Frieze step pattern

Processing Power

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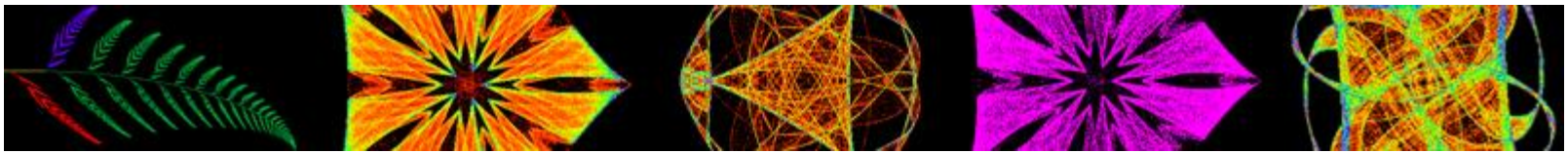
What is Processing?

Processing is an open source programming language and environment

for people who want to create images, animations, and interactions.

[processing.org]

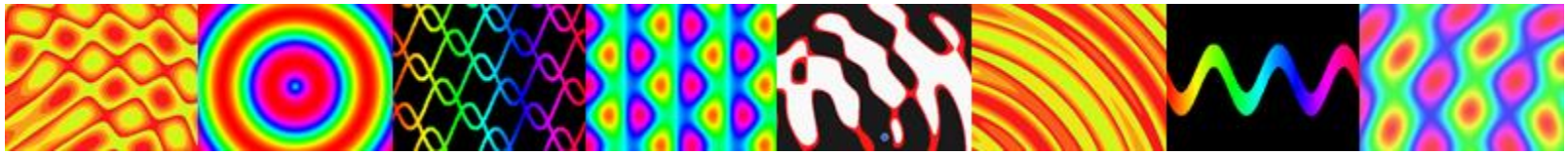


Iterated function system

When to use Processing

- Processing is great for rapidly writing small programs that involve any sort of visualization, 2D or 3D.
- Easy to:
  - Create a drawing window.
  - Write code without a lot of overhead.
  - Read, manipulate, and save images.
  - Generate animations.
  - Apply transformations.
  - Interact with user via key and mouse
  - Convert programs to javascript for running on web.

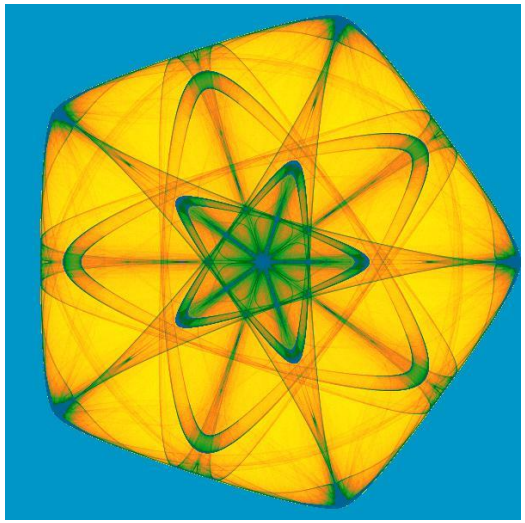
Rotate Dots Example



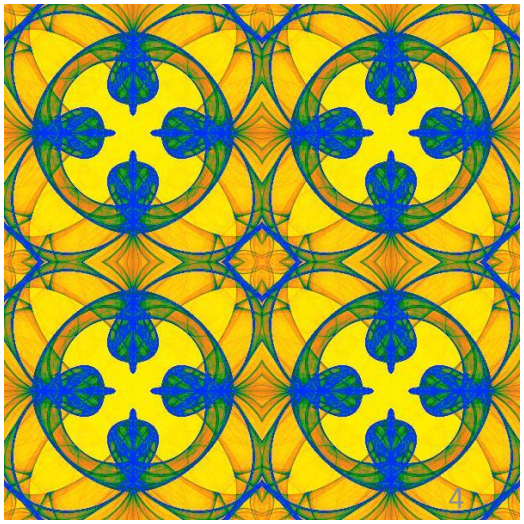
When Not To Use Processing

It is not recommended that you use Processing for programs that:

- Has a complex structure
- Involves large amounts of data
- Has complex user interaction.
- Is not visually oriented.



Iterated function system



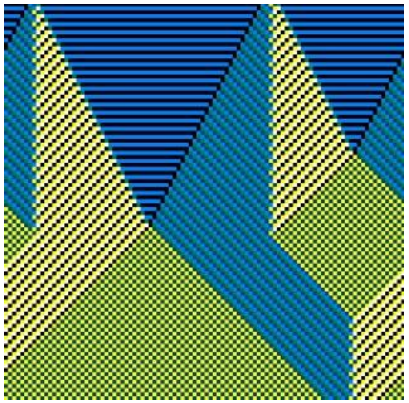
What Do I Do with Processing?

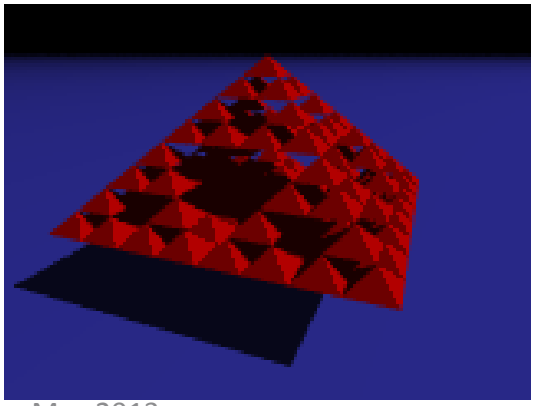
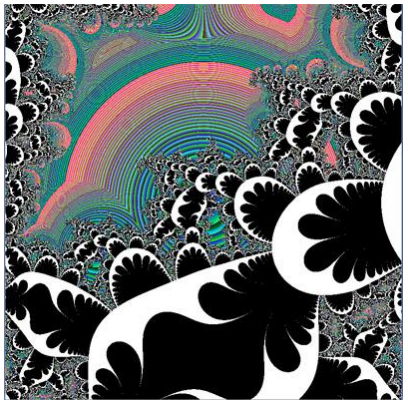
Art Creation

Exploration

Scientific & Mathematical Visualization

→ Understanding



Algorithmic Art

What is an Algorithm?

In the logician's voice:

An algorithm is

a finite procedure,

written in a fixed symbolic vocabulary,

governed by precise instructions,

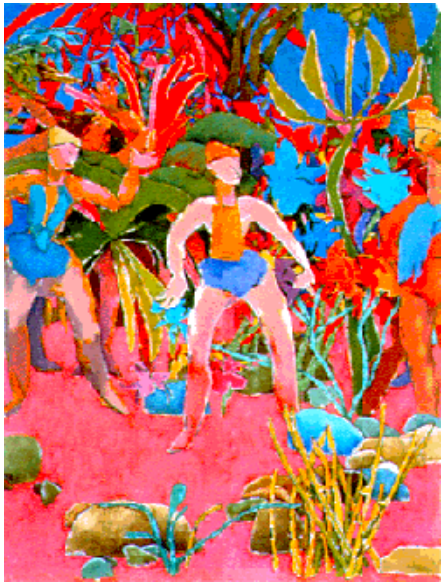
moving in discrete steps, 1, 2, 3,...,

whose execution requires no insight, cleverness, intuition, intelligence, or perspicuity,

and that sooner or later comes to an end.

From *The Advent of the Algorithm*, by David Berlinski

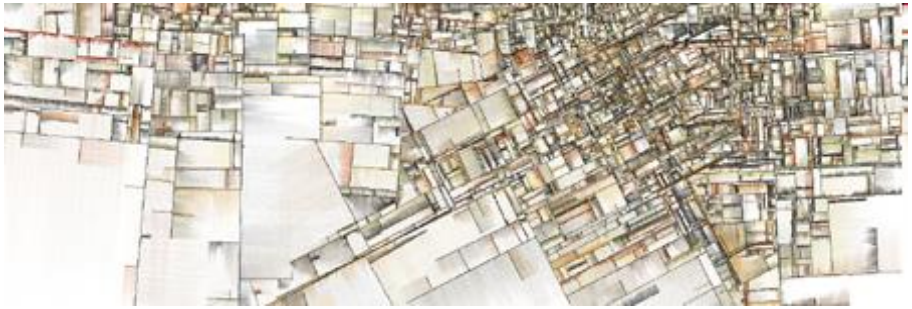
Janet Parke, *Souls Bend, Hearts Break*



Harold Cohen,
Painting by AARON

Art Creation

Jared Tarbell, Substrate 2003, http://www.complexification.net/gallery/

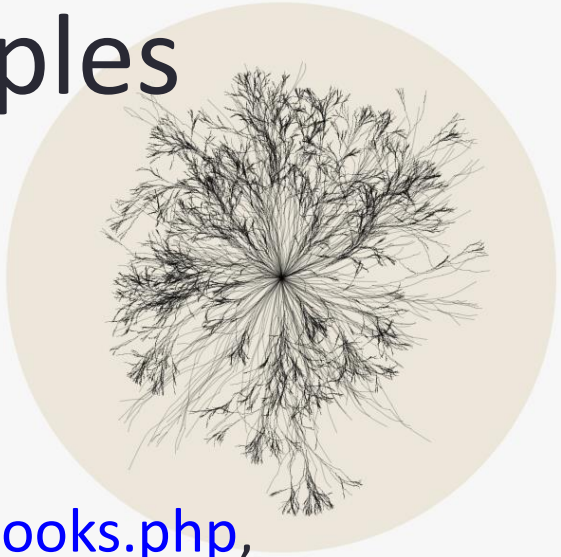


Mike Field,
Firestorm 2001
http://www.math.uh.edu/~mike/ag/recent/recent.html

Roman Verostko
Cyberflower Red 2002
http://www.verostko.com/gallery.html

Processing Art Examples

- Lots are online, e.g.
  - http://processing.org/exhibition/
  - http://www.openprocessing.org/
- Books:
  - Generative Art, http://zenbullets.com/books.php, Matt Pearson
  - Form + Code, http://formandcode.com/, Casey Reas, Chandler McWilliams, LUST

