Perlin Noise

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(slides with help from **Jyun-Ming Chen**, homepage.ttu.edu.tw/jmchen
and
Harriet Fell, http://www.ccs.neu.edu/home/fell)

The Oscar™

To Ken Perlin for the development of Perlin Noise, a technique used to produce natural appearing textures on computer generated surfaces for motion picture visual effects.

The Movies

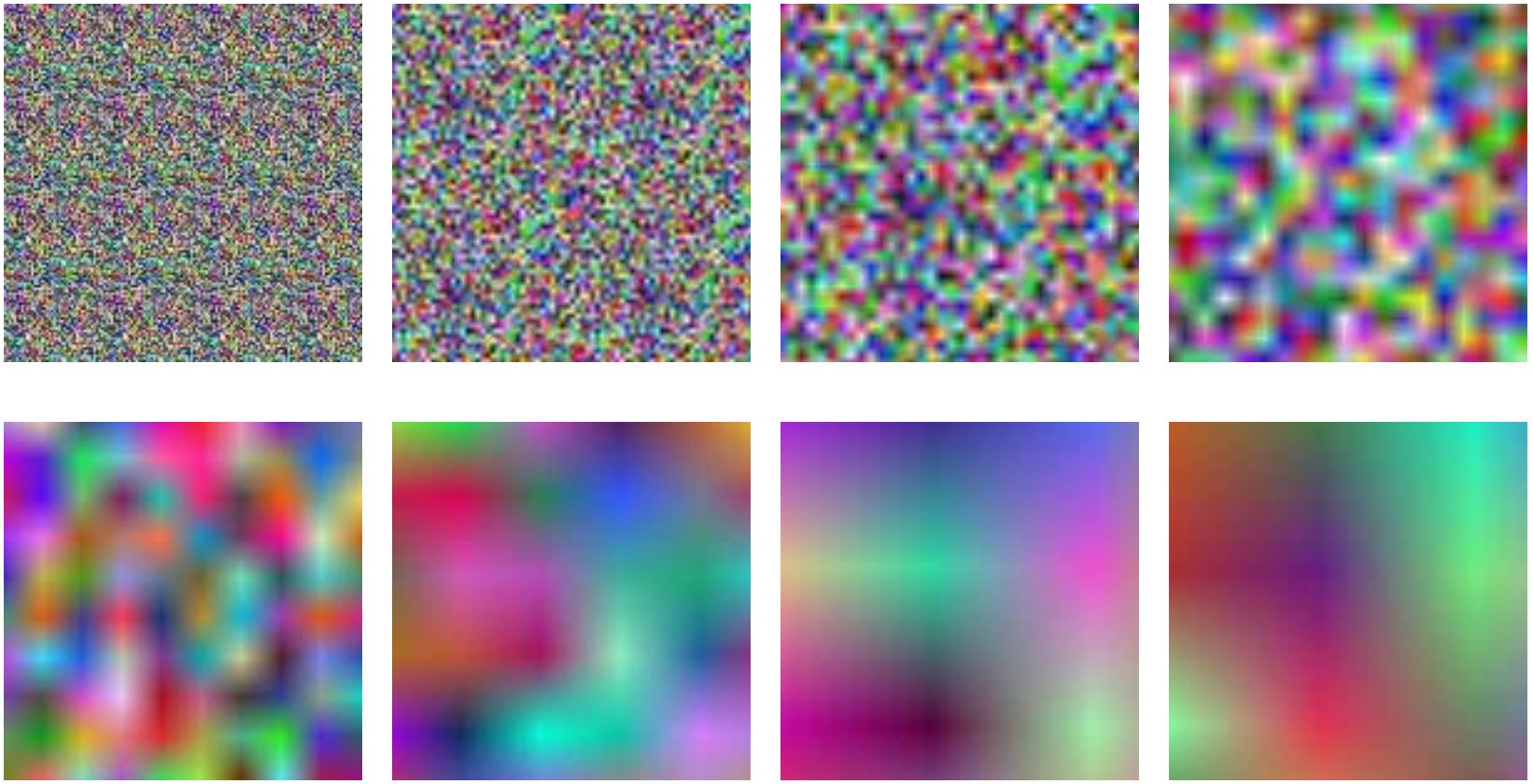
- James Cameron Movies (Abyss,Titanic,...)
- Animated Movies (Lion King, Moses,...)
- Arnold Movies (T2, True Lies, ...)
- Star Wars Episode I
- Star Trek Movies
- Batman Movies
- *and lots of others*

In fact, after around 1990 or so, *every* Hollywood effects film has used it.

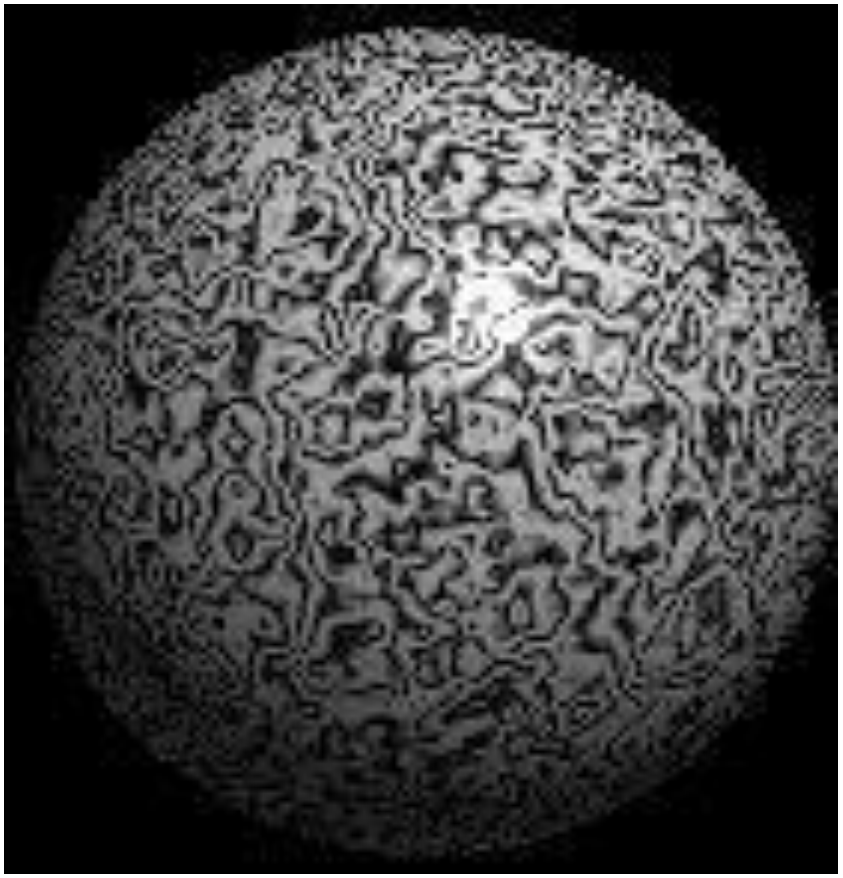
What is Noise?

