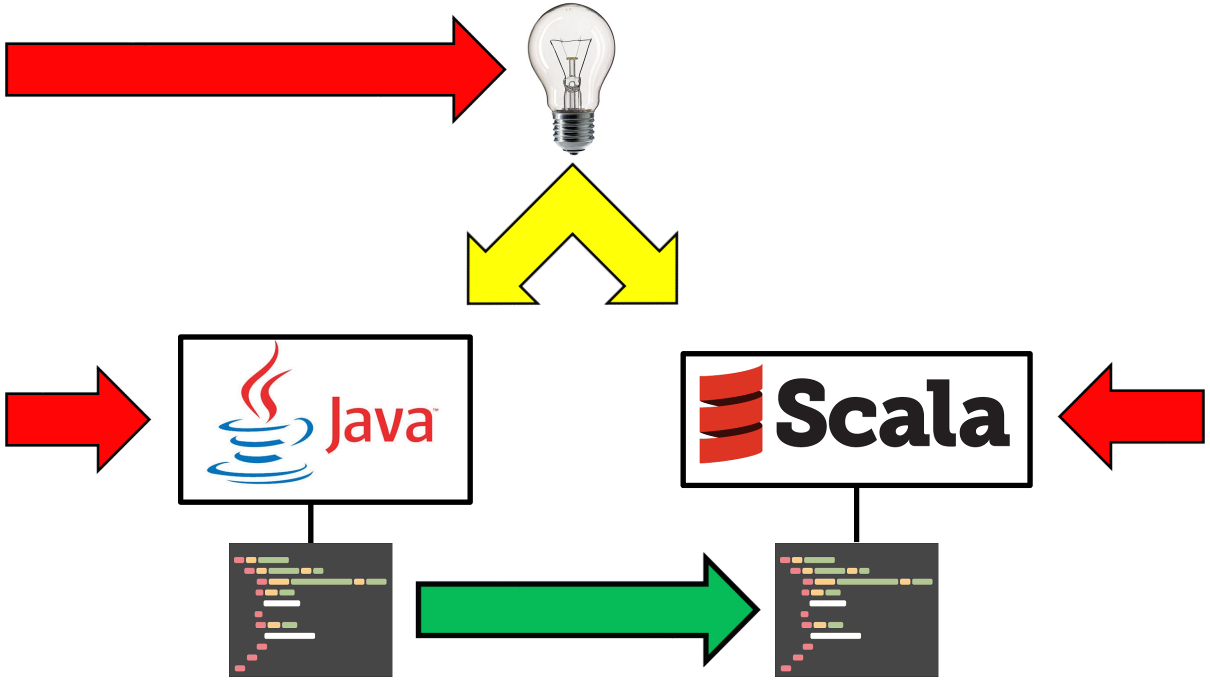
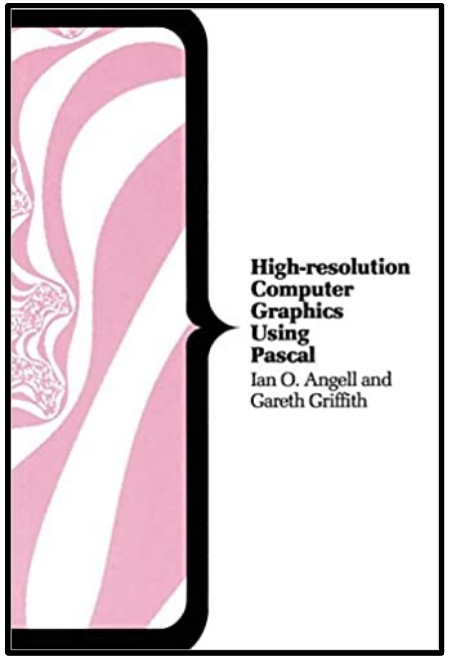




High-resolution Computer Graphics Using Pascal

Ian O. Angell and Gareth Griffith

slides by @philip_schwarz slideshare https://www.slideshare.net/pjschwarz

In this slide deck, which is an addendum to **Part 1**, we are going to do the following:

- Translate the **Scala** program from **Part 1** into **Java**
- Modify the **Scala** program so that rather than drawing **50** concentric **triangles**, it draws a **chessboard-like grid** in which each **cell** consists of **10** concentric **squares**.
- Eliminate an unsatisfactory feature of the above drawing by changing the **angle** by which **squares** are **twisted**, plus **improve** the drawing by **increasing** the **number** of **squares** drawn.

Let’s start translating the Scala program into Java.