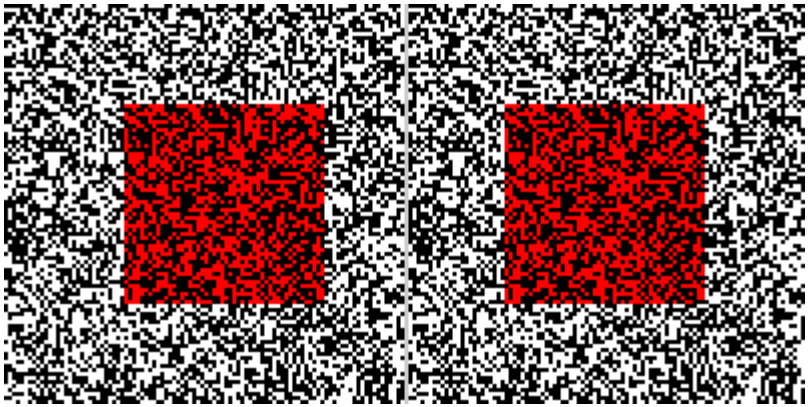


Diana Lange

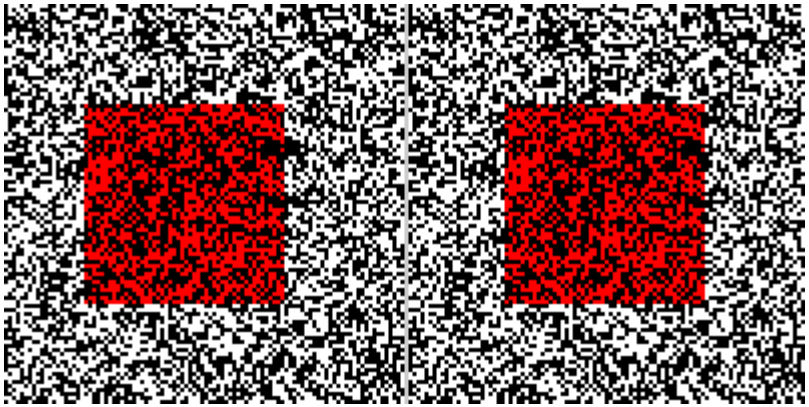
Marius Watz

Robert Hodgin

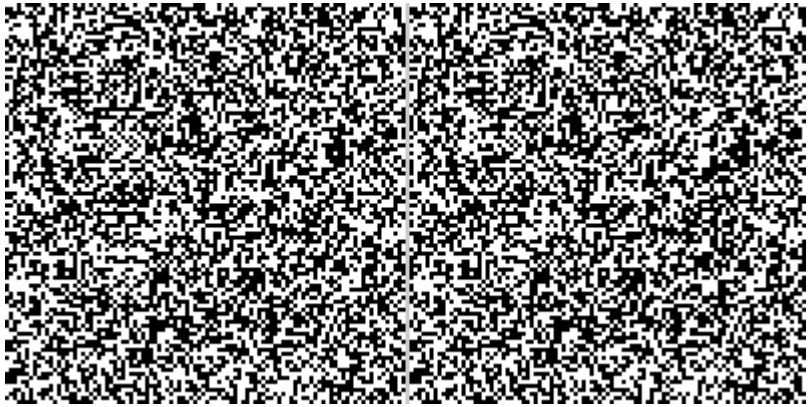
Exploration:
Random Dot Stereogram



Left eye: Shift = +10
Red square appears in front of back plane.



Left eye: Shift = -10
Red square appears behind back plane.



Don’t really need red color.
Shift = +10

Image Manipulation





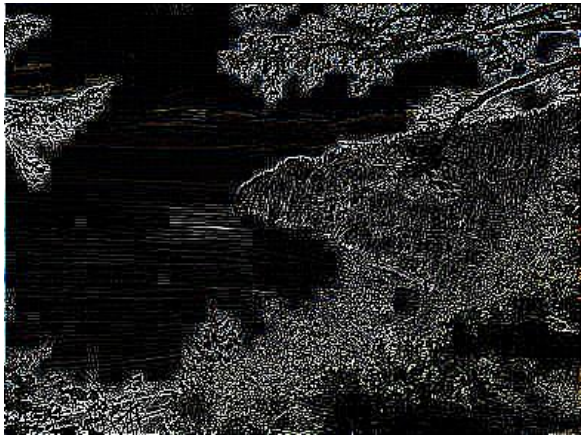
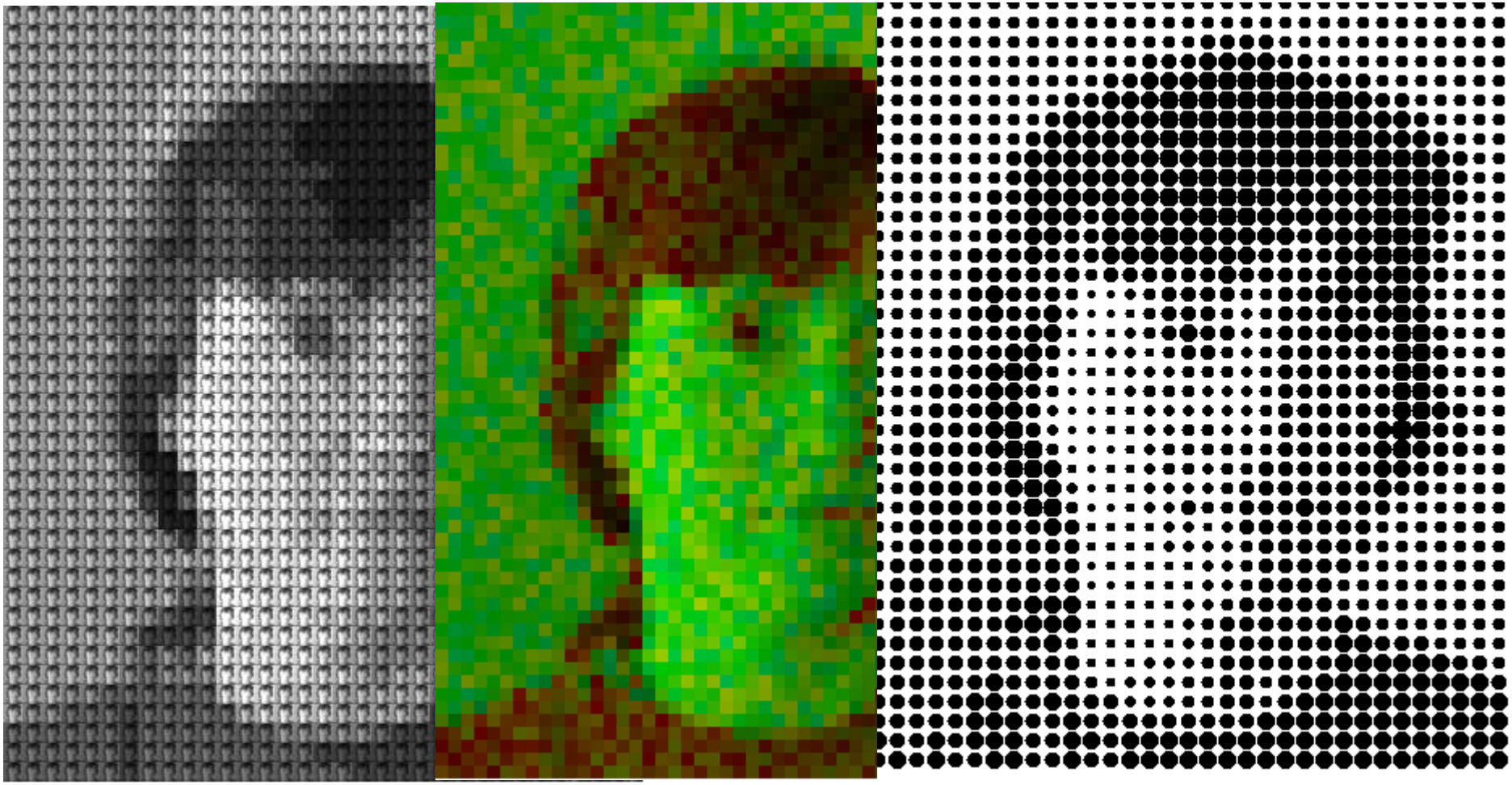



Image Manipulation



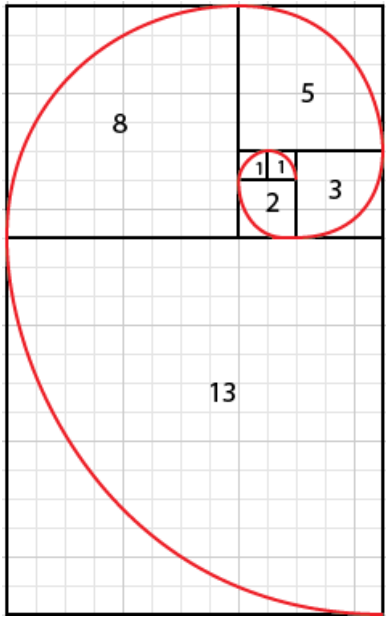
Visualization of Science and Math

Phyllotaxis (Leaf Arrangement):
Pine Cones, Cacti, & Fibonacci Numbers

Red: 8

Yellow: 13

White: 21



Fibonacci Sequence:

