PI Presentation

Fractals in VFX

research of Fractal, a brief illustration of the HDA produced

Di Yang

CONTENTS

PART 01

Introduction and Background

01 Introduction and Background

Benoit Mandelbrot(20 November 1924 – 14 October 2010)

Definition of Fractal

1. "a rough or fragmented geometric shape that can be split into parts, each of which is (at least approximately) a reduced-size copy of the whole"(Benoit Mandelbrot). This property is called **Self-similarity**

2. **Fractal Dimension** is a ratio providing a statistical index of complexity comparing how the detail in a fractal pattern changes with the scale at which it is measured.

01 Introduction and Background

Benoit Mandelbrot(20 November 1924 – 14 October 2010)

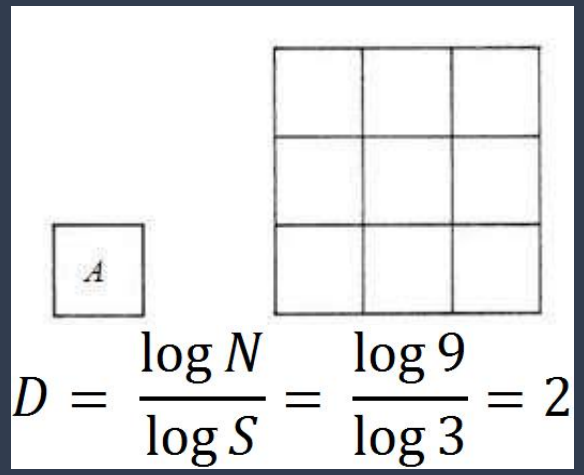
Self-similarity

Fractals are typically self-similar patterns, where self-similar means they are "the same from near as from far".

Some different Self-similarity:

- Exact self-similarity
- Quasi self-similarity
- Qualitative self-similarity
- Statistical self-similarity
- Multifractal scaling

01 Introduction and Background



Dimension Example: Dimension of a square

Fractal Dimension

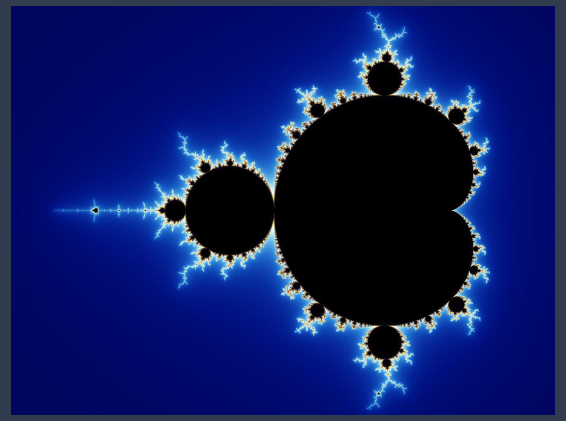
Dimension - **how much an object fills a space**

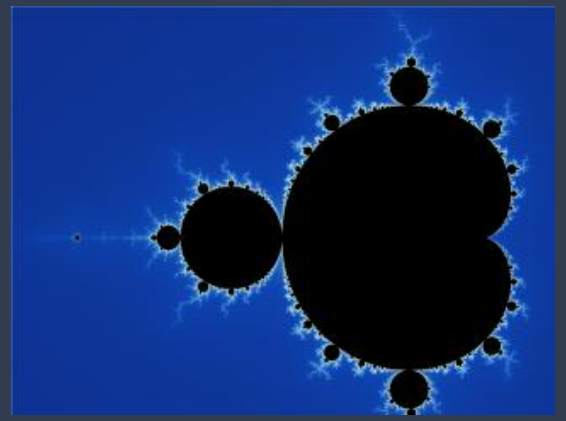
$$D = \frac{\log N}{\log S}$$

S represents the scaling factor and is always a natural number.

N represents the number of smaller, self-similar figures (for a scaling factor S) needed to create the larger figure.

01 Introduction and Background





By Created by Wolfgang Beyer with the program Ultra Fractal 3. - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=321973

WHAT IS A FRACTAL

A fractal is a never ending pattern that repeats itself at different scales.

1. Fractals are extremely complex, sometimes infinitely complex - meaning you can zoom in and find the same shapes forever

2. A fractal is made by repeating a simple process again and again.

01 Introduction and Background

Created by FractalFoundation
https://www.FractalFoundation.org
Fractals Are SMART: Science, Math & Art!