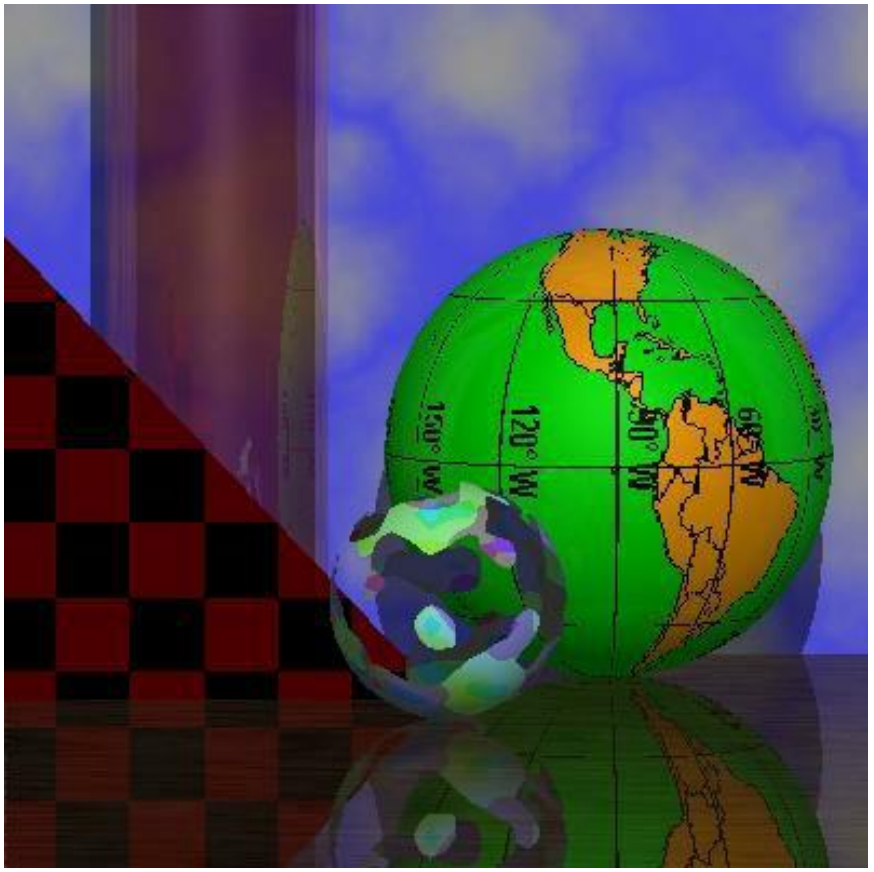
- Noise is a mapping from R^n to R - you input an n-dimensional point with real coordinates, and it returns a real value.
- n=1 for animation
- n=2 cheap texture hacks
- n=3 less-cheap texture hacks
- n=4 time-varying solid textures