0 1 1 2 3 5 8 13 21 34 55 89 …

Image taken from: http://faculty.smcm.edu/sgoldstine/pinecones.html

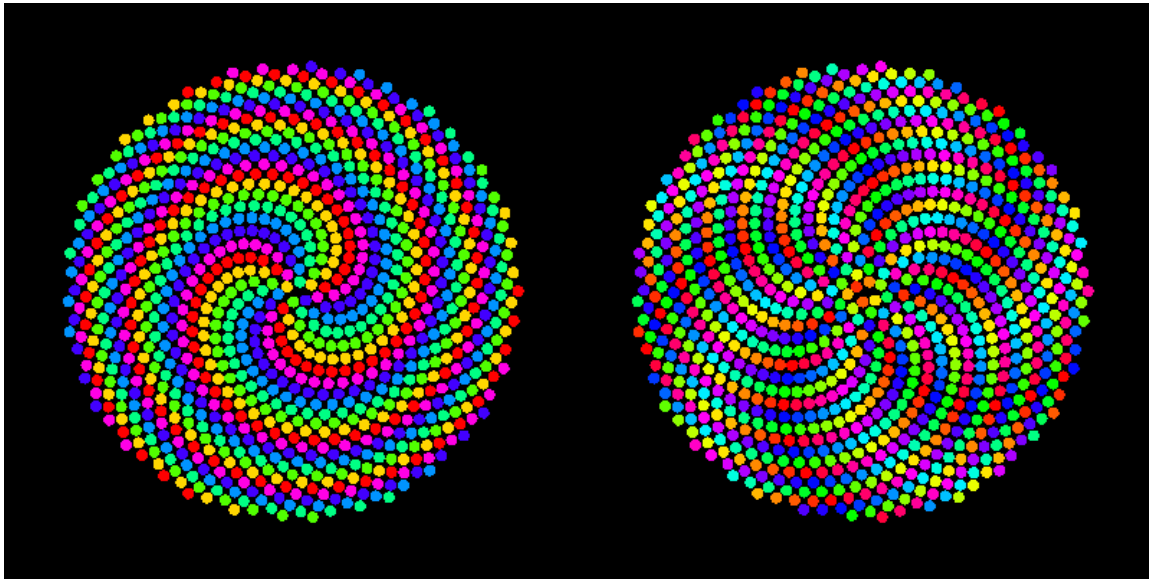
Also see:

http://www.maths.surrey.ac.uk/hosted-sites/R.Knott/Fibonacci/fibnat.html#plants

Phyllotaxis & Processing

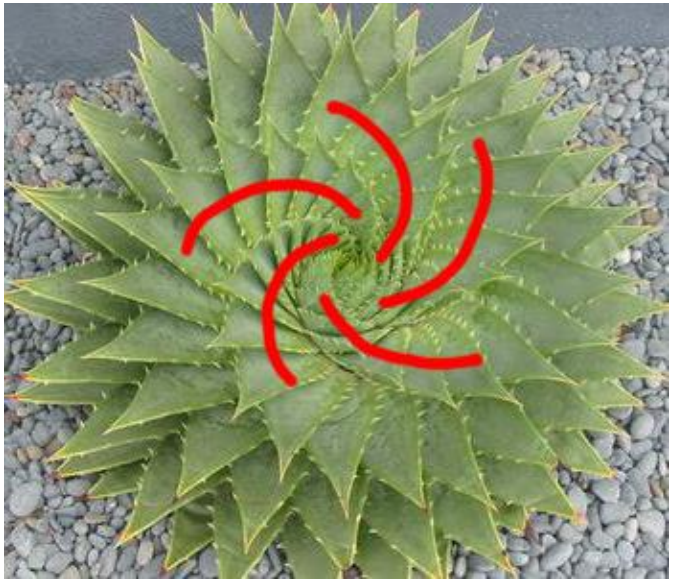
- Fibonacci Sequence:
  0 1 1 2 3 5 8 13 21 34 55 89 …

Phyllotaxis Example



21

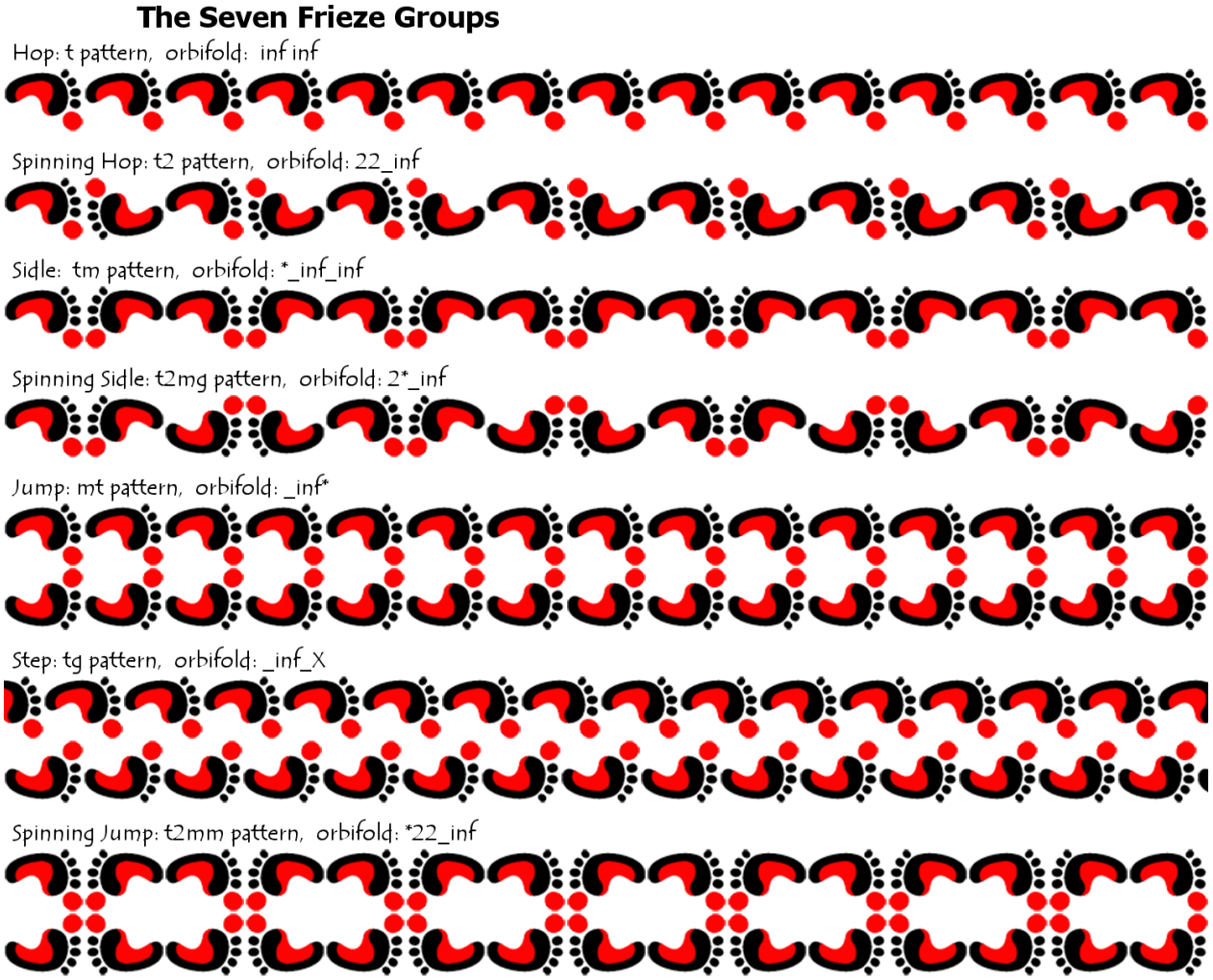
34



5

"Divergence angle" = angle between leaves = 360/tau = 222.5 (or 137.5°)
where tau=golden ratio

Understanding Transformations and Symmetry: Frieze Patterns



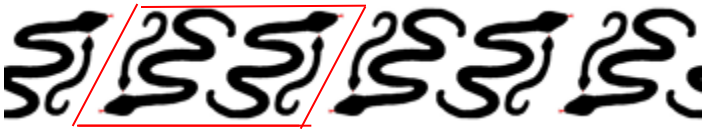
See FriezePatterns example (via Processing)

Symmetry & Processing

Hop

```
void setup() {
  icon = loadImage("snake.png");
  w = icon.width;
  h = icon.height;
  drawHop();
}
void drawHop() {
  for (int i = 0; i < 10; i++) {
     image(icon, 0, 0);
     translate(w,0);
  }
}
```

Spinning Hop



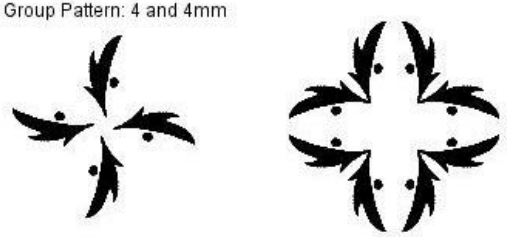
```
void translateRegion() {
  pushMatrix();
  image(icon, 0, 0);
  translate(w,0);
  rotateHor();
  popMatrix();
}

void rotateHor() {
    pushMatrix();
    translate(w/2,h/2);
    rotate(radians(180));
    translate(-w/2,-h/2);
    image(icon, 0, 0);
    popMatrix();
}
```