@philip_schwarz

```scala
case class Point(x: Float, y: Float)
```

```scala
case class Triangle(a: Point, b: Point, c: Point)
```

```scala
object Triangle:

  def apply(centre:Point,side:Float,height:Float): Triangle =
    val Point(x,y) = centre
    val halfSide = 0.5F * side
    val bottomLeft = Point(x - halfSide, y - 0.5F * height)
    val bottomRight = Point(x + halfSide, y - 0.5F * height)
    val top = Point(x, y + 0.5F * height )
    Triangle(bottomLeft,bottomRight,top)
```

```java
public record Point(Float x, Float y) { }
```

```java
public record Triangle(Point a, Point b, Point c) {

  static Triangle instance(Point centre,Float side,Float height) {
    float x = centre.x(), y = centre.y();
    var halfSide = 0.5F * side;
    var bottomLeft = new Point(x - halfSide, y - 0.5F * height);
    var bottomRight = new Point(x + halfSide, y - 0.5F * height);
    var top = new Point(x, y + 0.5F * height);
    return new Triangle(bottomLeft,bottomRight,top);
  }
}
```

```scala
LazyList
   .iterate(triangle)(shrinkAndTwist)
   .take(50)
   .foreach(draw)
```

```java
Stream
   .iterate(triangle, this::shrinkAndTwist)
   .limit(50)
   .forEach(t -> draw(g, t, panelHeight));
```

```scala
class TrianglesPanel extends JPanel:

  setBackground(Color.white)

  override def paintComponent(g: Graphics): Unit =

    super.paintComponent(g)

    val panelSize: Dimension = getSize()
    val panelWidth = panelSize.width - 1
    val panelHeight = panelSize.height - 1
    val panelCentre = Point(panelWidth / 2, panelHeight / 2)
    val triangleSide = 0.95F * Math.min(panelWidth, panelHeight)
    val triangleHeight = (0.5F * triangleSide) * Math.sqrt(3).toFloat

    …<shrinkAndTwist, draw and drawLine functions>…

    val triangle = Triangle(panelCentre,
                            triangleSide,
                            triangleHeight)

    LazyList
      .iterate(triangle)(shrinkAndTwist)
      .take(50)
      .foreach(draw)
```

```java
public class TrianglesPanel extends JPanel {

  public TrianglesPanel() {
    setBackground(Color.white);
  }

  public void paintComponent(Graphics g){

    super.paintComponent(g);

    Dimension panelSize = getSize();
    int panelWidth = panelSize.width - 1;
    int panelHeight = panelSize.height - 1;
    var panelCentre = new Point(panelWidth / 2F, panelHeight / 2F);
    var triangleSide = 0.95F * Math.min(panelWidth, panelHeight);
    var triangleHeight = (0.5F * triangleSide) * (float)Math.sqrt(3);

    var triangle = Triangle.instance(panelCentre,
                                     triangleSide,
                                     triangleHeight);

    Stream
      .iterate(triangle, this::shrinkAndTwist)
      .limit(50)
      .forEach(t -> draw(g, t, panelHeight));
  }

  …<shrinkAndTwist, draw and drawLine functions>…
}
```

```scala
val shrinkAndTwist: Triangle => Triangle =
  val q = 0.05F
  val p = 1 - q
  def combine(a: Point, b: Point) =
    Point(p * a.x + q * b.x, p * a.y + q * b.y)
  { case Triangle(a,b,c) =>
      Triangle(combine(a,b), combine(b,c), combine(c,a)) }
```

```scala
val draw: Triangle => Unit =
  case Triangle(a, b, c) =>
    drawLine(a, b)
    drawLine(b, c)
    drawLine(c, a)
```

```scala
def drawLine(a: Point, b: Point): Unit =
  val (ax,ay) = a.deviceCoords(panelHeight)
  val (bx,by) = b.deviceCoords(panelHeight)
  g.drawLine(ax, ay, bx, by)
```

```scala
extension (p: Point)
  def deviceCoords(panelHeight: Int): (Int, Int) =
    (Math.round(p.x), panelHeight - Math.round(p.y))
```

```java
Triangle shrinkAndTwist(Triangle t) {
  return new Triangle(
    combine(t.a(), t.b()),
    combine(t.b(), t.c()),
    combine(t.c(), t.a())
  );
}

Point combine(Point a, Point b) {
  var q = 0.05F;
  var p = 1 - q;
  return new Point(p * a.x() + q * b.x(), p * a.y() + q * b.y());
}
```

```java
void draw(Graphics g, Triangle t, int panelHeight) {
  drawLine(g, t.a(), t.b(), panelHeight);
  drawLine(g, t.b(), t.c(), panelHeight);
  drawLine(g, t.c(), t.a(), panelHeight);
}
```

```java
void drawLine(Graphics g, Point a, Point b, int panelHeight) {
  var aCoords = deviceCoords(a, panelHeight);
  var bCoords = deviceCoords(b, panelHeight);
  int ax = aCoords.x, ay = aCoords.y, bx = bCoords.x, by = bCoords.y;
  g.drawLine(ax, ay, bx, by);
}
```

```java
java.awt.Point deviceCoords(Point p, int panelHeight) {
  return new java.awt.Point(Math.round(p.x()), panelHeight - Math.round(p.y()));
}
```

```scala
@main def main: Unit =
  // Create a frame/panel on the event dispatching thread
  SwingUtilities.invokeLater(
    new Runnable():
      def run: Unit = Triangles()
  )
```

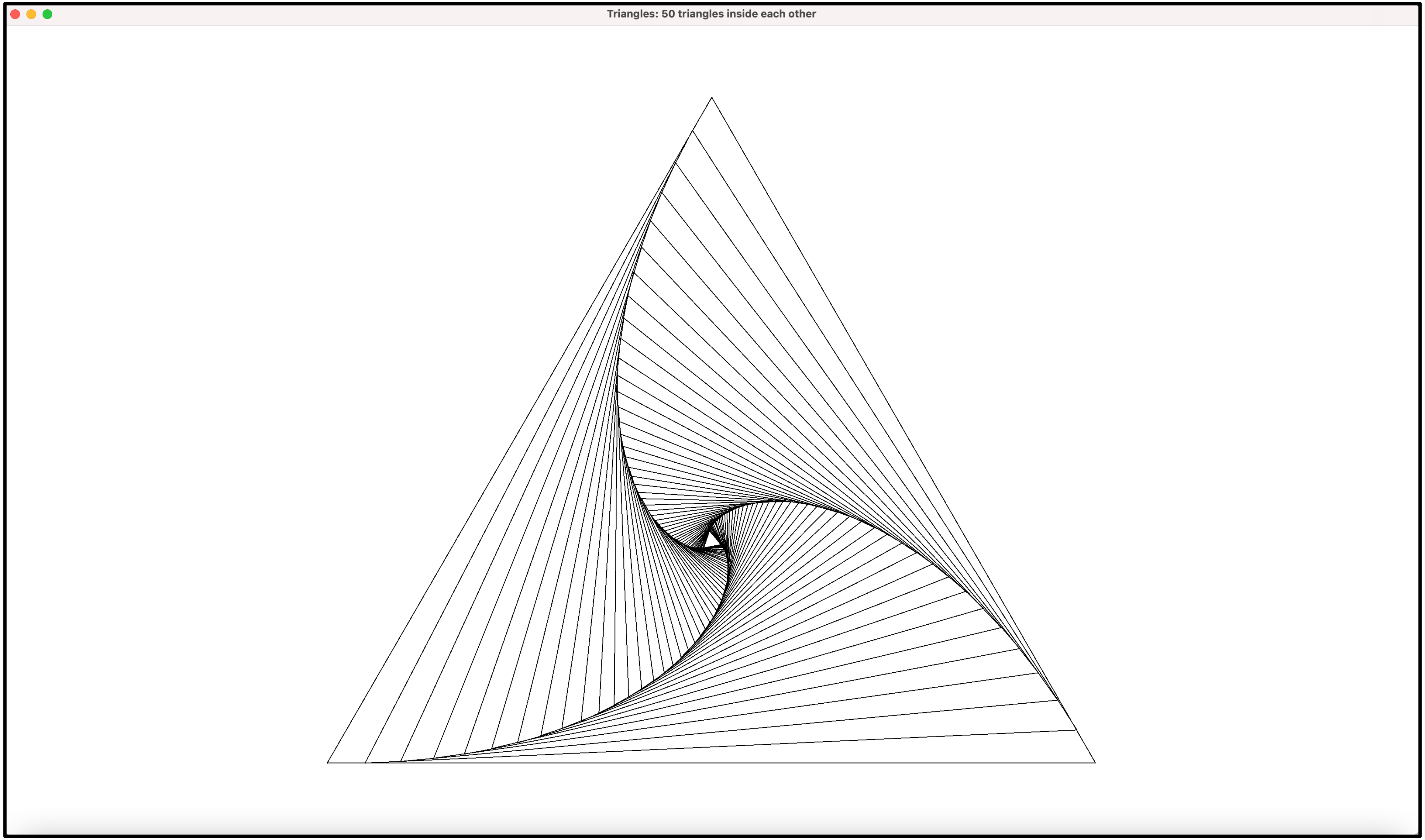
```scala
class Triangles:
  JFrame.setDefaultLookAndFeelDecorated(true)
  val frame =
    new JFrame("Triangles: 50 triangles inside each other")
  frame.setDefaultCloseOperation(WindowConstants.EXIT_ON_CLOSE)
  frame.setSize(600, 400)
  frame.add(TrianglesPanel())
  frame.setVisible(true)
```

```java
public class Triangles {

  public static void main(String[] args) {
    // Create a frame/panel on the event dispatching thread
    SwingUtilities.invokeLater(
      () -> new Triangles().drawTriangles()
    );
  }

  void drawTriangles() {
    JFrame.setDefaultLookAndFeelDecorated(true);
    var frame = new JFrame("Triangles: 50 triangles inside each other");
    frame.setDefaultCloseOperation(WindowConstants.EXIT_ON_CLOSE);
    frame.setSize(600, 400);
    frame.add(new TrianglesPanel());
    frame.setVisible(true);
  }
}
```