Noise is Smooth Randomness

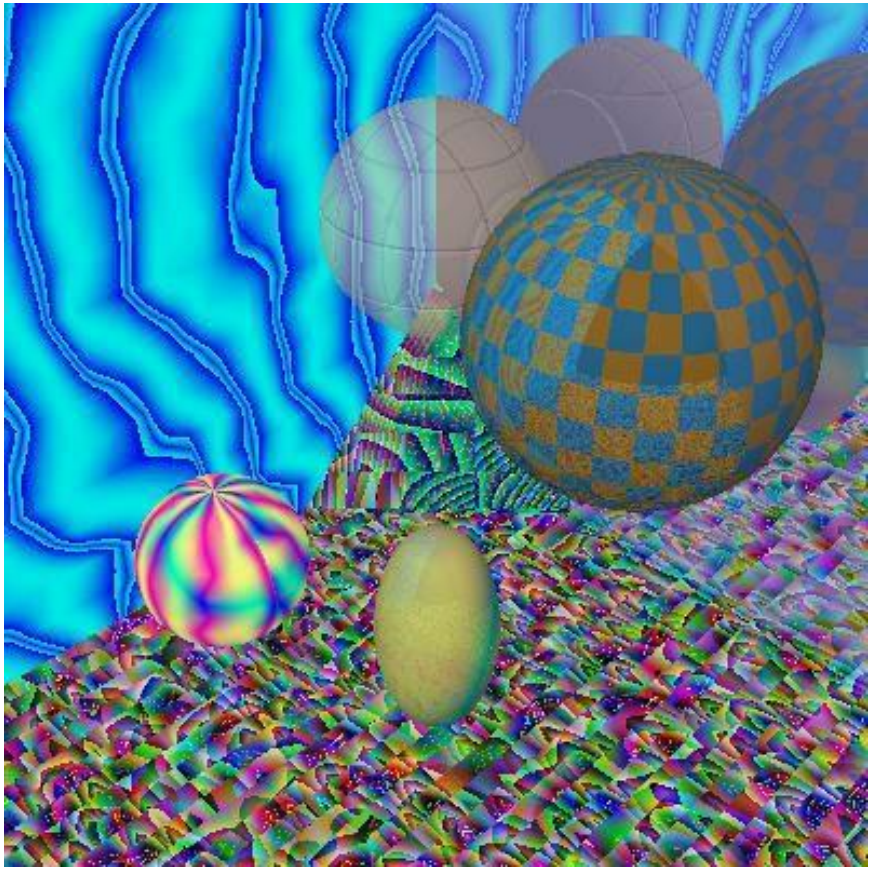


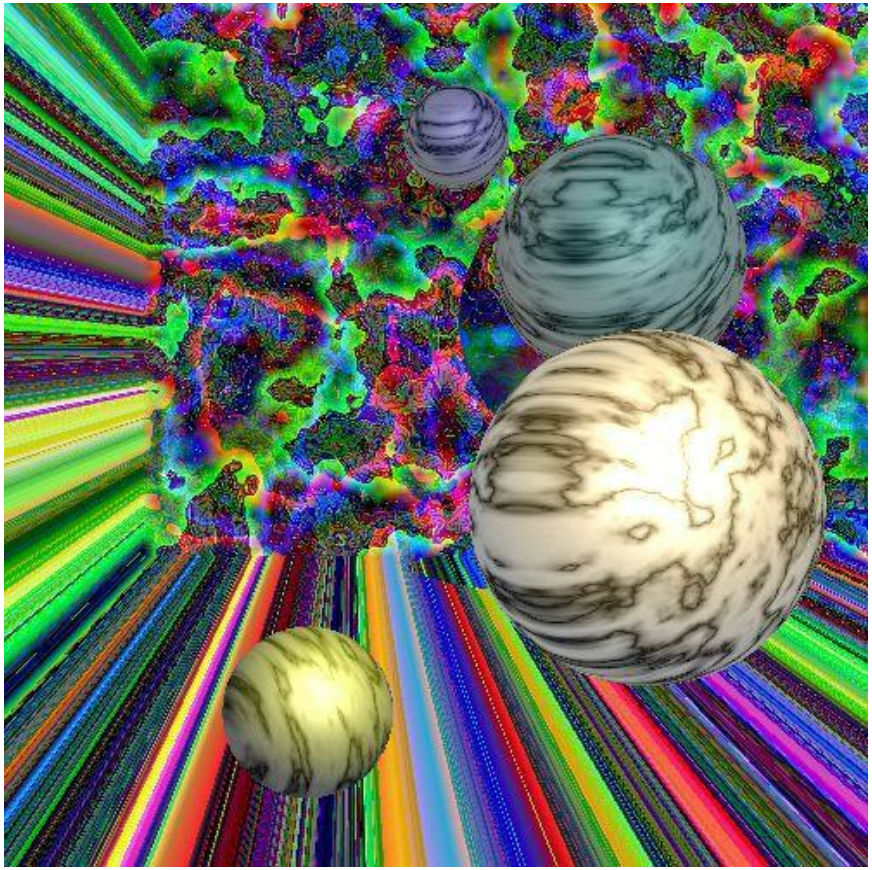
Example Images



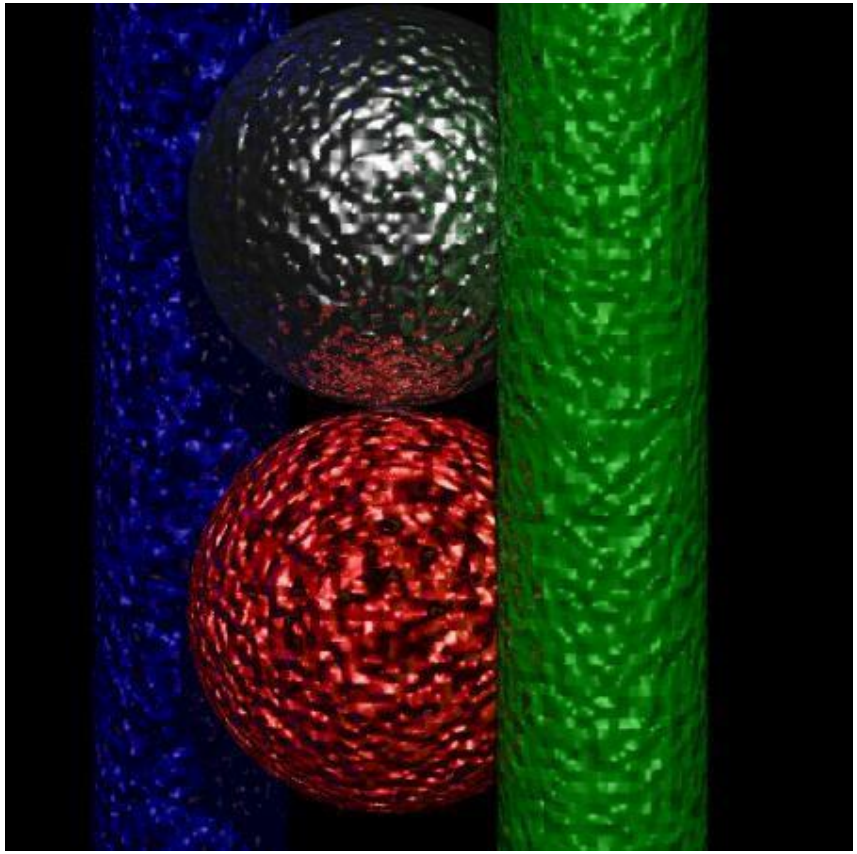


Example Images

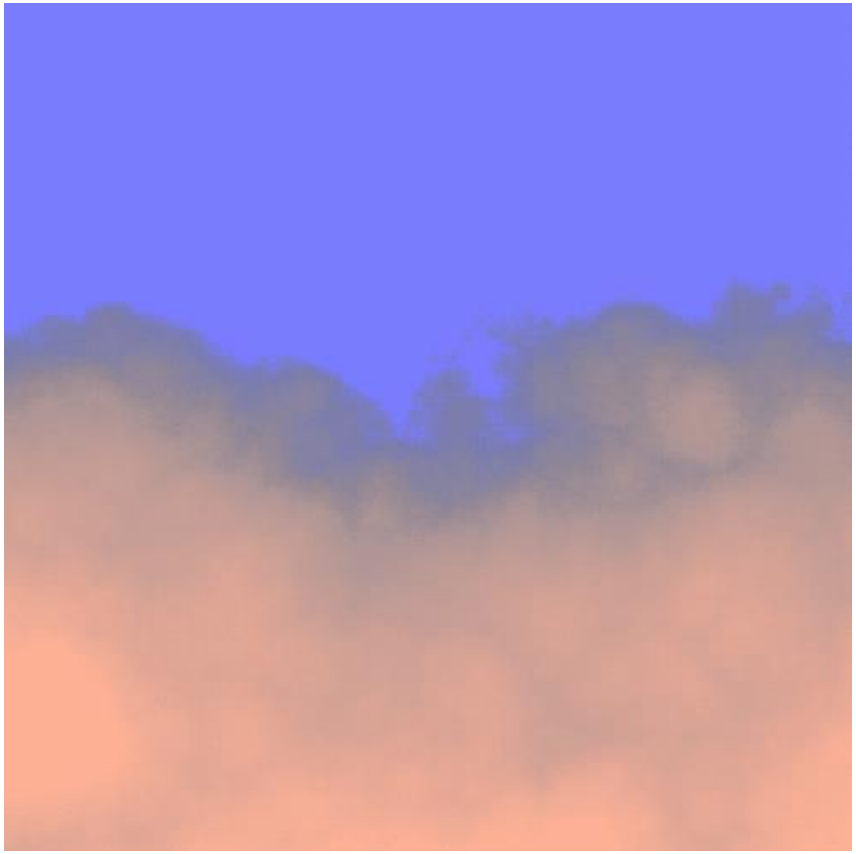


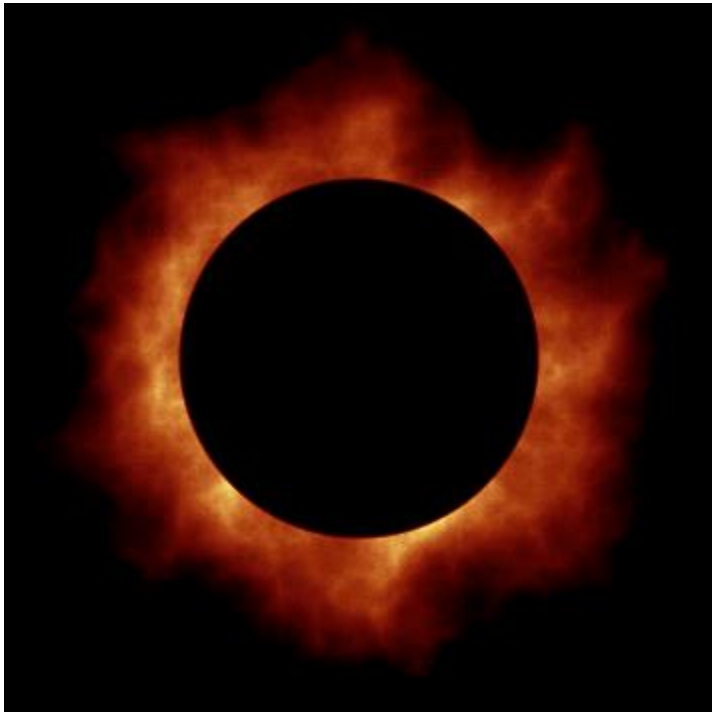


Example Images