Fractals in Natural

Fractals are found all over nature, spanning a huge range of scales.

Branching :

We find the same patterns again and again, from the tiny branching of our blood vessels and neurons to the branching of trees, lightning bolts, and river networks.

Spiral :

The spiral is another extremely common fractal in nature, found over a huge range of scales.

.....

01 Introduction and Background

Marvel's 'Doctor Strange.'

Fractals in VFX

1. It is widely used in various movies:

   Tron Legacy (2010), Inception (2010) or Limitless (2011),Lucy (2014), **Doctor Strange (2016)**, Suicide Squad (2016) and Guardians of the Galaxy Vol. 2 (2017)

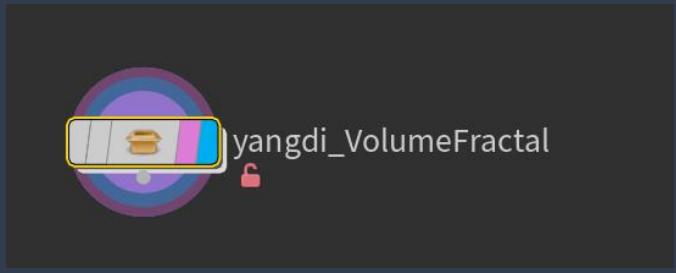
2. Film directors have been increasingly using CGI fractals for creating mesmerizing fantasy landscapes,

3. VFX studios have directly incorporated a custom CG fractal creation tool to their VFX pipeline, and directors had to deal with the unattainable nature of fractals.

PART 02

implementation process

02 Implementation Process



By DI Yang, GeometryFractal HDA

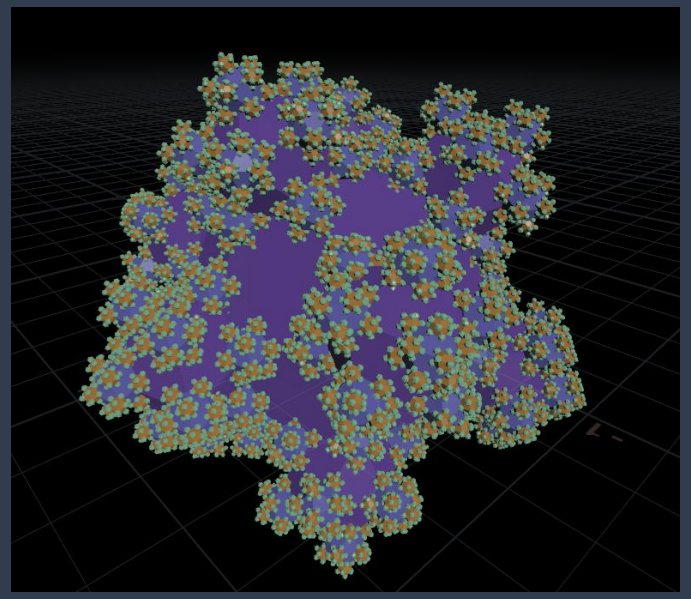
Dilemmas facing at the beginning

1. Programming with VEX or VOPSOP has huge advantages in implementing algorithms, intuitive and fast.
   but weak at deal with Geometry.

2. Using Houdini nodes also has problems in calculating and time-consuming

Make two different HDAs handle different situations between volume and geometry.