On the next slide we check that the **Java** program works as intended.



Triangles: 50 triangles inside each other

Now we turn to an exercise that sees us modify the **Scala** program so that rather than drawing **50** concentric **triangles**, it draws a **chessboard-like grid** in which each **cell** consists of **10** concentric **squares**.

Exercises

…

1.2 **Replace the triangles of program *Triangles.java* with squares and draw a great many of them, arranged in a chessboard, as show in** Fig 1.11.

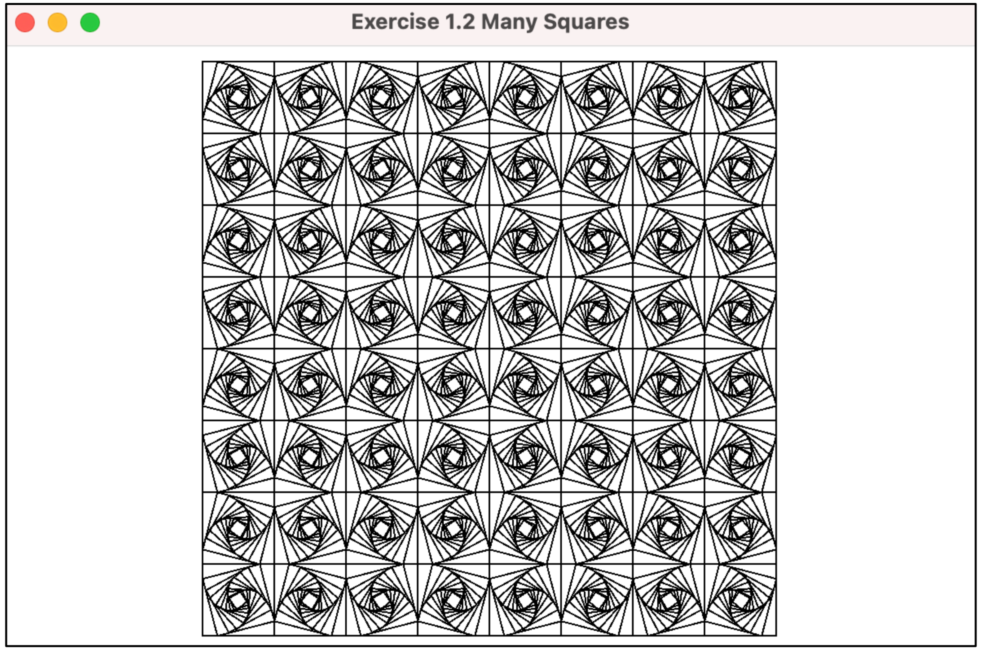


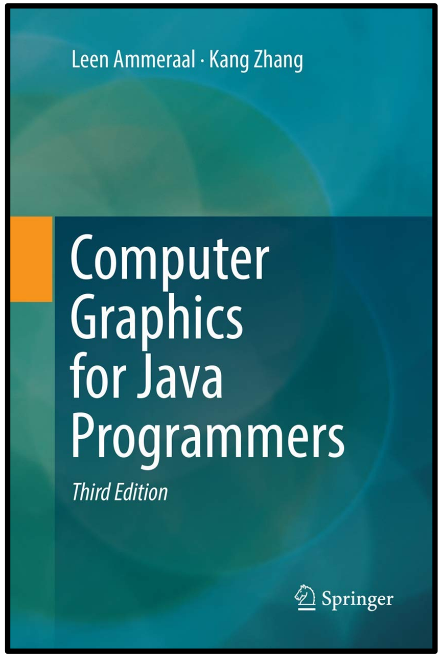
Figure 1.11 A chessboard of squares

As usual, this **chessboard**, consists of $n \times n$ **normal squares** (with horizontal and vertical edges), where $n = 8$.

Each of these actually consists of k **squares of different sizes**, with $k = 10$.

Finally, the value $q = 0.2$ (and $p = 1 - q = 0.8$) was used to **divide each edge into two parts** with **ratio** $p : q$ (see also program ***Triangles.java*** of section 1.2), but **the interesting pattern of Fig 1.11 was obtained by reversing the roles of** p **and** q **in half of the** $n \times n$ **'normal' squares, which is similar to the black and white squares of a normal chessboard**.

Your program should accept the values n, k and q as program arguments.