Symmetry: Point Group

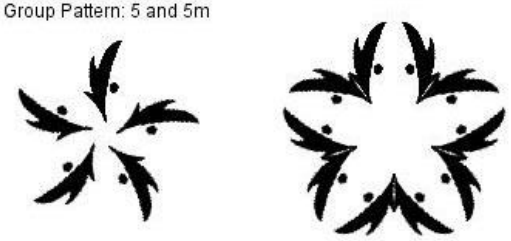
Point Group Pattern: 2 and 2mm

Point Group Pattern: 3 and 3m

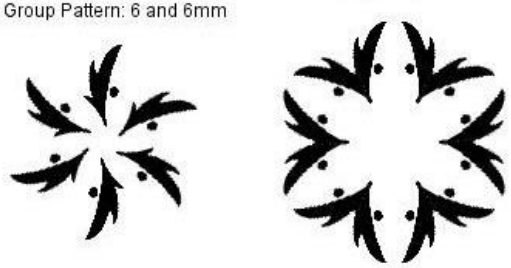
Point Group Pattern: 4 and 4mm



Point Group Pattern: 5 and 5m



Point Group Pattern: 6 and 6mm

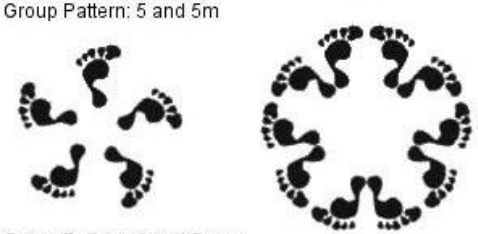


Point Group Pattern: 2 and 2mm

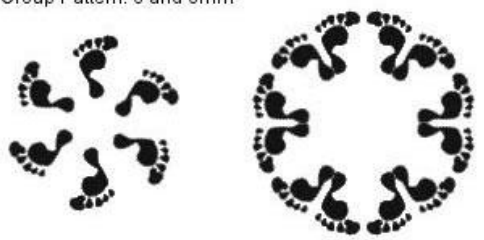
Point Group Pattern: 3 and 3m

Point Group Pattern: 4 and 4mm

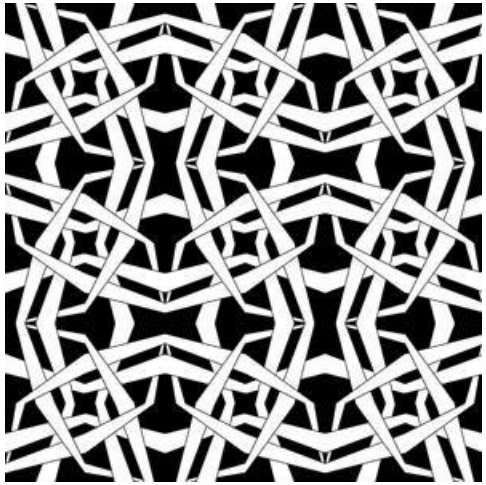
Point Group Pattern: 5 and 5m

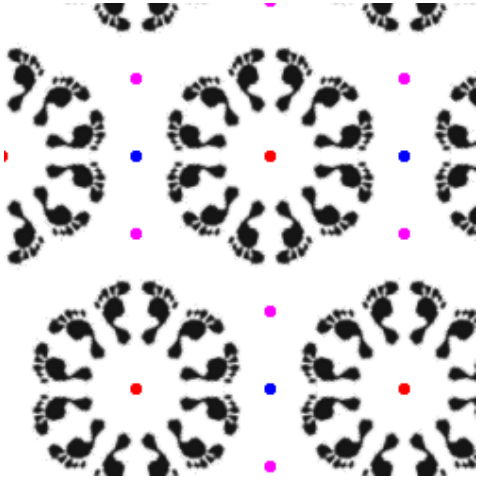


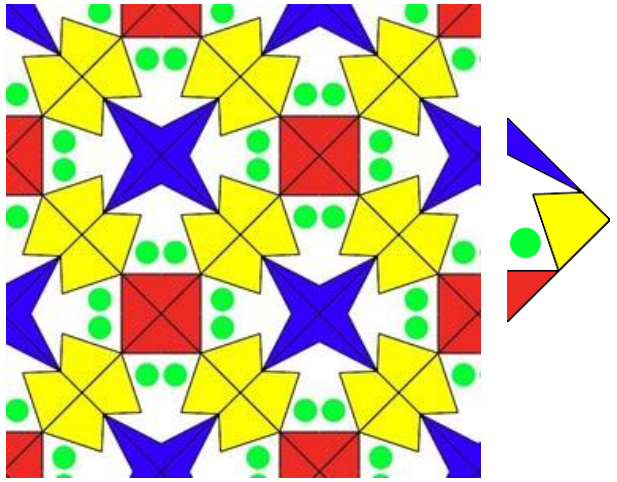
Point Group Pattern: 6 and 6mm



Symmetry : Wallpaper Group







Complex Numbers

- Physics: AC circuits, quantum mechanics
- Mathematics: Solutions to cubic and quartics
- Art & Science: Fractals
- Computer Graphics Transformations:
  - Complex numbers → 2D Rotations
  - Quaternions → 3D Rotations

"*So, progresses arithmetic sublety the end of which, as is said, is as refined as it is useless.*" Cardano (1501-1576)

Complex Numbers

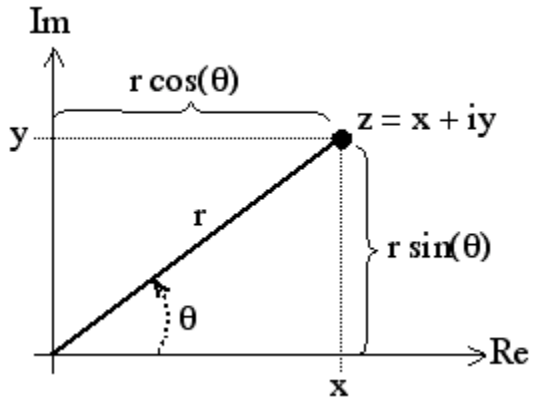
Rectangular Coordinates:

$$z = P(x,y) = x + i\,y, \quad \text{where } i = \sqrt{-1}$$

Polar Coordinates:

$$z = P(r, \Theta) = r\,e^{i\Theta}$$

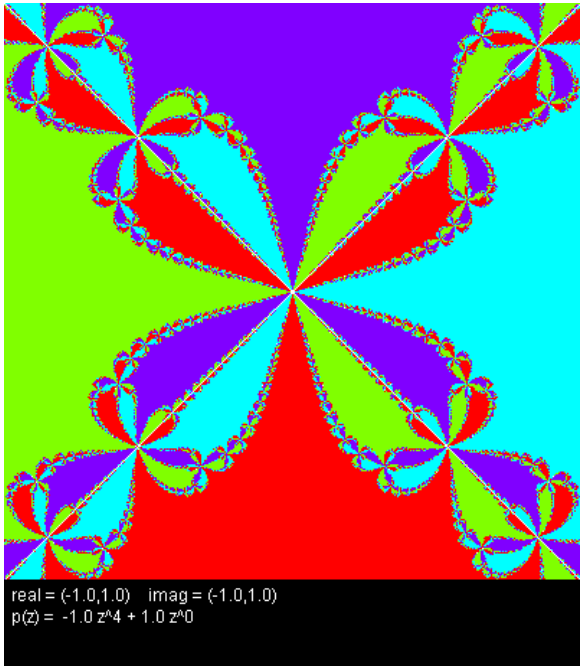
$$= r\,(\cos\Theta + i \sin\Theta)$$

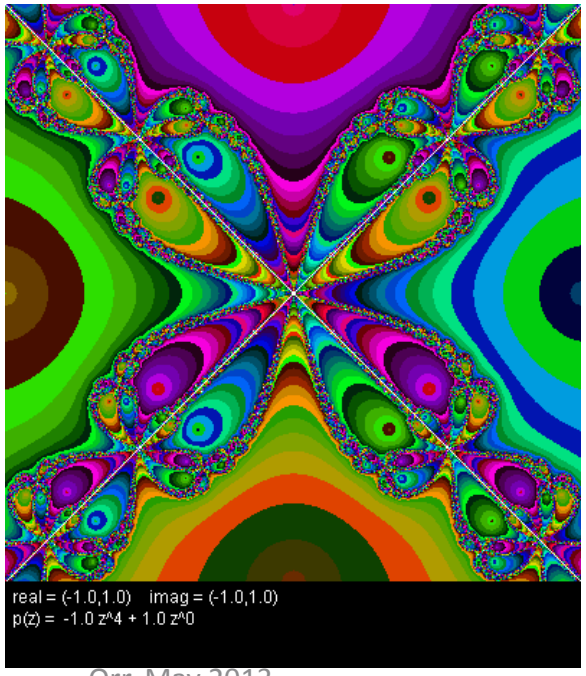


Complex Plane

Polynomiography

Formally, polynomiography is the art and science of visualization in approximation of zeros of polynomials. This visualization is via fractal and non-fractal images created based on the mathematical convergence properties of iteration functions. [*http://www.polynomiography.com/about.php*]