02 Implementation Process



By DI Yang, GeometryFractal HDA

Basic Fractals

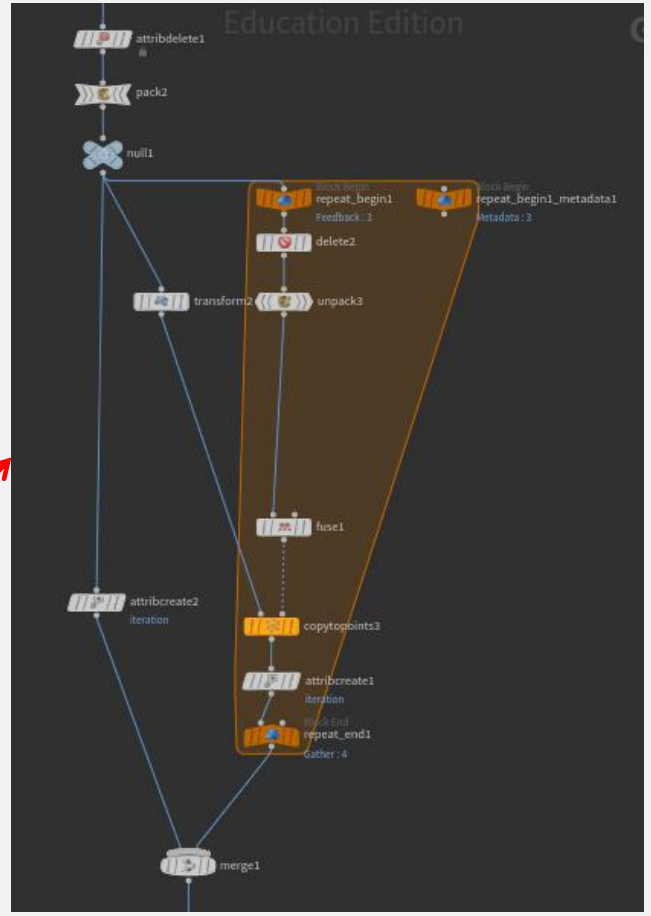
recreate the iterated one base on the older one.

According to fractal theory:

1. infinitely self-similar
2. iterated
3. having fractal dimensions

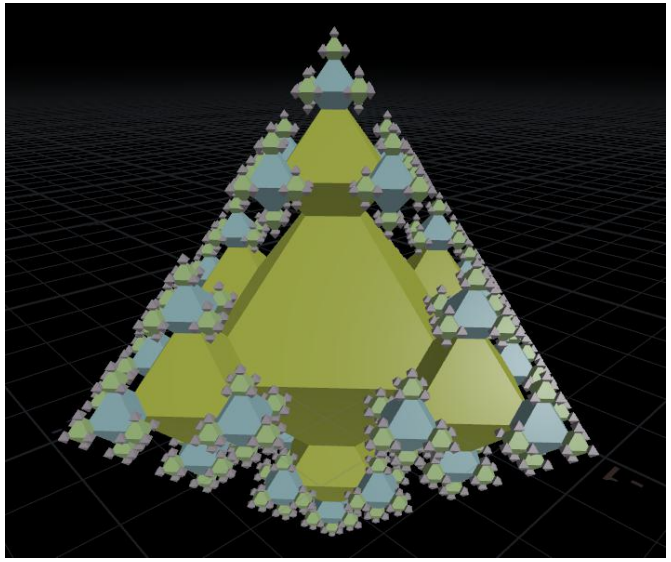
houdini nodes:

1. copytopoints
2. Forloop



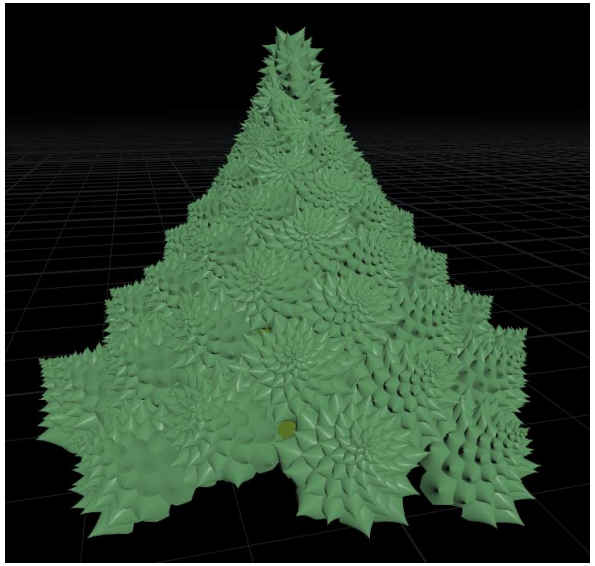
02 Implementation Process

Octahedron



Change the GeometryType to 2

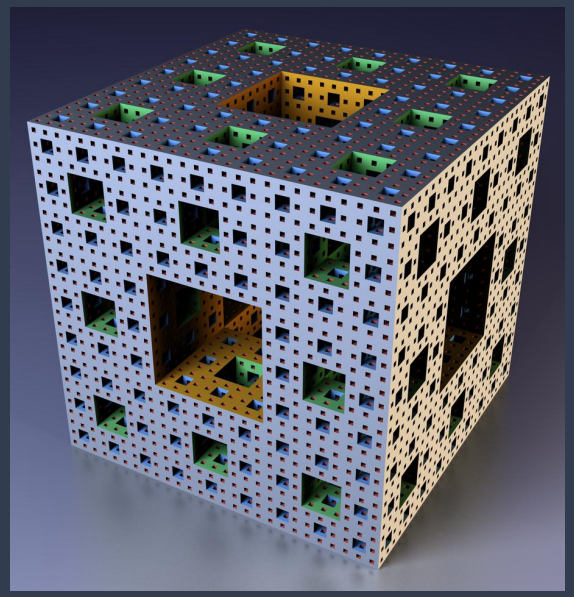
Romanesco broccoli



Check on Enableimport

ues the input#1 Geometry

02 Implementation Process



By Niabot - Own work, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=7818920

Menger sponge

The construction of a Menger sponge can be described as follows:

1. Begin with a cube.

2. Divide every face of the cube into nine squares, like Rubik's Cube. This subdivides the cube into 27 smaller cubes.

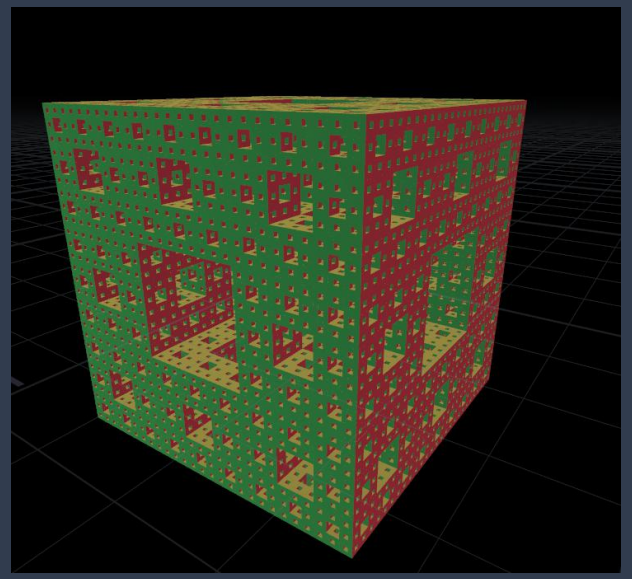
3. Remove the smaller cube in the middle of each face, and remove the smaller cube in the very center of the larger cube, leaving 20 smaller cubes. This is a level-1 Menger sponge (resembling a void cube).

4. Repeat steps two and three for each of the remaining smaller cubes, and continue to iterate ad infinitum.

(Daniel Shiffman and Wikipedia)

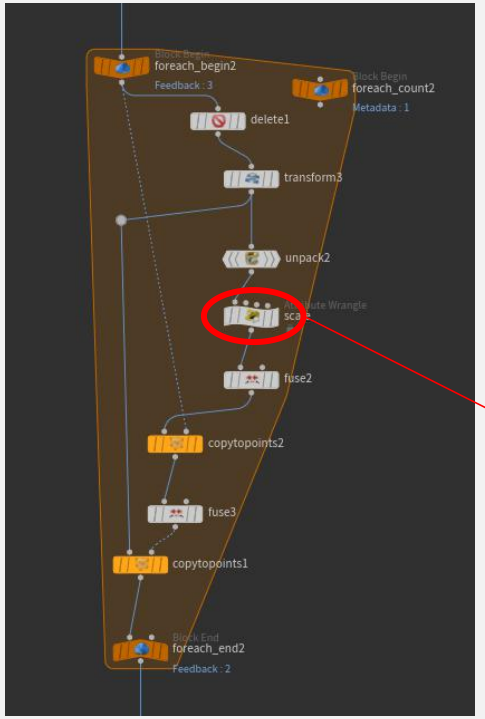
replace the older one by new iterated one.