Leen Ammeraal · Kang Zhang
Computer Graphics for Java Programmers
Third Edition
Springer

@philip_schwarz

On the next slide we start modifying the **Scala** program so that it meets the **new requirements** (though we are not going to bother getting the program to accept n, k and q as parameters).

```
case class Triangle(a: Point, b: Point, c: Point)
```

```
object Triangle:

  def apply(centre: Point, side: Float, height: Float): Triangle =
    val Point(x,y) = centre
    val halfSide = 0.5F * side
    val bottomLeft = Point(x - halfSide, y - 0.5F * height)
    val bottomRight = Point(x + halfSide, y - 0.5F * height)
    val top = Point(x, y + 0.5F * height )
    Triangle(bottomLeft,bottomRight,top)
```

```
case class Square(a: Point, b: Point, c: Point, d: Point)
```

```
object Square:

  def apply(centre: Point, side: Float): Square =
    val Point(x,y) = centre
    val halfSide = 0.5F * side
    val bottomLeft = Point(x - halfSide, y - halfSide)
    val bottomRight = Point(x + halfSide, y - halfSide)
    val topRight = Point(x + halfSide, y + halfSide)
    val topLeft = Point(x - halfSide, y + halfSide)
    Square(bottomLeft,bottomRight,topRight,topLeft)
```

We are going to use a **for comprehension** to work through each of the 64 **cells** in the 8×8 **grid**, ensuring that each time we move from one **cell** to the next, we **invert** the **direction** (right = clockwise and left = counterclockwise) in which we **twist** the **concentric squares** drawn within a **cell**.

```
LazyList
  .iterate(triangle)(shrinkAndTwist)
  .take(50)
  .foreach(draw)
```

```
for
  (row, startDirection) <- (0 until gridSize)
                             zip alternatingDirections(Direction.Right)
  (col, twistDirection) <- (0 until gridSize)
                             zip alternatingDirections(startDirection)
  square = Square(squareCentre(row,col),squareSide)
yield LazyList
        .iterate(square)(shrinkAndTwist(twistDirection))
        .take(10)
        .foreach(draw)
```

```
enum Direction:
  case Left, Right
  def reversed: Direction = if this == Right then Left else Right
```

```
def alternatingDirections(startDirection: Direction): LazyList[Direction] =
  LazyList.iterate(startDirection)(_.reversed)
```

```
def squareCentre(row: Int, col: Int): Point =
  Point(panelCentre.x-(gridSize/2*squareSide)+(col*squareSide)+squareSide/2,
        panelCentre.y-(gridSize/2*squareSide)+(row*squareSide)+squareSide/2)
```

```scala
object TrianglesPanel extends JPanel:

  setBackground(Color.white)

  override def paintComponent(g: Graphics): Unit =

    super.paintComponent(g)

    val panelSize: Dimension = getSize()
    val panelWidth = panelSize.width - 1
    val panelHeight = panelSize.height - 1
    val panelCentre = Point(panelWidth / 2, panelHeight / 2)
    val triangleSide = 0.95F * Math.min(panelWidth, panelHeight)
    val triangleHeight = (0.5F * triangleSide) * Math.sqrt(3).toFloat

    …<shrinkAndTwist, draw and drawLine functions>…

    val triangle = Triangle(panelCentre,
                            triangleSide,
                            triangleHeight)

    LazyList
      .iterate(triangle)(shrinkAndTwist)
      .take(50)
      .foreach(draw)
```

```scala
object SquaresPanel extends JPanel:

  setBackground(Color.white)

  override def paintComponent(g: Graphics): Unit =

    super.paintComponent(g)

    val panelSize: Dimension = getSize()
    val panelWidth = panelSize.width - 1
    val panelHeight = panelSize.height - 1
    val panelCentre = Point(panelWidth / 2, panelHeight / 2)
    val gridSize = 8
    val squareSide: Float = 0.95F * Math.min(panelWidth, panelHeight) / gridSize

    …<shrinkAndTwist, draw and drawLine functions>…

    def squareCentre(row: Int, col: Int): Point =
      Point(panelCentre.x-(gridSize/2*squareSide)+(col*squareSide)+squareSide/2,
            panelCentre.y-(gridSize/2*squareSide)+(row*squareSide)+squareSide/2)

    for
      (row, startDirection) <- (0 until gridSize)
                               zip alternatingDirections(Direction.Right)
      (col, twistDirection) <- (0 until gridSize)
                               zip alternatingDirections(startDirection)
      square = Square(squareCentre(row,col),squareSide)
    yield LazyList
            .iterate(square)(shrinkAndTwist(twistDirection))
            .take(10)
            .foreach(draw)
```

```scala
val shrinkAndTwist: Triangle => Triangle =
  val q = 0.05F
  val p = 1 - q
  def combine(a: Point, b: Point) =
    Point(p * a.x + q * b.x, p * a.y + q * b.y)
  { case Triangle(a,b,c) =>
      Triangle(
        combine(a,b),
        combine(b,c),
        combine(c,a)) }
```

```scala
def shrinkAndTwist(direction: Direction): Square => Square =
  val q = if direction == Direction.Right then 0.2F else 0.8F
  val p = 1 - q
  def combine(a: Point, b: Point) =
    Point(p * a.x + q * b.x, p * a.y + q * b.y)
  { case Square(a,b,c,d) =>
      Square(
        combine(a,b),
        combine(b,c),
        combine(c,d),
        combine(d,a)) }
```

```scala
val draw: Triangle => Unit =
  case Triangle(a, b, c) =>
    drawLine(a, b)
    drawLine(b, c)
    drawLine(c, a)
```

```scala
val draw: Square => Unit =
  case Square(a, b, c, d) =>
    drawLine(a, b)
    drawLine(b, c)
    drawLine(c, d)
    drawLine(d, a)
```

```scala
def drawLine(a: Point, b: Point): Unit =
  val (ax,ay) = a.deviceCoords(panelHeight)
  val (bx,by) = b.deviceCoords(panelHeight)
  g.drawLine(ax, ay, bx, by)
```

```scala
def drawLine(a: Point, b: Point): Unit =
  val (ax,ay) = a.deviceCoords(panelHeight)
  val (bx,by) = b.deviceCoords(panelHeight)
  g.drawLine(ax, ay, bx, by)
```