Perlin's Clouds and Corona

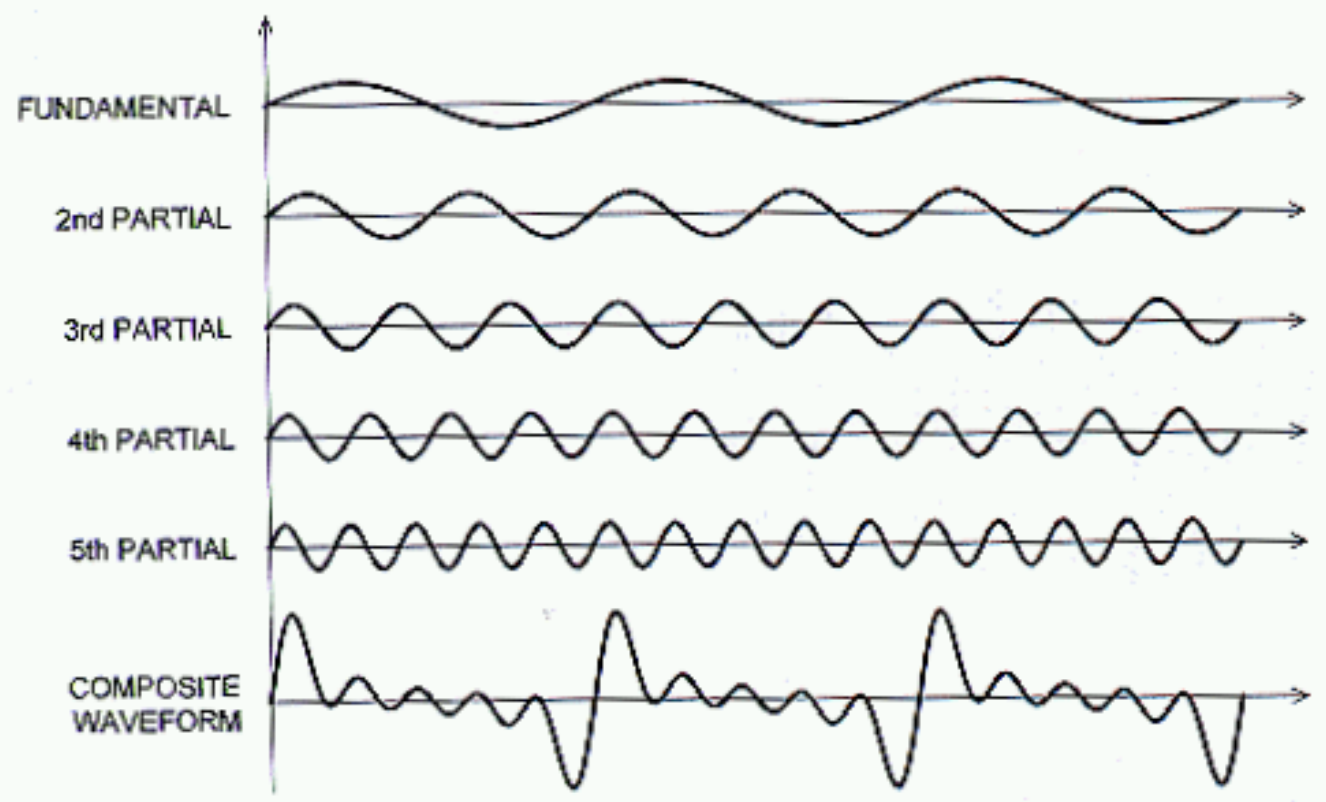




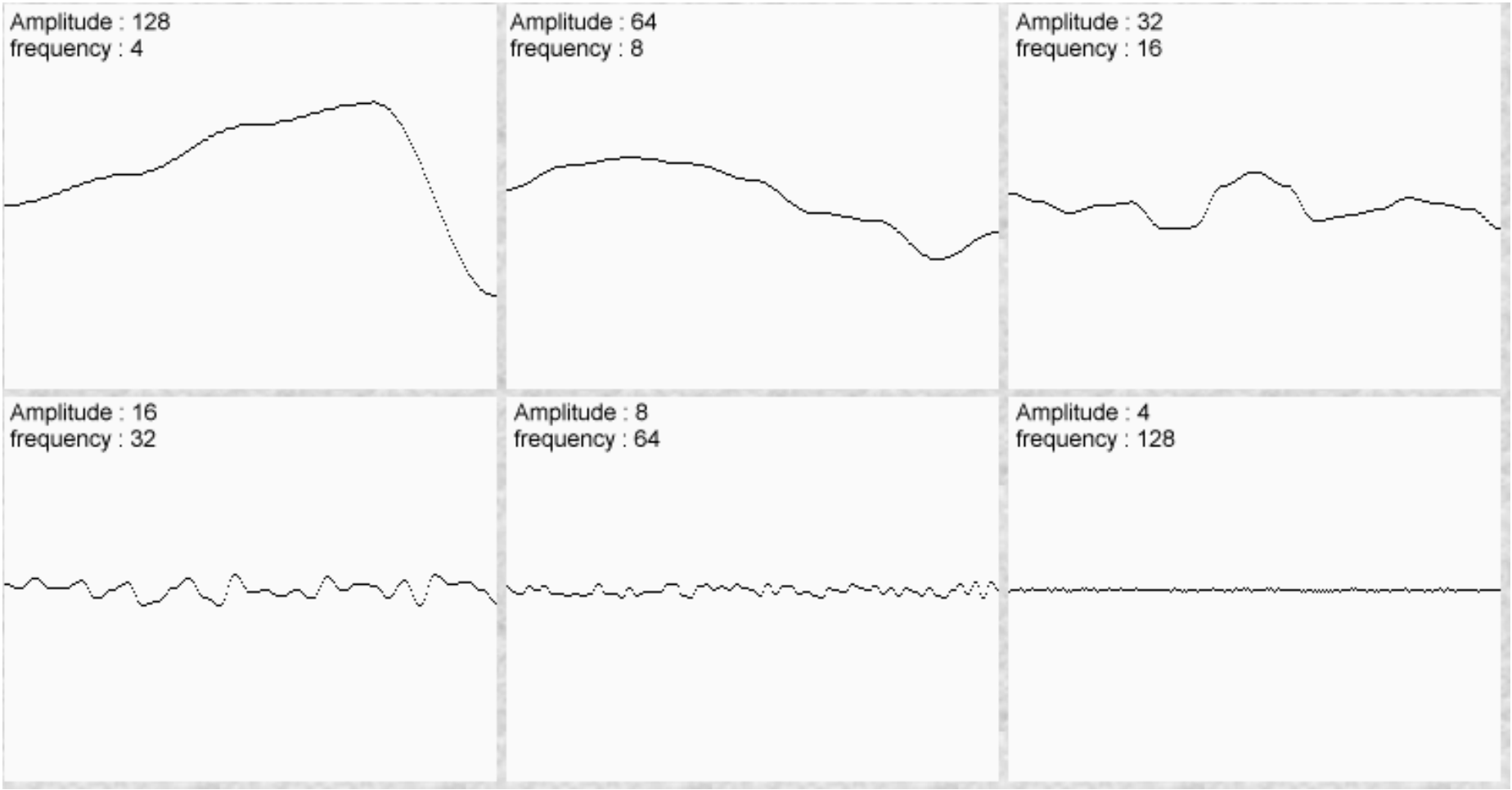
Perlin Noise Function

- Take lots of such smooth functions, with various frequencies and amplitudes
  - Idea similar to fractal, Fourier series, …
- Add them all together to create a nice noisy function.