02 Implementation Process



By DI Yang, GeometryFractal HDA

Implementation in houdini

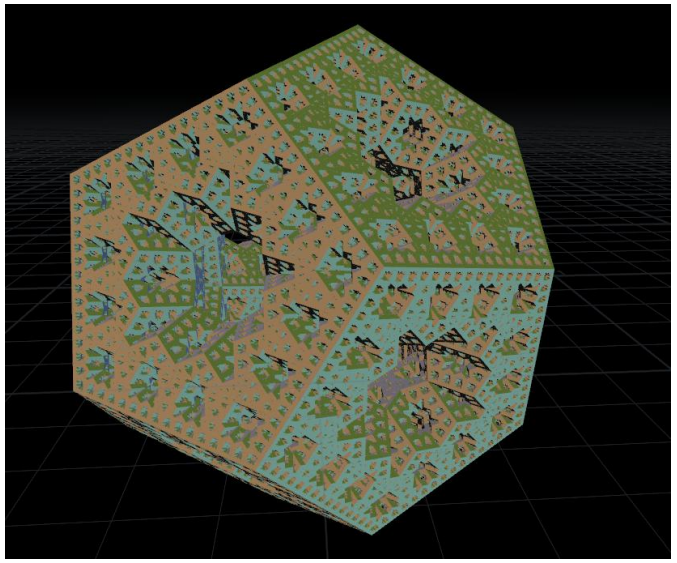


Use the same theory as Basic Fractal, no longer merge the original geometry

```
int pts[] = primpoints(0, @primnum);
int splitnum = chi("splitnum");
for(int i=0; i<len(pts); i++){
    float pscale = point(0, "pscale", pts[i]);
    float scale = (splitnum - 1.0) / splitnum;

    vector pos1 = point(0, "P", pts[i]);
    vector pos2 = point(0, "P", pts[(i+1) % len(pts)]);

    vector spos1 = pos1 * scale;
    vector spos2 = pos2 * scale;


    for(int n=0; n<splitnum-1; n++){

        vector newspos = spos1 + (spos2 - spos1) / (splitnum - 1.0) * n;
        //vector sposm = (spos1 + spos2) * 0.5;

        int npt = addpoint(0, newspos);
        //int pt2 = addpoint(0, sposm);
        setpointattrib(0, "pscale", npt, pscale * (1.0 / splitnum));
        //setpointattrib(0, "pscale", pt2, pscale * (1.0 / splitnum));
    }
}

removeprim(0, @primnum, 1);
```

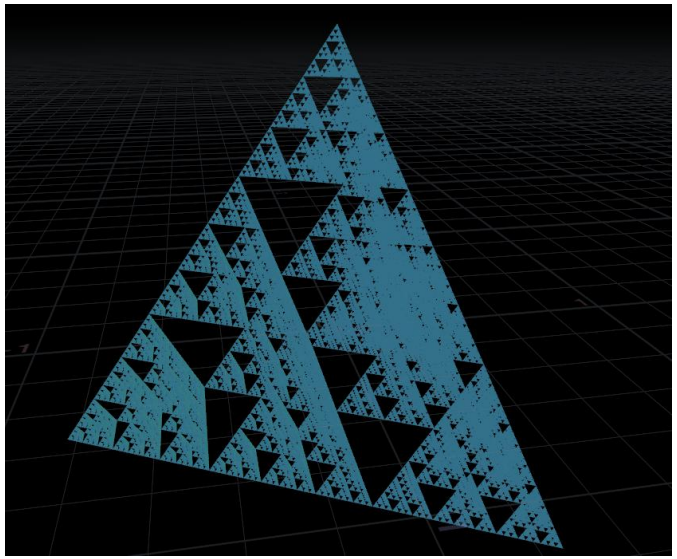
02 Implementation Process

Dodecahedron



change the imput to Dodecahedron

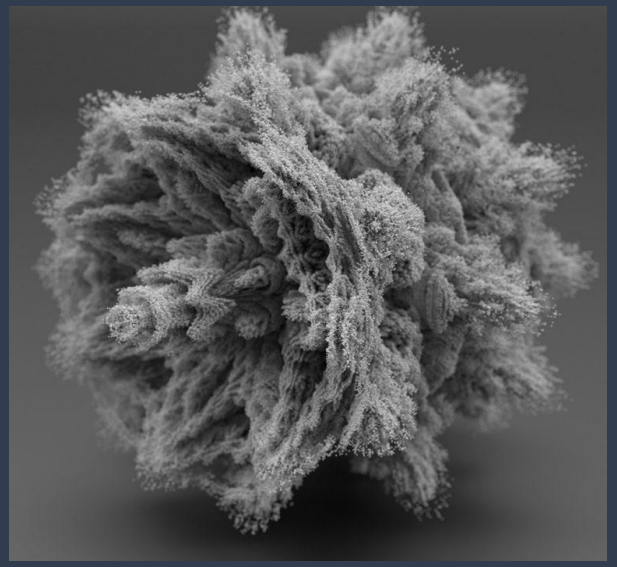
Tetrahedron



change the imput to Tetrahedron

It is also known as the Sierpinski Triangle

02 Implementation Process



Mandelbulb (rendered in Arnold for Maya)