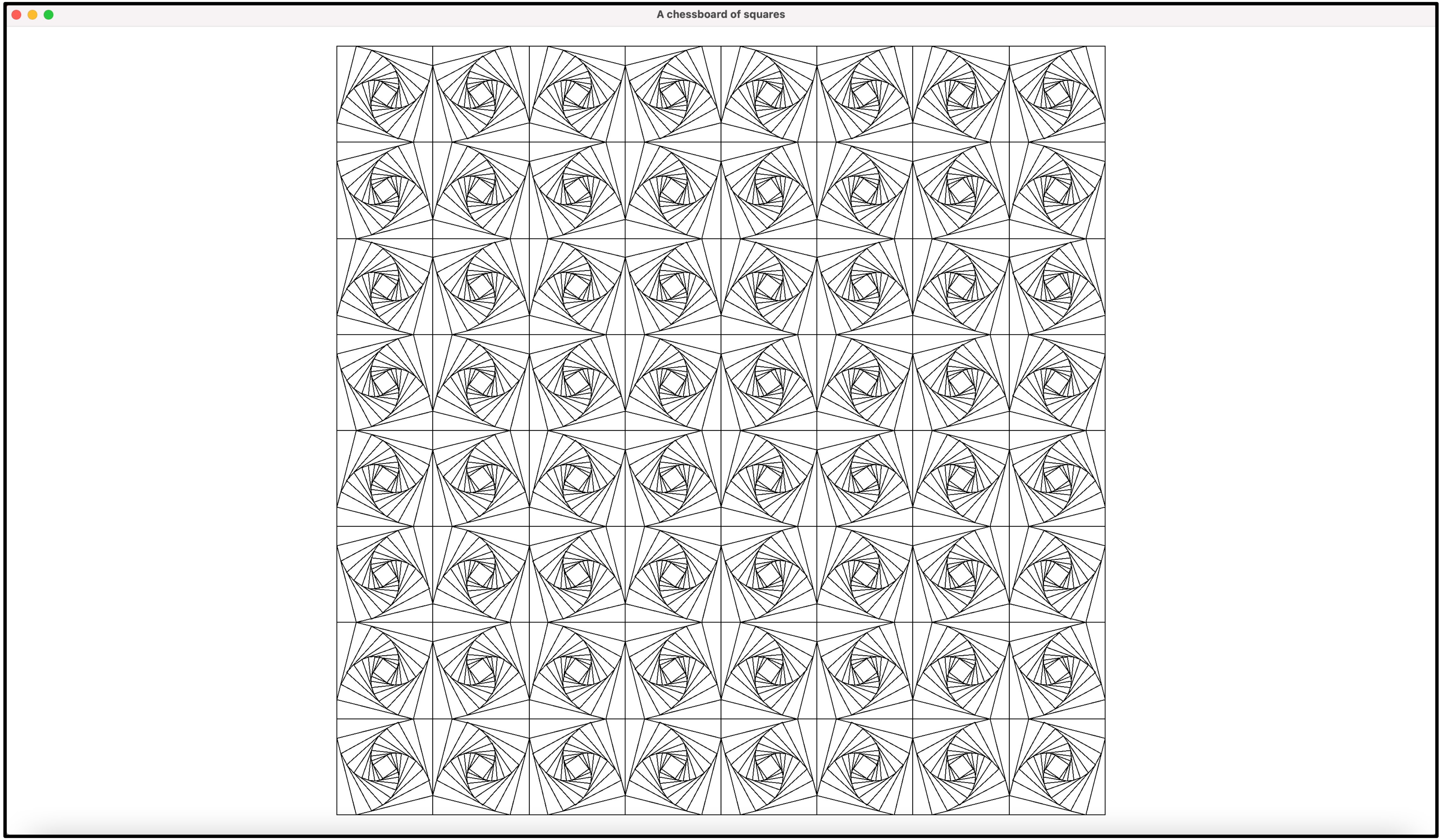
```
@main def trianglesMain: Unit =
  // Create the frame/panel on the event dispatching thread
  SwingUtilities.invokeLater(
    new Runnable():
      def run: Unit = drawTriangles
  )
```

```
def drawTriangles: Unit =
  JFrame.setDefaultLookAndFeelDecorated(true)
  val frame =
    new JFrame("Triangles: 50 triangles inside each other")
  frame.setDefaultCloseOperation(
    WindowConstants.EXIT_ON_CLOSE)
  frame.setSize(600, 400)
  frame.add(TrianglesPanel)
  frame.setVisible(true)
```

```
@main def squaresMain: Unit =
  // Create the frame/panel on the event dispatching thread
  SwingUtilities.invokeLater(
    new Runnable():
      def run: Unit = drawSquares
  )
```

```
def drawSquares: Unit =
  JFrame.setDefaultLookAndFeelDecorated(true)
  val frame =
    new JFrame("A chessboard of squares")
  frame.setDefaultCloseOperation(
    WindowConstants.EXIT_ON_CLOSE)
  frame.setSize(600, 400)
  frame.add(SquaresPanel)
  frame.setVisible(true)
```

On the next slide we have a go at running the modified **Scala** program.



A chessboard of squares

@philip_schwarz

That’s nice, but it turns out that there is an **unsatisfactory feature** in that drawing: we can improve the drawing by removing that feature and **increasing** the **number** of **squares** drawn.

This idea is further illustrated by drawing the pattern shown in figure 3.3a.

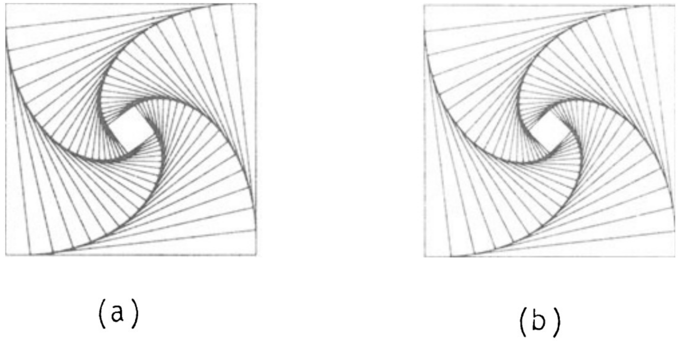


Figure 3.3

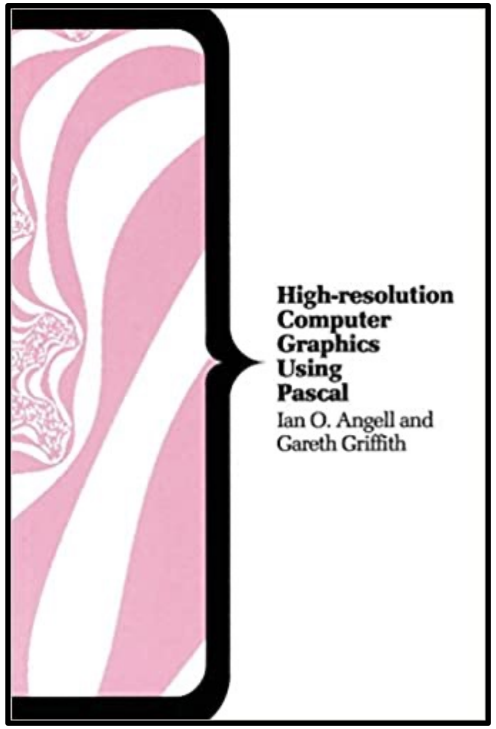
At first sight it looks complicated, but on closer inspection it is seen to be simply a square, outside a square, outside a square etc.