Fourier Analysis

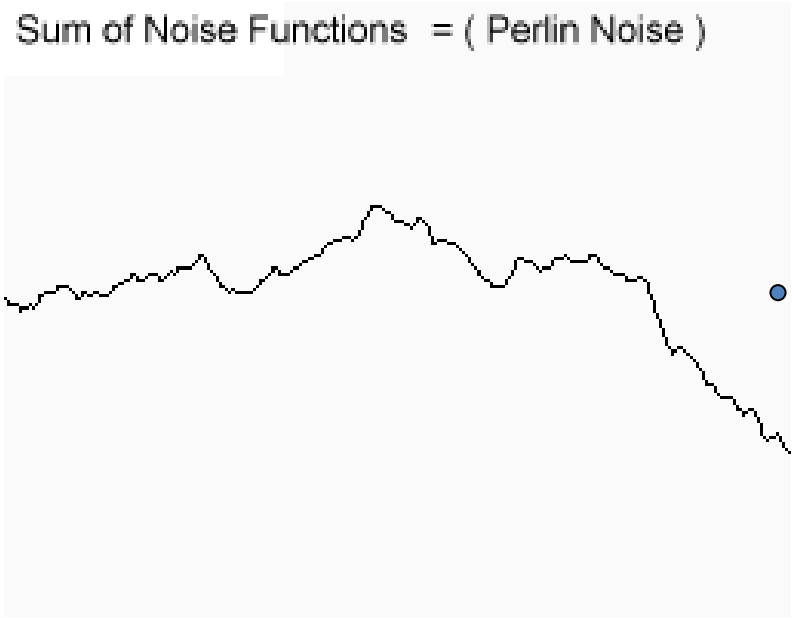


Example


Amplitude : 128
frequency : 4
Amplitude : 64
frequency : 8
Amplitude : 32
frequency : 16
Amplitude : 16
frequency : 32
Amplitude : 8
frequency : 64
Amplitude : 4
frequency : 128

Example (cont)