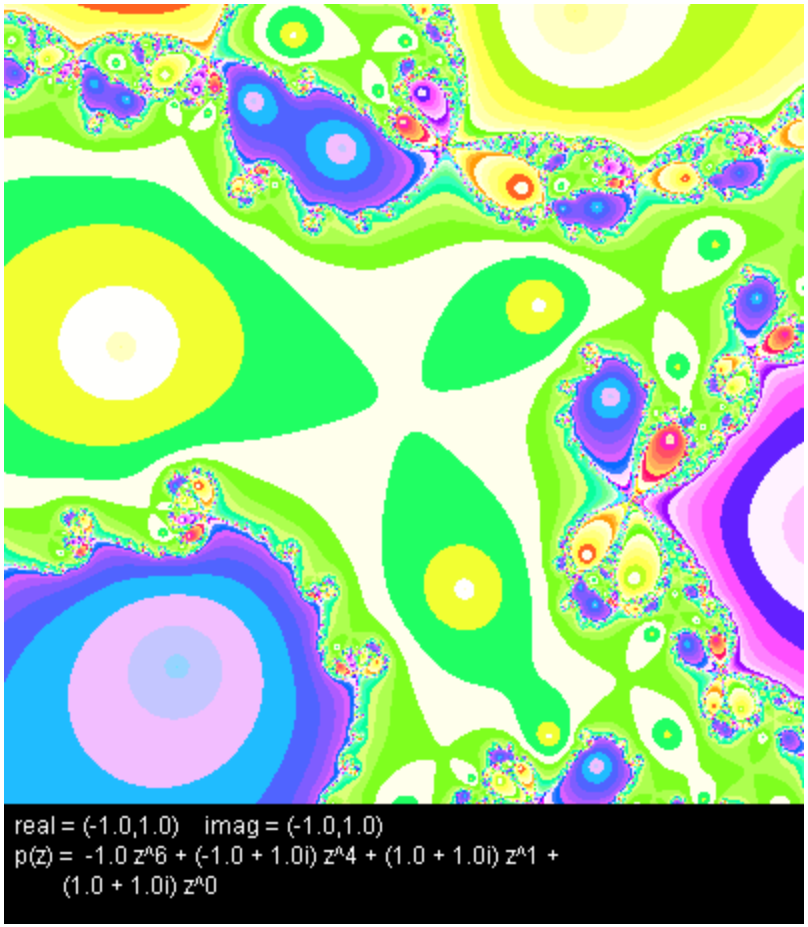


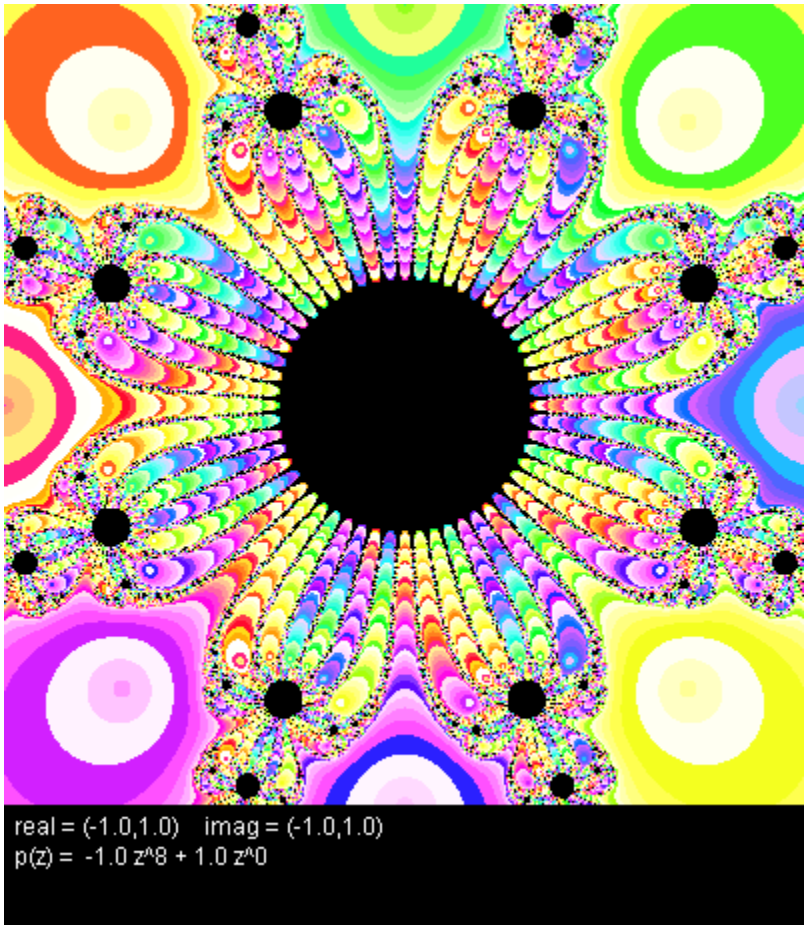


$P(z) = - z^4 + 1$

Roots: 1, -1, i, -i

Polynomiography





$P(z) = - z^6 + (-1 + i)\, z^4 + (1 + i)\, z + (1 + i)$

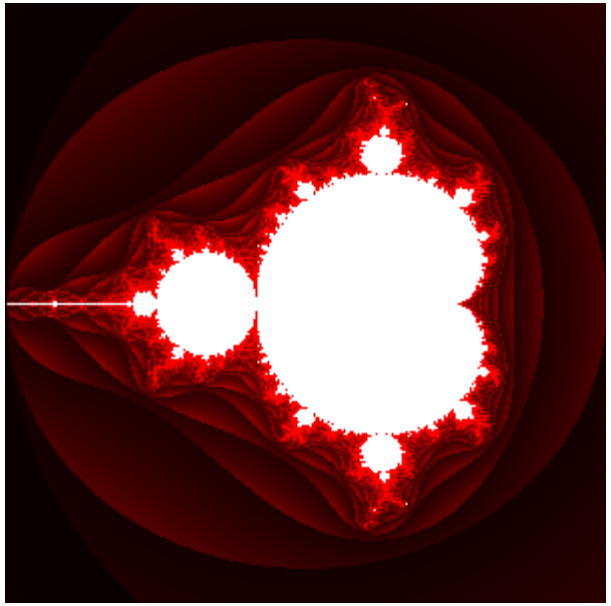
$P(z) = - z^8 + 1$

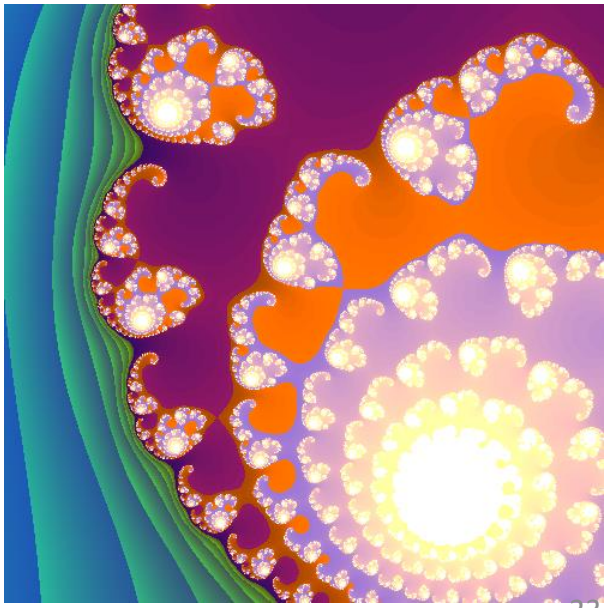
Fractals

Mandelbrot and Julia Sets:

Iterate: $z_n = z^2_{n-1} + c$

What is happening?





Complex Functions as Transformations

Consider:

$$\mathbf{F(z) = w + z}$$ where w = constant

If we write

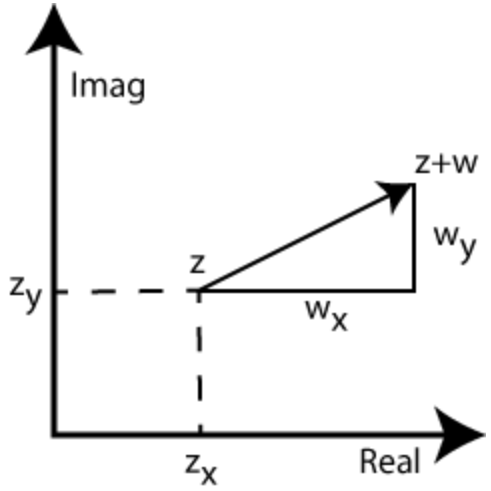
$$z = z_x + i\, z_y \text{ and } w = w_x + i\, w_y$$

Then

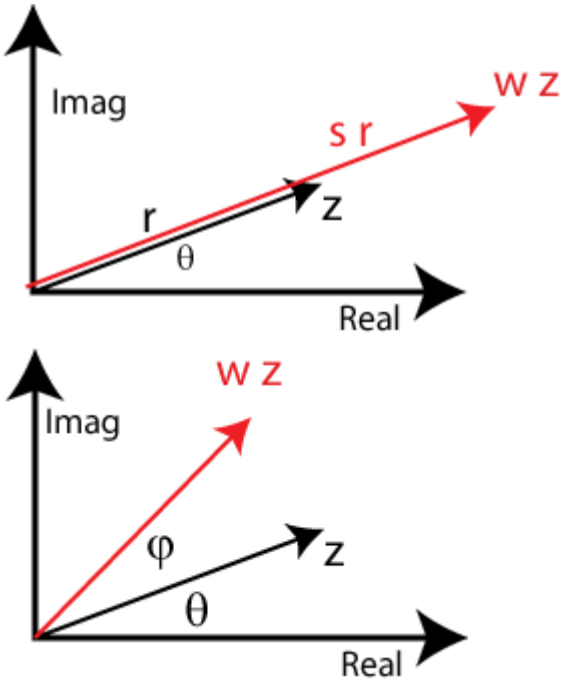
$$F(z) = (w_x + i\, w_y) + (z_x + i\, z_y)$$

$$= (w_x + z_x) + i\,(w_y + z_y)$$

= translation by w



Complex Functions as Transformations



Consider:

$F(z) = w\,z$ where w = constant

If we write

$z = r\,e^{i\Theta}$ and $w = s\,e^{i\phi}$

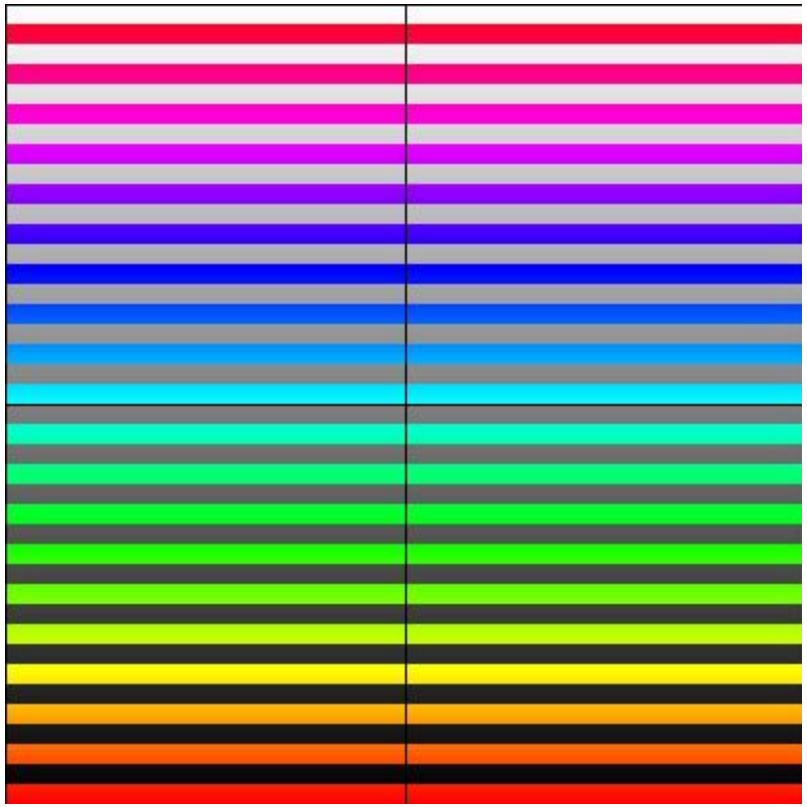
Then

$$F(z) = w\,z = (s\,e^{i\phi})\,(r\,e^{i\Theta}) = (s\,r)\,e^{i(\Theta+\phi)}$$

If $\phi = 0$, $F(z) = s\,r\,e^{i\Theta} = s\,z$ = **scale by s**

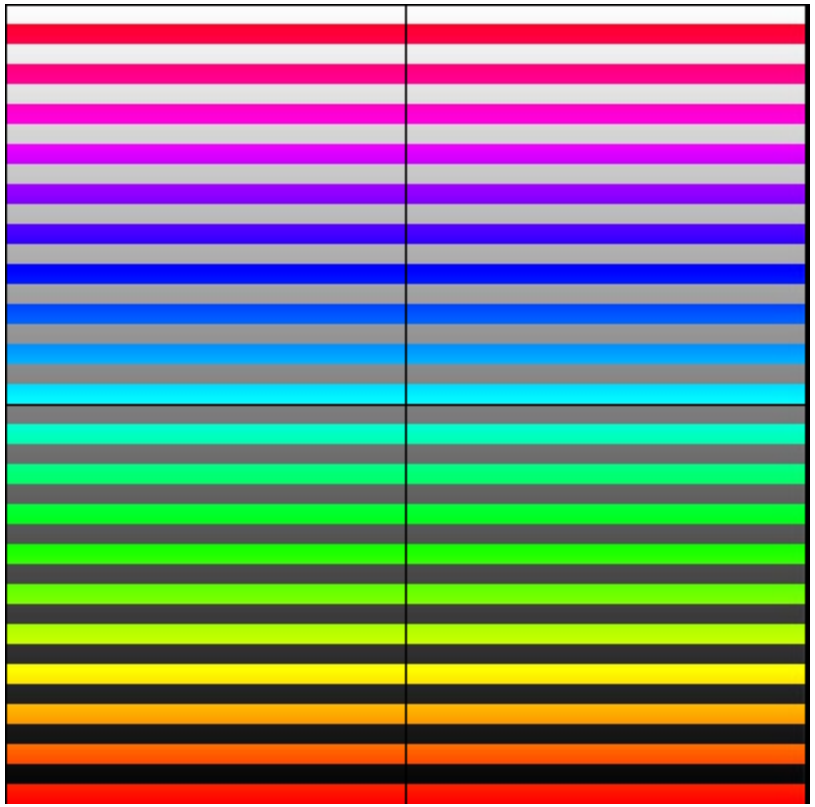
If $s = 1$, $F(z) = r\,e^{i(\Theta+\phi)} = z\,e^{i\phi}$ = **rotation by ϕ**