The squares are getting successively smaller and they are rotating through a constant angle. In order to draw the diagram, a technique is needed which, when given a general square, draws a smaller internal square rotated through this fixed angle.

Suppose the general square has corners $\{(x_i, y_i) \mid i = 1, 2, 3, 4\}$ and the i^{th} side of the square is the line joining (x_i, y_i) to (x_{i+1}, y_{i+1}) - assuming additions of subscripts are modulo 4 - that is, $4 + 1 \equiv 1$.

A general point on this side of the square, (x'_i, y'_i), is given by

$$((1 - \mu) \times x_i + \mu \times x_{i+1}, (1 - \mu) \times y_i + \mu \times y_{i+1}) \text{ where } 0 \le \mu \le 1$$



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Gareth Griffith

In fact $\mu : 1 - \mu$ is the ratio in which the side is cut by this point. If μ is fixed and the four points $\{(x_i, y_i) \mid i = 1, 2, 3, 4\}$ are calculated in the above manner, then the sides of the new square make an angle

$$\alpha = tan^{-1}[\mu/(1 - \mu)]$$

with the corresponding side of the outer square. So by keeping μ fixed for each new square, the angle between consecutive squares remains constant at α. In figure 3.3a … there are 21 squares and $\mu = 0.1$.

There is an unsatisfactory feature of the pattern in figure 3.3a: the inside of the pattern is 'untidy', the sides of the innermost square being neither parallel to nor at $\pi/4$ radians to the corresponding side of the outermost square.

This is corrected simply by changing the value of μ so as to produce the required relationship between the innermost and outermost squares.

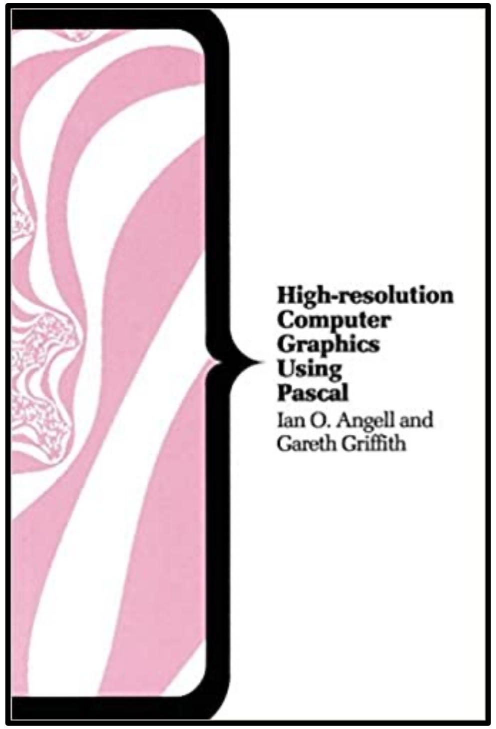
As was previously noted, with the calculation of each new inner square, the corresponding sides are rotated through an angle of $tan^{-1}[\mu/(1 - \mu)]$ radians.

After $n + 1$ squares are drawn, the inner square is rotated by $n \times tan^{-1}[\mu/(1 - \mu)]$ radians relative to the outer square. For a satisfactory diagram this angle must be an integer multiple of $\pi/4$.

That is, $n \times tan^{-1}[\mu/(1 - \mu)] = t(\pi/4)$ for some integer t, and hence

$$\mu = \frac{tan[t(\pi/4\text{n})]}{tan[t(\pi/4\text{n})]+1}$$

To produce figure 3.3b, $n = 20$ and $t = 3$ are chosen.



```
def shrinkAndTwist(direction: Direction): Square => Square =
  val q = if direction == Direction.Right then 0.2F else 0.8F
  val p = 1 - q
  def combine(a: Point, b: Point) =
    Point(p * a.x + q * b.x, p * a.y + q * b.y)
  { case Square(a,b,c,d) =>
      Square(
        combine(a,b),
        combine(b,c),
        combine(c,d),
        combine(d,a)) }
```

```
def shrinkAndTwist(direction: Direction): Square => Square =
  val q = if direction == Direction.Right then mu else 1 - mu
  val p = 1 - q
  def combine(a: Point, b: Point) =
    Point(p * a.x + q * b.x, p * a.y + q * b.y)
  { case Square(a,b,c,d) =>
      Square(
        combine(a,b),
        combine(b,c),
        combine(c,d),
        combine(d,a)) }
```

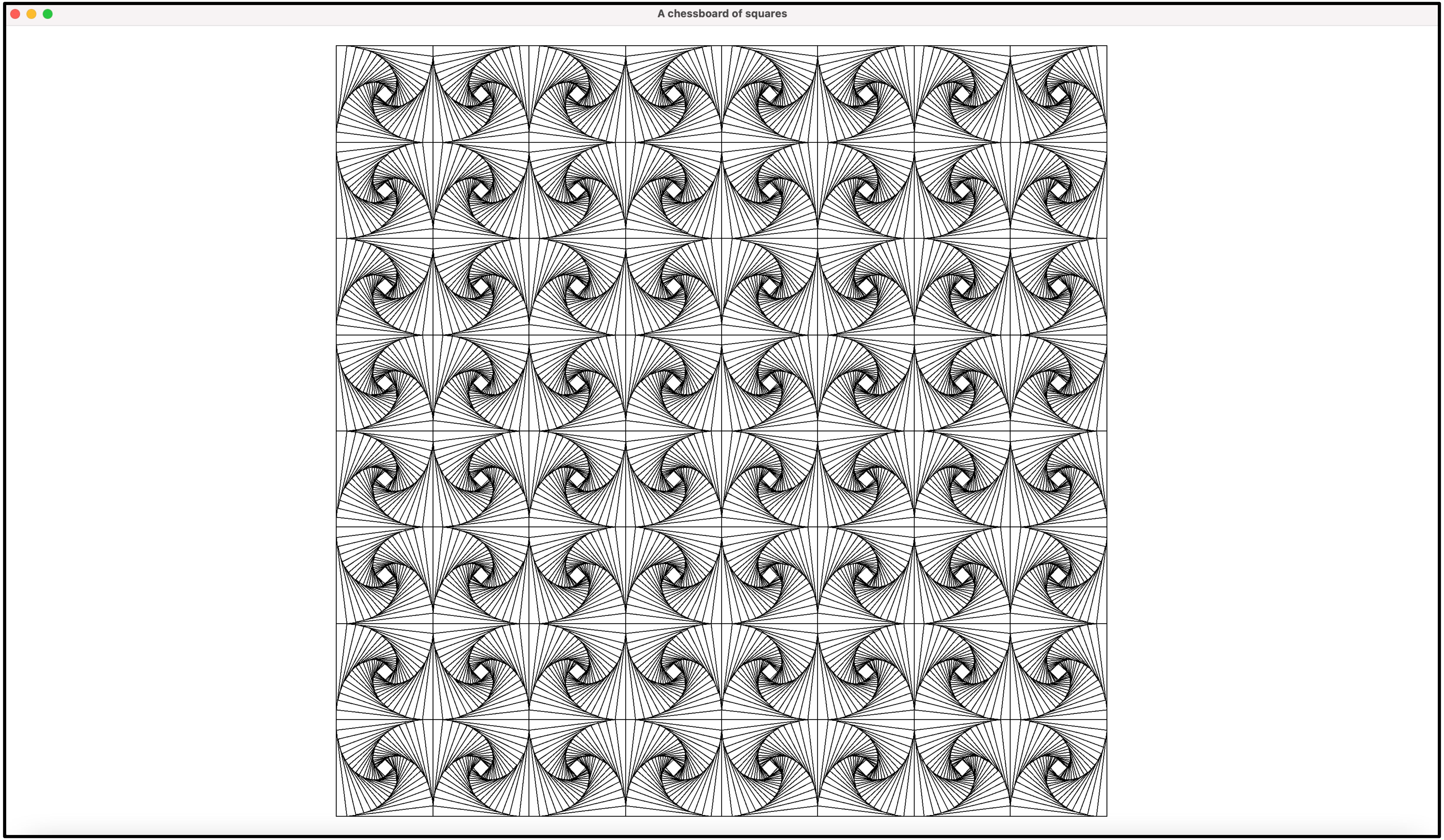
```
val squareCount = 20
```

```
val mu: Float =
  val t = 3
  val x = Math.tan(t * (Math.PI/(4 * squareCount)))
  (x / (x + 1)).toFloat
```