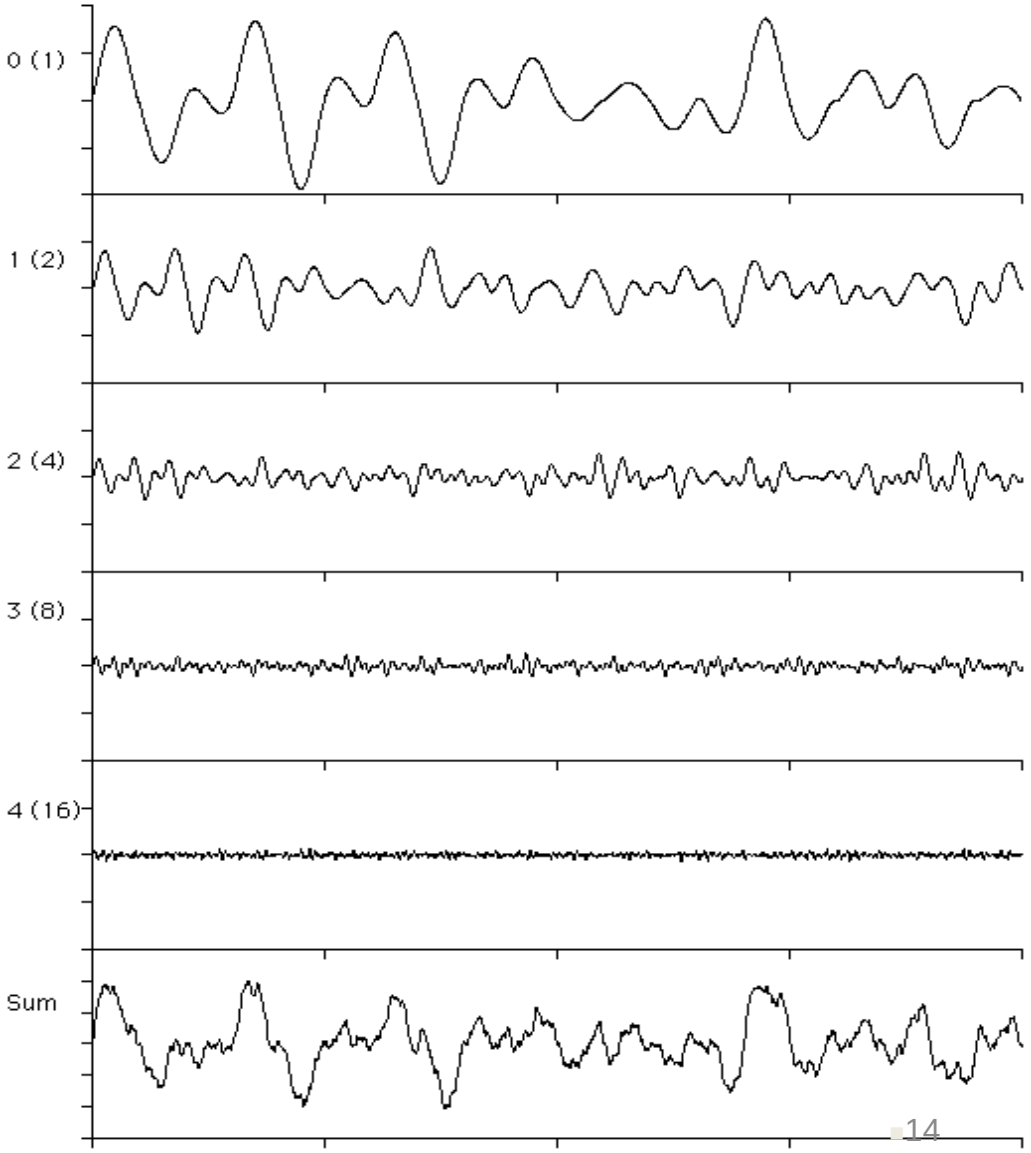
- Function has large, medium and small variations.



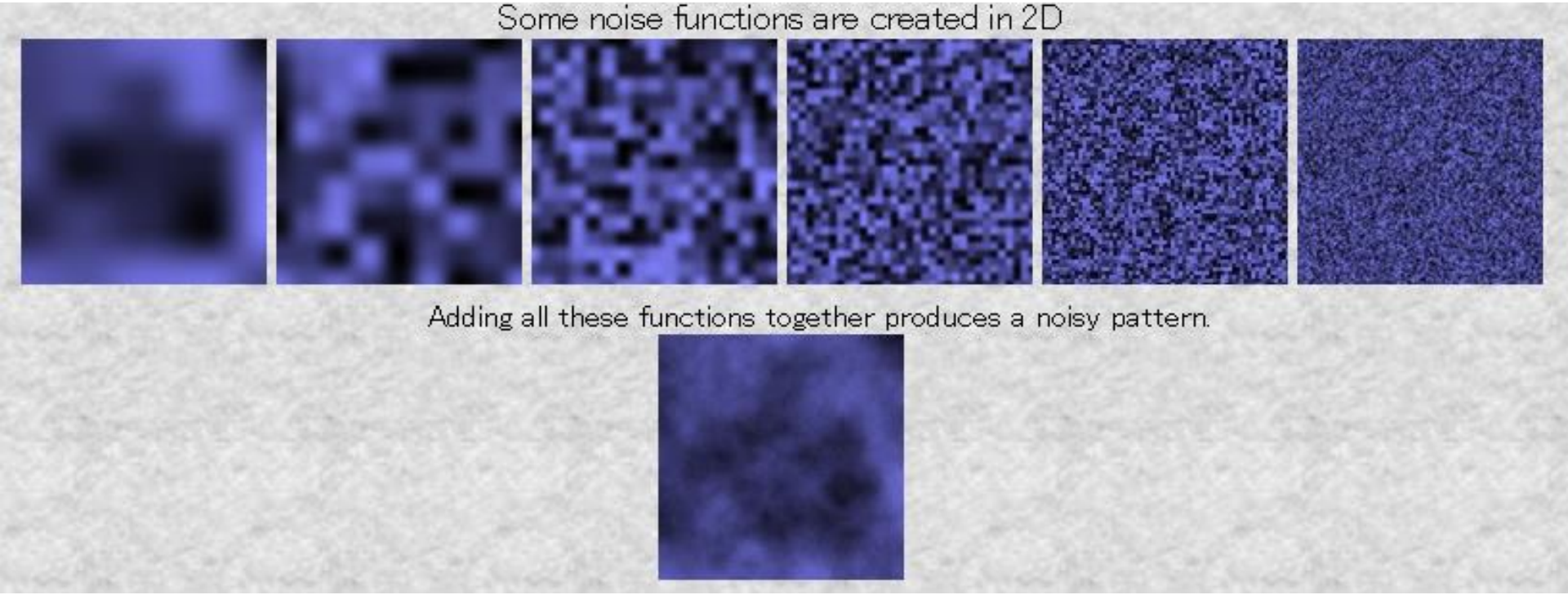
Similar to the ideas of fractal

Alternate formula

$$\mathrm{NOISE}(\mathbf{x}) = \sum_{i=0}^{N-1} \frac{\mathrm{Noise}(b^i \mathbf{x})}{a^i}$$