Example: z → w*z, w=.5



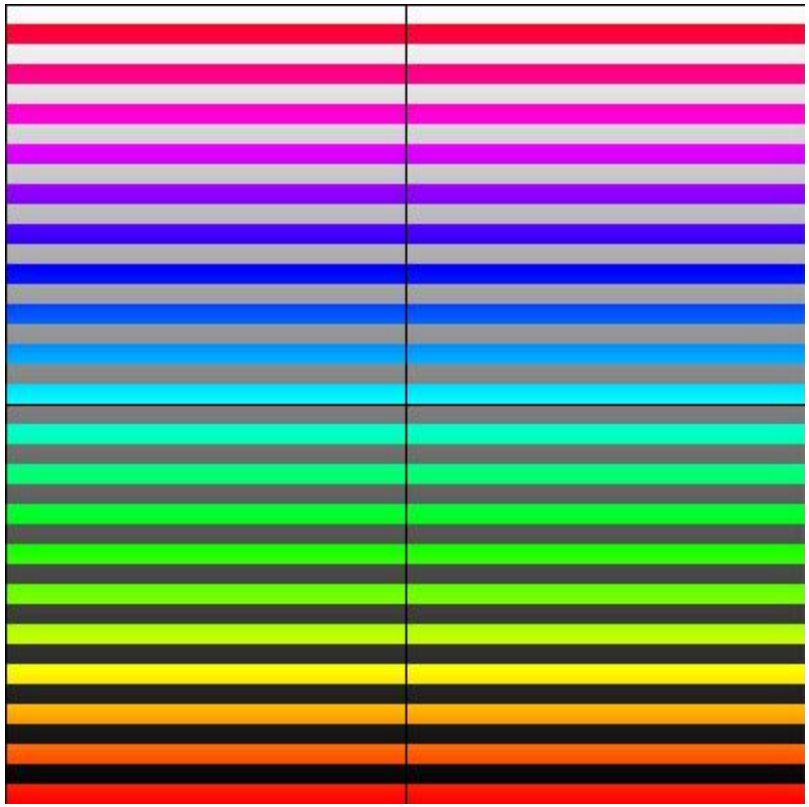
-1 < x < 1, -1 < y < 1

Example: $z \rightarrow w*z$, $w= 2$



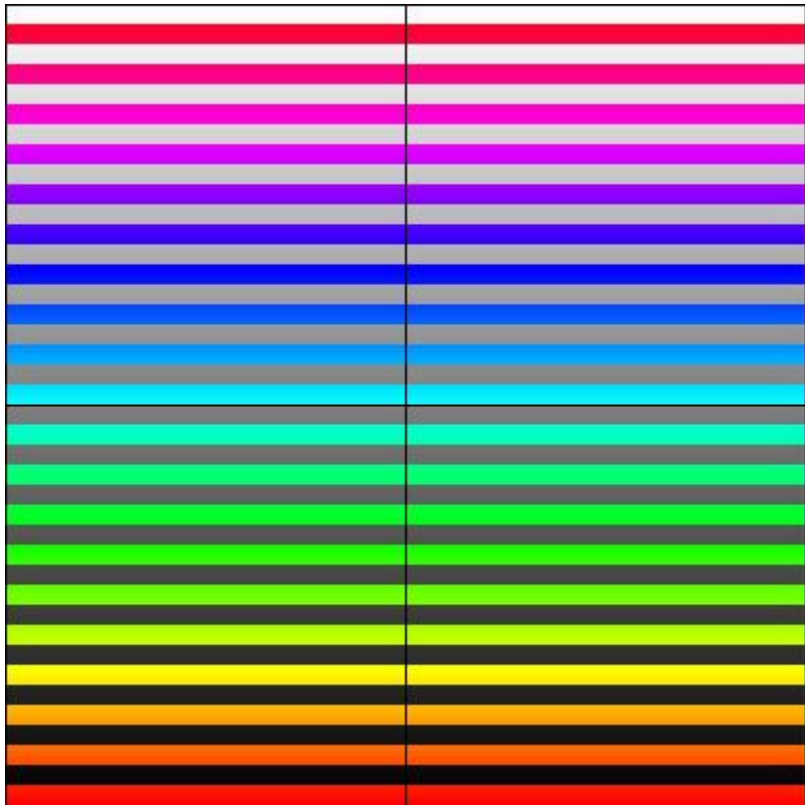
$-1 < x < 1, \quad -1 < y < 1$

Example:
$z \rightarrow w*z$, $w = e^{i\Theta}$, $\Theta = 45^{o}$



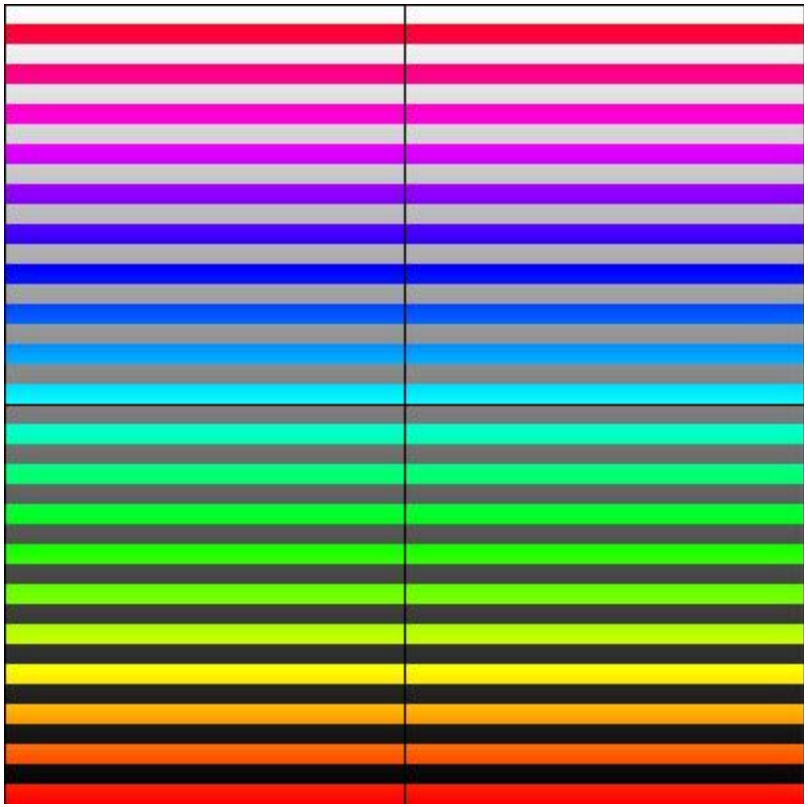
$-1 < x < 1, \quad -1 < y < 1$

Example: z → w+z, w=.2+.4i



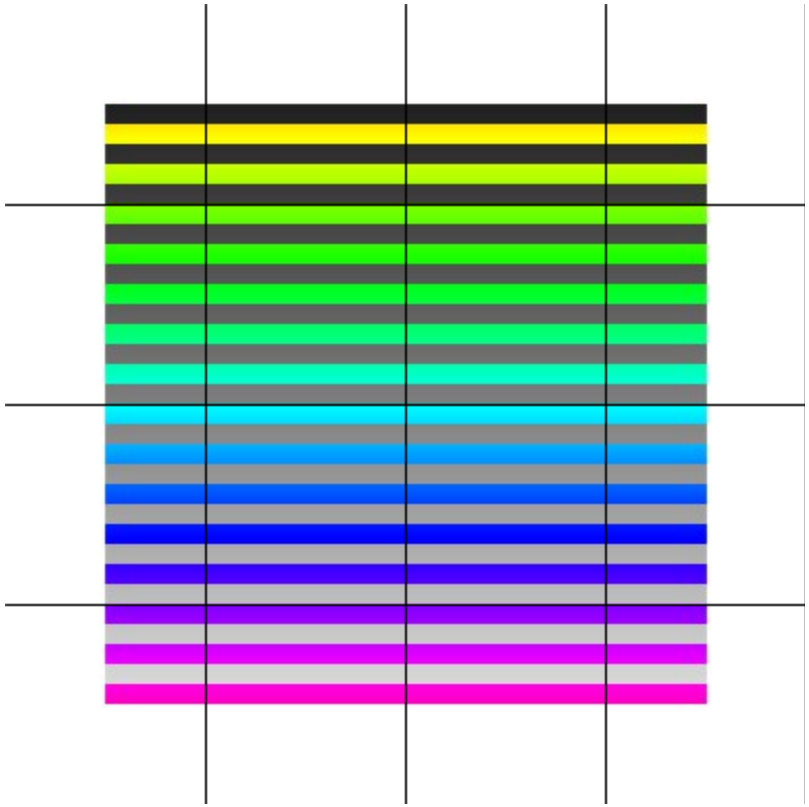
$-1 < x < 1, \quad -1 < y < 1$

Example: $z \rightarrow z^2$



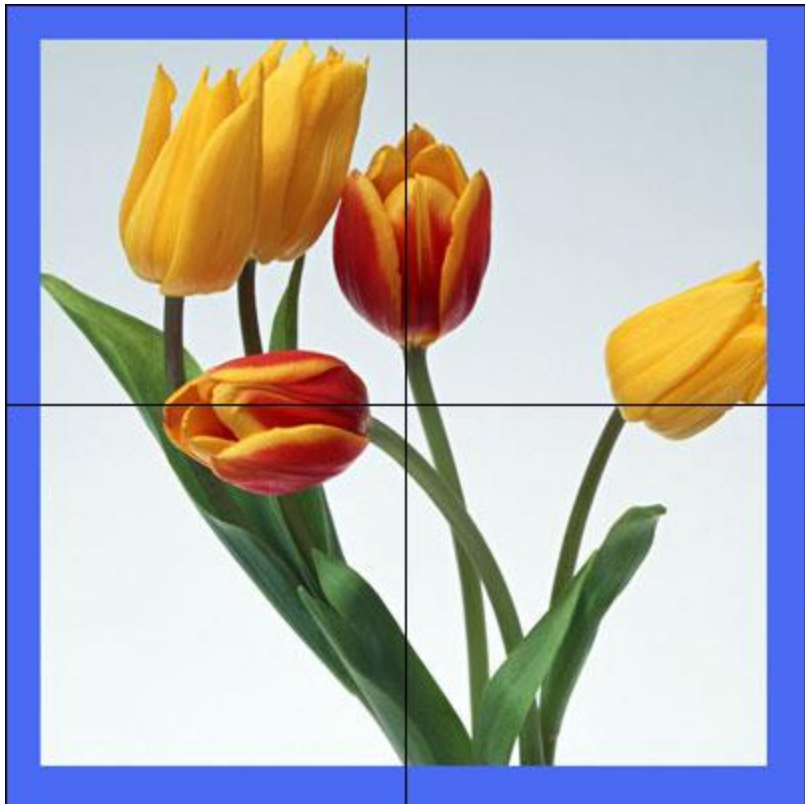
$-1 < x < 1, \quad -1 < y < 1$

Example: $z \rightarrow z^5$



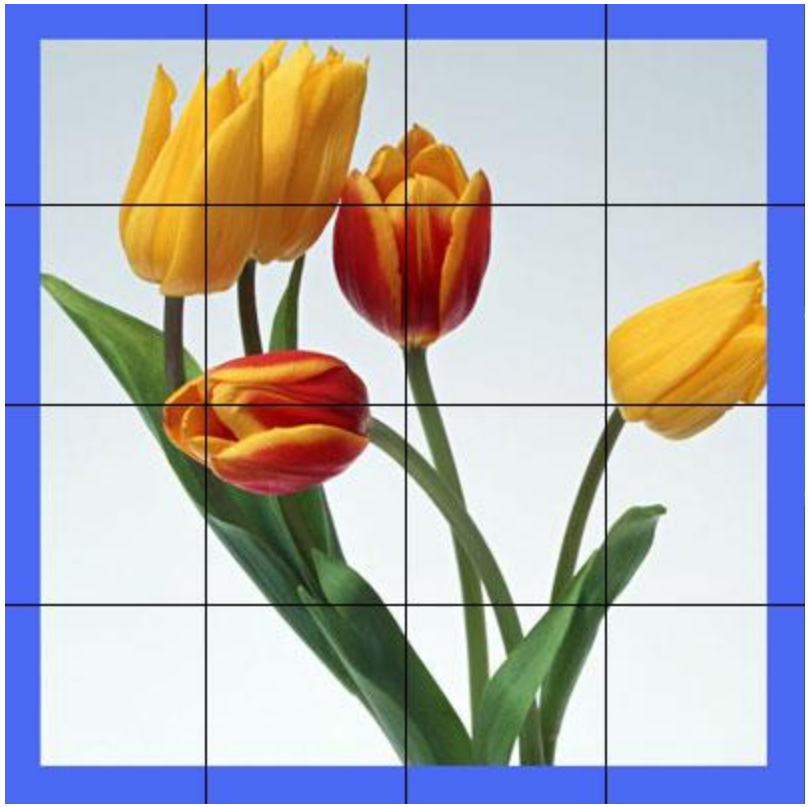
$-2 < x < 2, \quad -2 < y < 2$

Example: $z \rightarrow z^2$



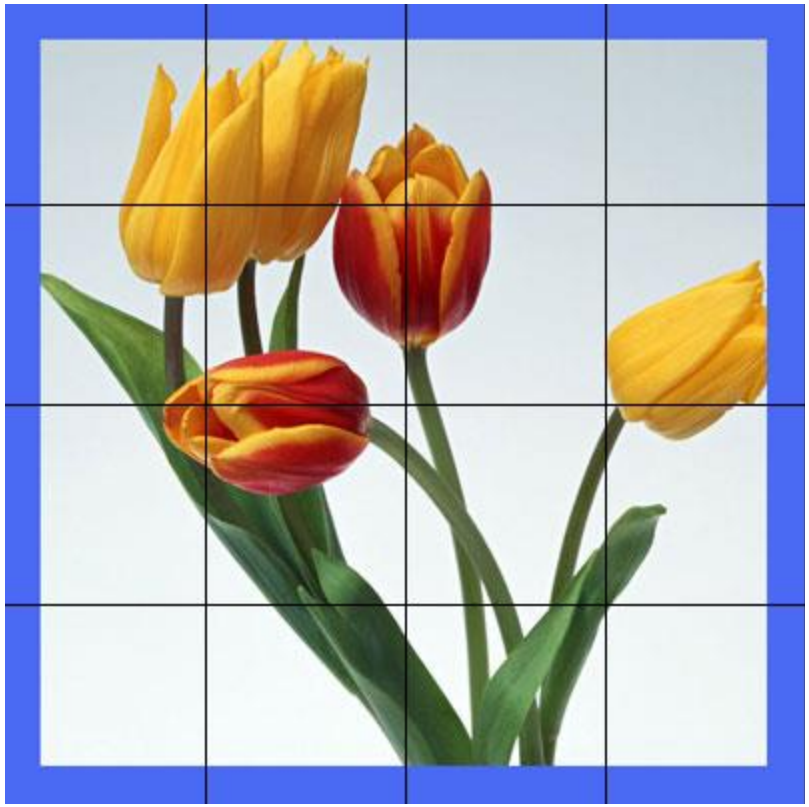
$-1 < x < 1, \quad -1 < y < 1$

Example: $z \rightarrow z^2 - 2$



$-2 < x < 2, \quad -2 < y < 2$

Example: $z \rightarrow z^3 - 1$