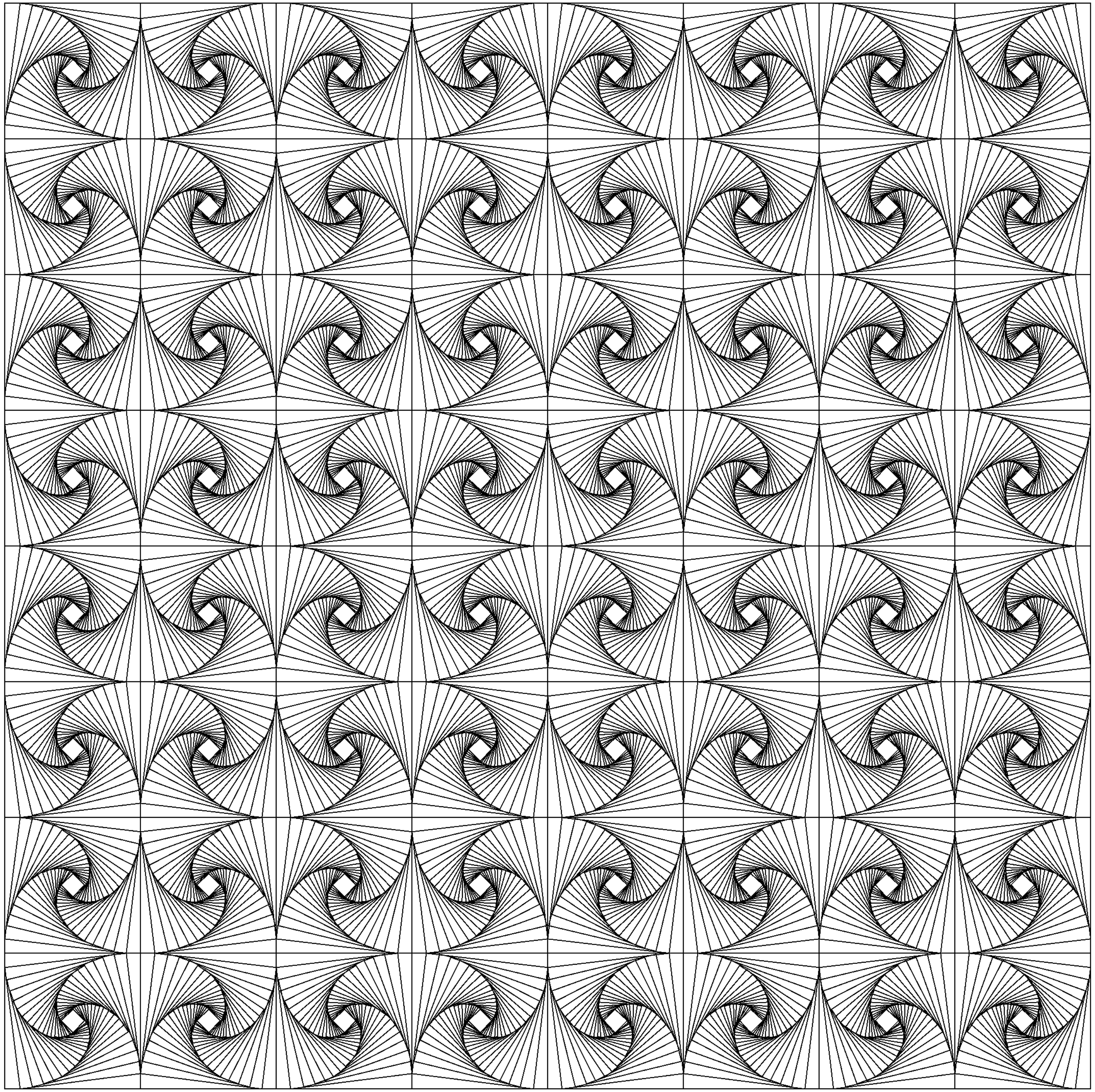
```
LazyList
  .iterate(square)(shrinkAndTwist(twistDirection))
  .take(10)
  .foreach(draw)
```