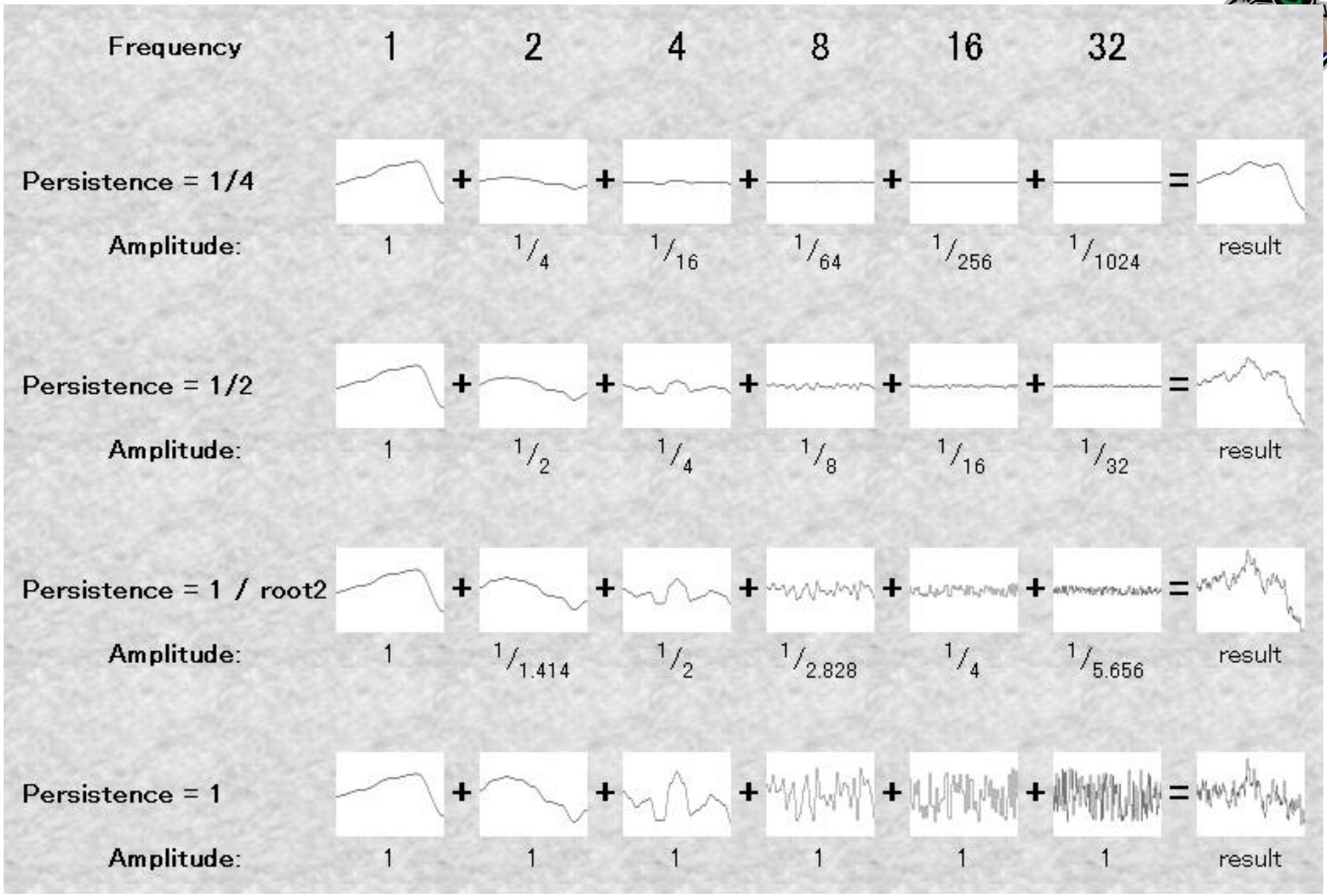
2 dimensions



Persistence

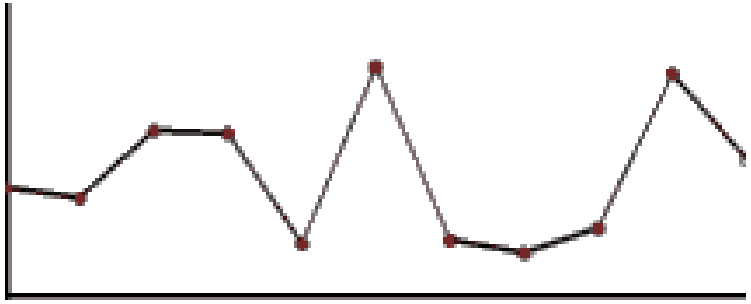
- You can create Perlin noise functions with different characteristics by using other frequencies and amplitudes at each step
  - Is a multiplier that determines how quickly the amplitudes diminish for each successive octave in a Perlin-noise function.

$$\text{frequency} = 2^i$$
$$\text{amplitude} = \text{persistence}^i$$


Frequency
1
2
4
8
16
32
Persistence = 1/4
Amplitude:
1
1/4
1/16
1/64
1/256
1/1024
result
Persistence = 1/2
Amplitude:
1
1/2
1/4
1/8
1/16
1/32
result
Persistence = 1 / root2
Amplitude:
1
1/1.414
1/2
1/2.828
1/4
1/5.656
result
Persistence = 1
Amplitude:
1
1
1
1
1
1
result

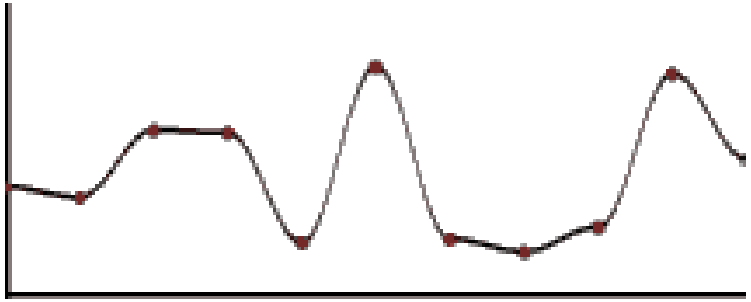
Interpolation

- Linear Interpolation



function
Linear_Interpolate(**a**, **b**, **x**)
return **a***(**1**-**x**) + **b*****x**

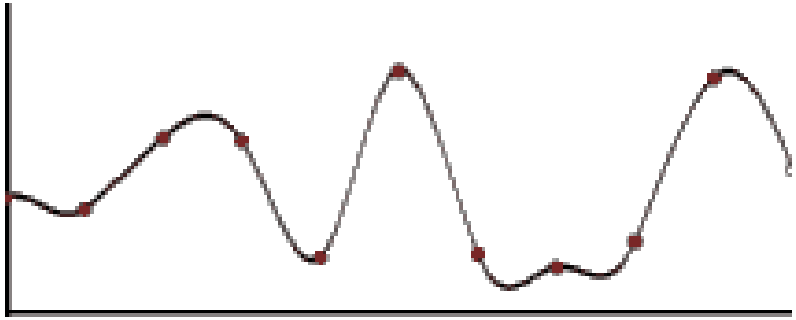
- Cosine Interpolation

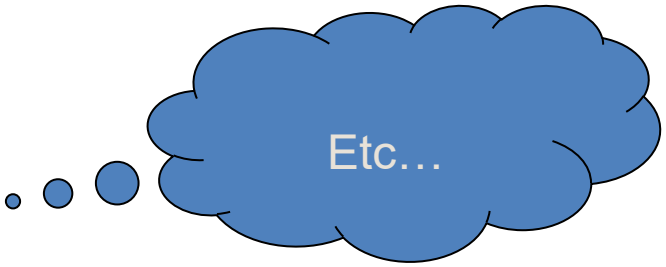


function
Cosine_Interpolate(**a**, **b**, **x**)
ft = **x** * **3.1415927**
f = (**1** - cos(**ft**)) * **.5**
return **a***(**1**-**f**) + **b***f