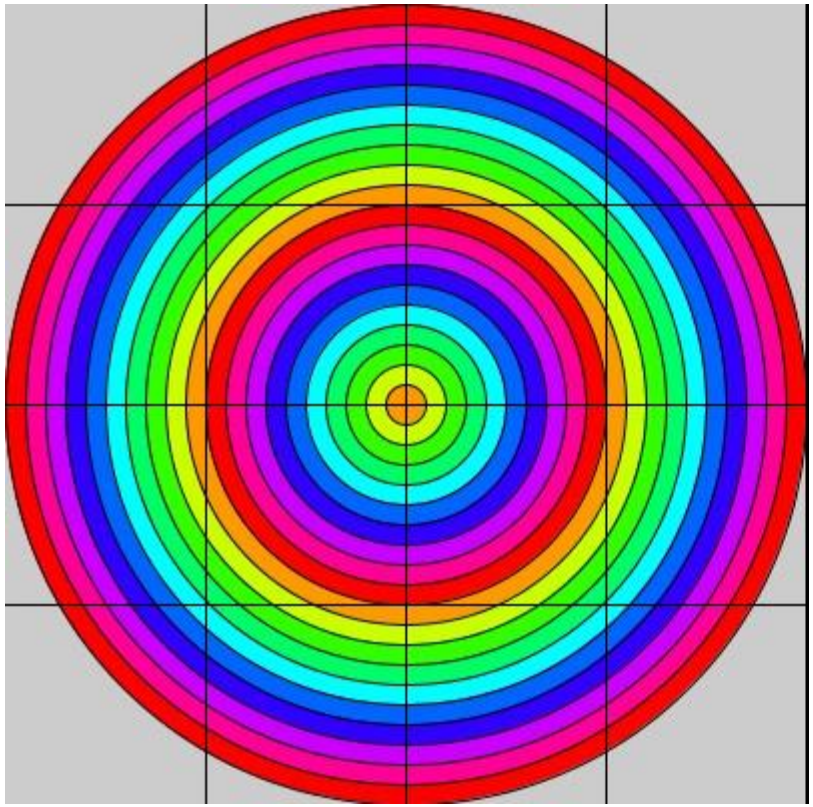


$-2 < x < 2, \quad -2 < y < 2$

Example: $z \rightarrow z^3 + 1$

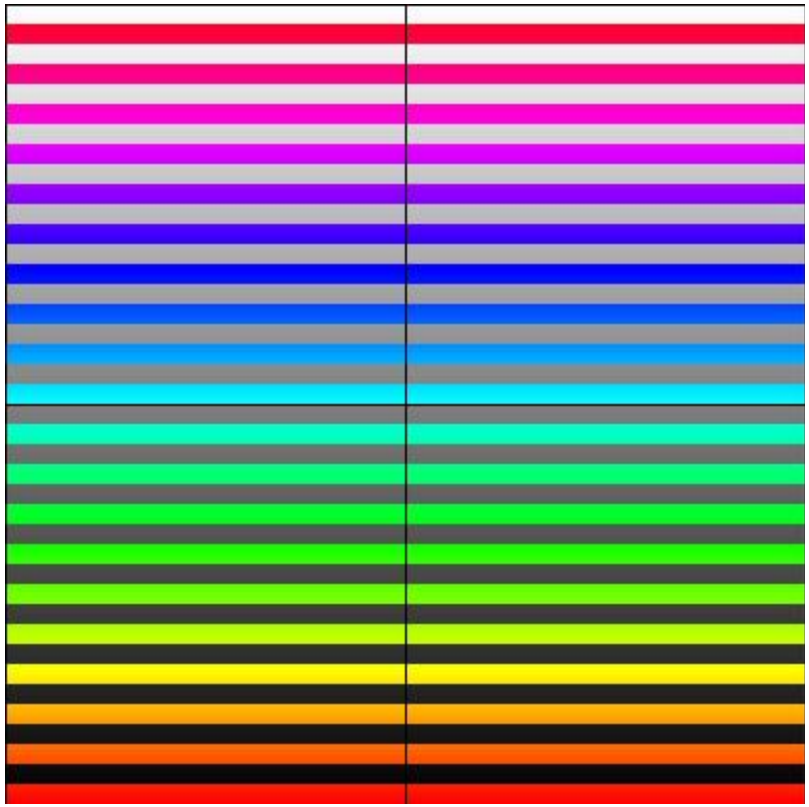
$-2 < x < 2, \quad -2 < y < 2$

Example: $z \rightarrow z^4 + 1$



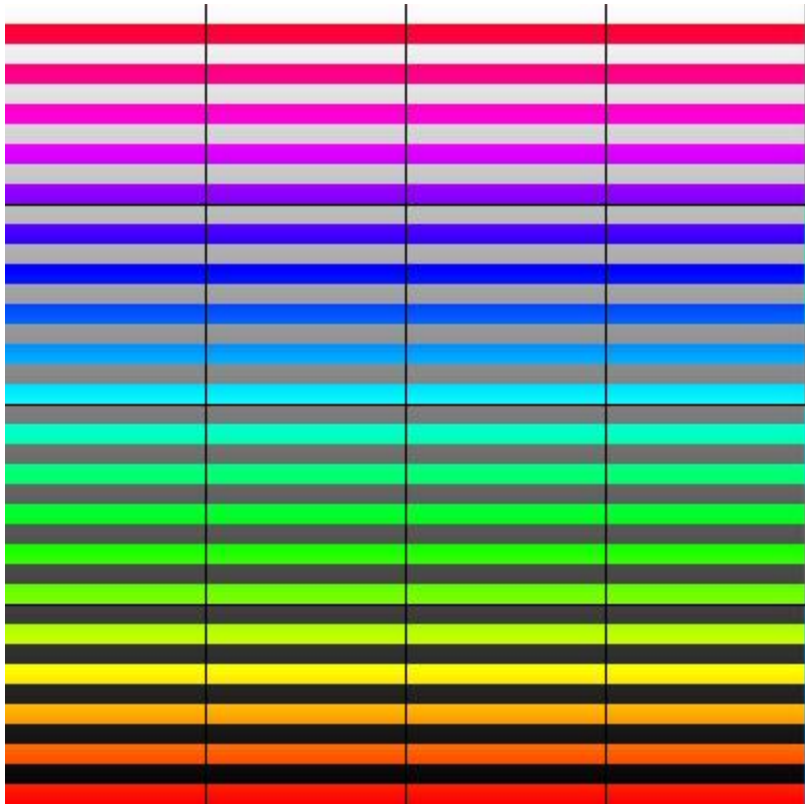
$-2 < x < 2, \quad -2 < y < 2$

Example: $z \rightarrow \sqrt{z} = \sqrt{r}\, e^{i\Theta/2}$



$-1 < x < 1, \quad -1 < y < 1$

Example: $z \rightarrow 1/z$



$-2 < x < 2, \quad -2 < y < 2$

Periodic Real Valued Functions on the Complex Plane

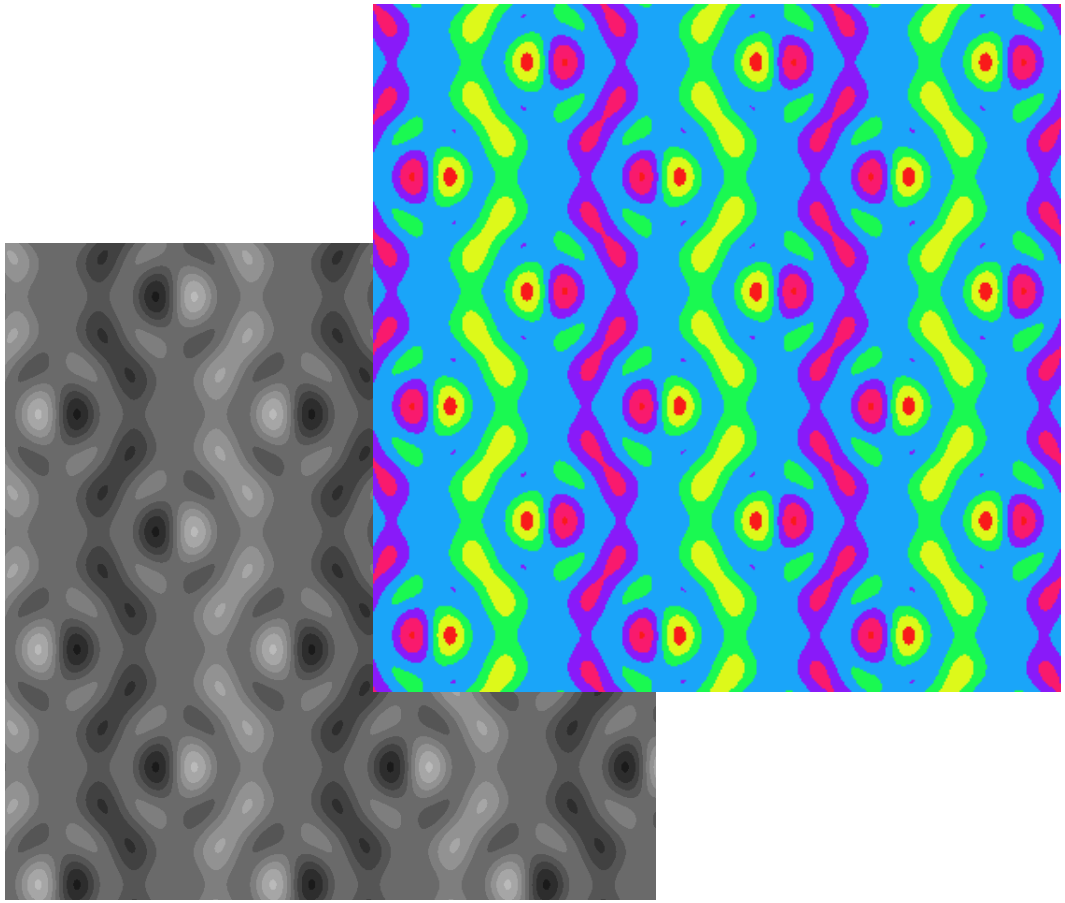
$F(z) = v$ where $z \in C$ and $v \in R$

We can choose F to be periodic such as those containing terms of the form:

cos(aX)*cos(bY)

and

sin(cX)*sin(dY)



Conclusions

- Processing is a powerful programming environment for visualization
- Can be used to
  - Create art
  - Understand math and science
  - General exploration.