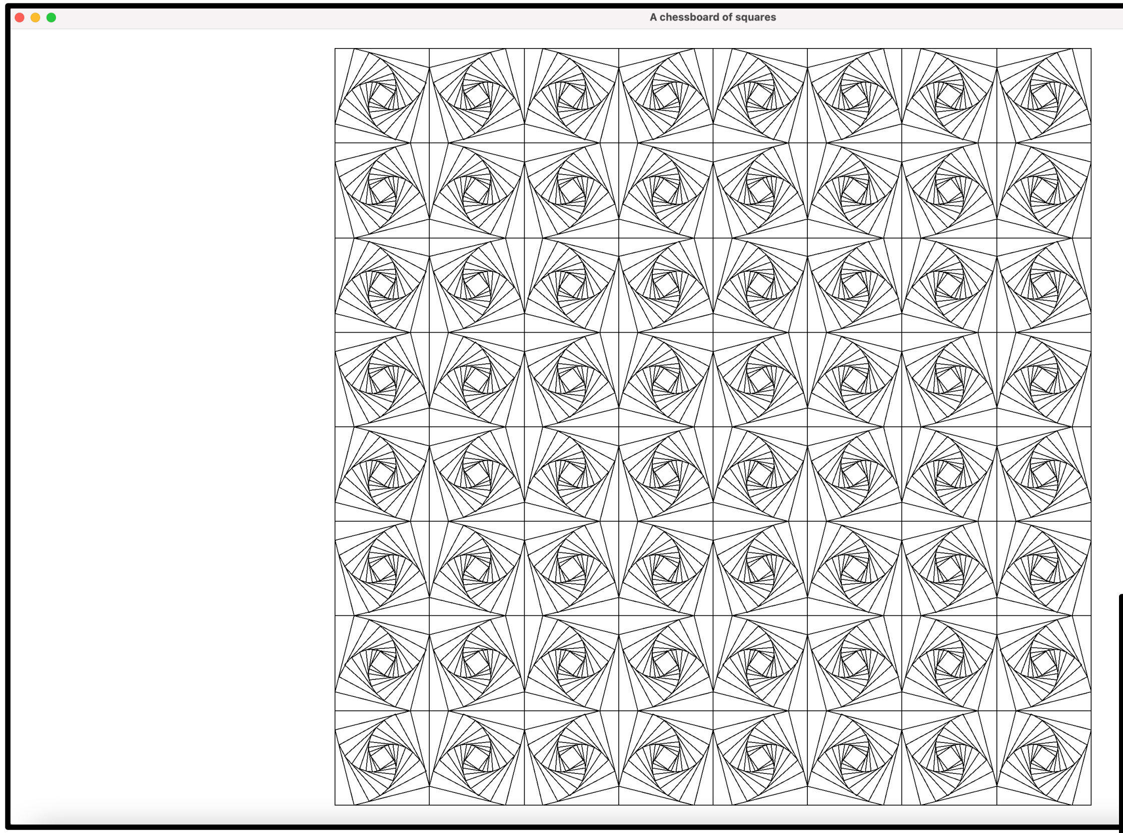
```
LazyList
  .iterate(square)(shrinkAndTwist(twistDirection))
  .take(squareCount + 1)
  .foreach(draw)
```

Let' run the improved **Scala** program.



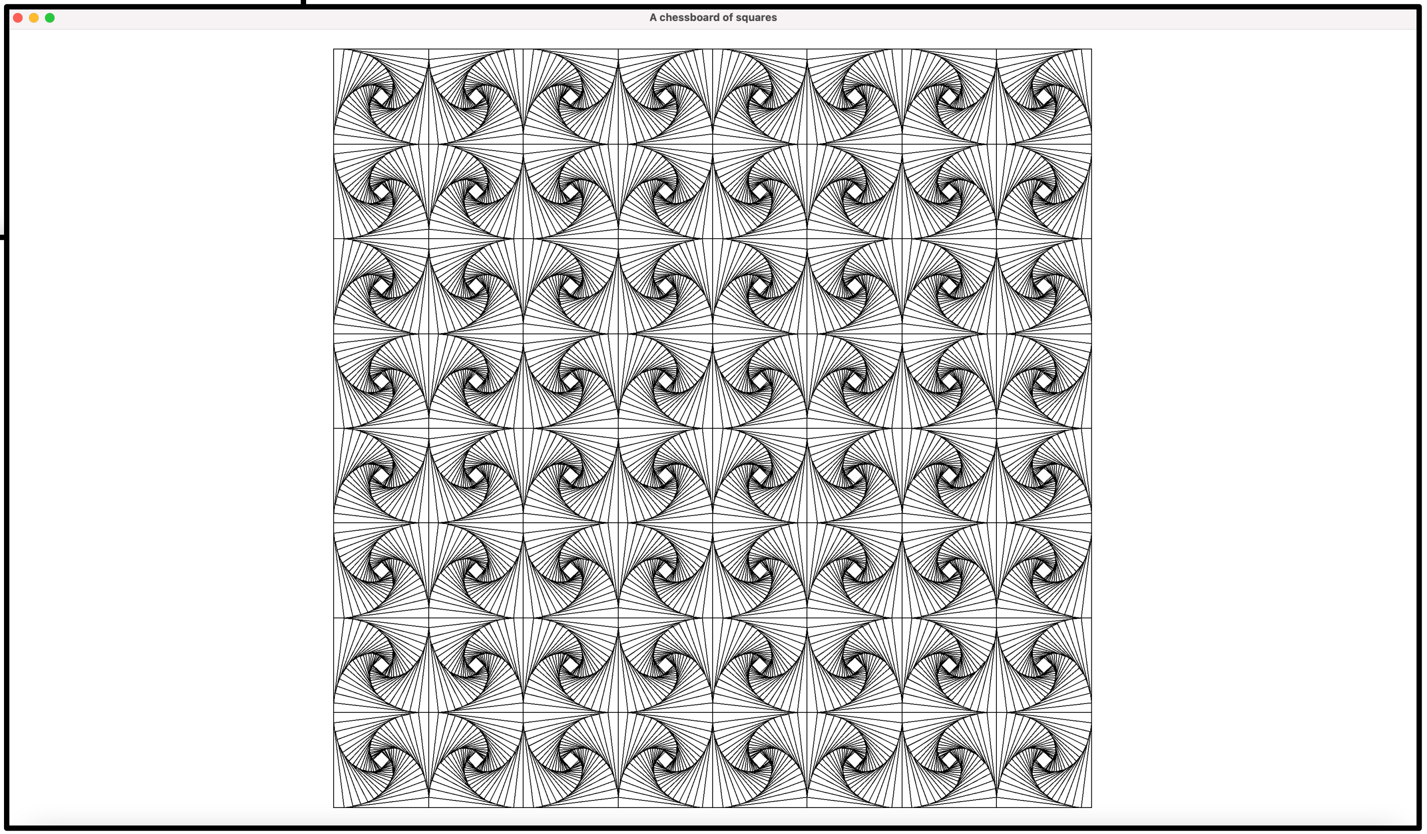
A chessboard of squares





A chessboard of squares

Before and after the improvements



A chessboard of squares

That’s all. I hope you enjoyed that.

@philip_schwarz