Interpolation

- Cubic Interpolation





Example Code


```
/* (copyright Ken Perlin) */
#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#define B 0x100
#define BM 0xff
#define N 0x1000
#define NP 12   /* 2^N */
#define NM 0xfff
static p[B + B + 2];
static float g3[B + B + 2][3];
static float g2[B + B + 2][2];
static float g1[B + B + 2];
static start = 1;
static void init(void);
#define s_curve(t) ( t * t * (3. - 2. * t) )
#define lerp(t, a, b) ( a + t * (b - a) )
#define setup(i,b0,b1,r0,r1)\
    t = vec[i] + N;  b0 = ((int)t) & BM;  b1 = (b0+1) & BM;  r0 = t - (int)t; r1 = r0 - 1.;
double noise1(double arg)
{
                    int bx0, bx1;
                    float rx0, rx1, sx, t, u, v, vec[1];
                    vec[0] = arg;
                    if (start) {
                        start = 0;
                        init();
                    }
                    setup(0, bx0,bx1, rx0,rx1);
                    sx = s_curve(rx0);
                    u = rx0 * g1[ p[ bx0 ] ];
                    v = rx1 * g1[ p[ bx1 ] ];
                    return lerp(sx, u, v);
}
float noise2(float vec[2])
{
                    int bx0, bx1, by0, by1, b00, b10, b01, b11;
                    float rx0, rx1, ry0, ry1, *q, sx, sy, a, b, t, u, v;
                    register i, j;
                    if (start) {
                        start = 0;
                        init();
                    }
                    setup(0, bx0,bx1, rx0,rx1);
                    setup(1, by0,by1, ry0,ry1);
                    i = p[ bx0 ];
                    j = p[ bx1 ];
                    b00 = p[ i + by0 ];
                    b10 = p[ j + by0 ];
                    b01 = p[ i + by1 ];
                    b11 = p[ j + by1 ];
                    sx = s_curve(rx0);
                    sy = s_curve(ry0);
#define at2(rx,ry) ( rx * q[0] + ry * q[1] )
                    q = g2[ b00 ] ; u = at2(rx0,ry0);
                    q = g2[ b10 ] ; v = at2(rx1,ry0);
                    a = lerp(sx, u, v);
                    q = g2[ b01 ] ; u = at2(rx0,ry1);
                    q = g2[ b11 ] ; v = at2(rx1,ry1);
                    b = lerp(sx, u, v);
                    return lerp(sy, a, b);
}

float noise3(float vec[3])
{
                    int bx0, bx1, by0, by1, bz0, bz1, b00, b10, b01, b11;
                    float rx0, rx1, ry0, ry1, rz0, rz1, *q, sy, sz, a, b, c, d, t, u, v;
                    register i, j;
                    if (start) {
                      start = 0;
                      init();
                    }
                    setup(0, bx0,bx1, rx0,rx1);
                    setup(1, by0,by1, ry0,ry1);
                    setup(2, bz0,bz1, rz0,rz1);
                    i = p[ bx0 ];
                    j = p[ bx1 ];
                    b00 = p[ i + by0 ];
                    b10 = p[ j + by0 ];
                    b01 = p[ i + by1 ];
                    b11 = p[ j + by1 ];
                    t  = s_curve(rx0);
                    sy = s_curve(ry0);
                    sz = s_curve(rz0);
#define at3(rx,ry,rz) ( rx * q[0] + ry * q[1] + rz * q[2] )
                    q = g3[ b00 + bz0 ] ; u = at3(rx0,ry0,rz0);
                    q = g3[ b10 + bz0 ] ; v = at3(rx1,ry0,rz0);
                    a = lerp(t, u, v);
                    q = g3[ b01 + bz0 ] ; u = at3(rx0,ry1,rz0);
                    q = g3[ b11 + bz0 ] ; v = at3(rx1,ry1,rz0);
                    b = lerp(t, u, v);
                    c = lerp(sy, a, b);
                    q = g3[ b00 + bz1 ] ; u = at3(rx0,ry0,rz1);
                    q = g3[ b10 + bz1 ] ; v = at3(rx1,ry0,rz1);
                    a = lerp(t, u, v);
                    q = g3[ b01 + bz1 ] ; u = at3(rx0,ry1,rz1);
                    q = g3[ b11 + bz1 ] ; v = at3(rx1,ry1,rz1);
                    b = lerp(t, u, v);
                    d = lerp(sy, a, b);
                    return lerp(sz, c, d);
}
static void normalize2(float v[2])
{
                    float s;
                    s = sqrt(v[0] * v[0] + v[1] * v[1]);
                    v[0] = v[0] / s;
                    v[1] = v[1] / s;
}
static void normalize3(float v[3])
{
                    float s;
                    s = sqrt(v[0] * v[0] + v[1] * v[1] + v[2] * v[2]);
                    v[0] = v[0] / s;
                    v[1] = v[1] / s;
                    v[2] = v[2] / s;
}
static void init(void)
{
                    int i, j, k;
                    for (i = 0 ; i < B ; i++) {
                      p[i] = i;
                      g1[i] = (float)((random() % (B + B)) - B) / B;
                      for (j = 0 ; j < 2 ; j++)
                        g2[i][j] = (float)((random() % (B + B)) - B) / B;
                      normalize2(g2[i]);
                      for (j = 0 ; j < 3 ; j++)
                        g3[i][j] = (float)((random() % (B + B)) - B) / B;
                      normalize3(g3[i]);
                    }
                    while (--i) {
                      k = p[i];
                      p[i] = p[j = random() % B];
                      p[j] = k;
                    }
                    for (i = 0 ; i < B + 2 ; i++) {
                      p[B + i] = p[i];
                      g1[B + i] = g1[i];
                      for (j = 0 ; j < 2 ; j++)
                        g2[B + i][j] = g2[i][j];
                      for (j = 0 ; j < 3 ; j++)
                        g3[B + i][j] = g3[i][j];
                    }
}
```

http://mrl.nyu.edu/~perlin/