http://www.cgbreak.com/news/articles/3d-fractals-in-vfx/

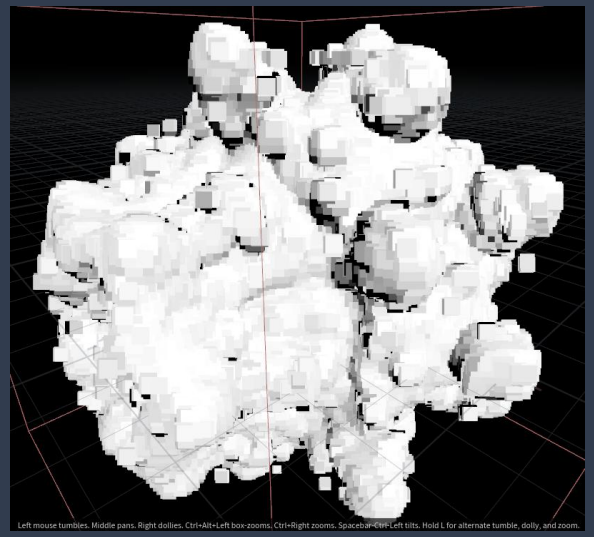
Mandelbulb

The Mandelbulb is a three-dimensional fractal, constructed by Daniel White and Paul Nylander using spherical coordinates in 2009.

The Mandelbulb has many different formula, this HDA complete three formulas:

- White and Nylander's formula
- Cubic formula
- Quintic formula

02 Implementation Process



By DI Yang, VolumeFractal HDA

Implementation in houdini

Get this Formula from Wikipedia:

White and Nylander's formula for the "*n*th power" of the vector $\mathbf{v} = \langle x, y, z \rangle$ in $\mathbb{R}^3$ is

$$\mathbf{v}^n := r^n \langle \sin(n\theta)\cos(n\phi), \sin(n\theta)\sin(n\phi), \cos(n\theta) \rangle$$

where

$r = \sqrt{x^2 + y^2 + z^2}$,

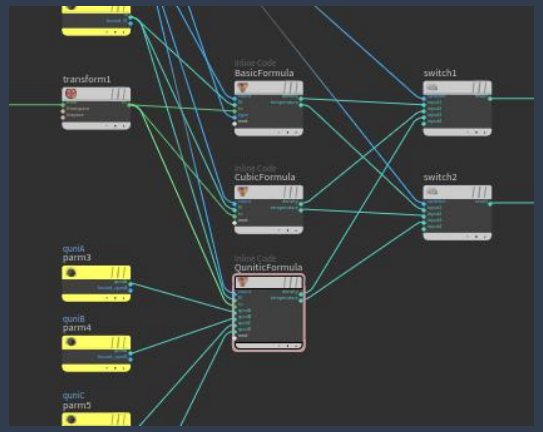
$\phi = \arctan(y/x) = \arg(x + yi)$, and

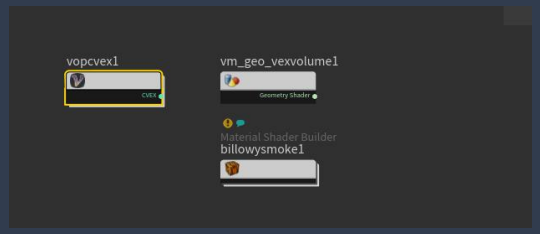
$\theta = \arctan(\sqrt{x^2 + y^2}/z) = \arccos(z/r)$.

Implemented in VEX:

```
vector v = @P;
for(int i=0; i<iteration; i++){
    float r = length(v);
    float phi = atan2(v.y, v.x);
    float theta = atan2(sqrt(v.x * v.x + v.y*v.y), v.z);

    float vr = pow(r, n);
    float vx = sin(n * theta) * cos(n * phi);
    float vy = sin(n * theta) * sin(n * phi);
    float vz = cos(n * theta);

    v = set(vx, vy, vz) * vr + P0;

    if(length(v) > 10){
        @density = 0.0;
    }
```

02 Implementation Process





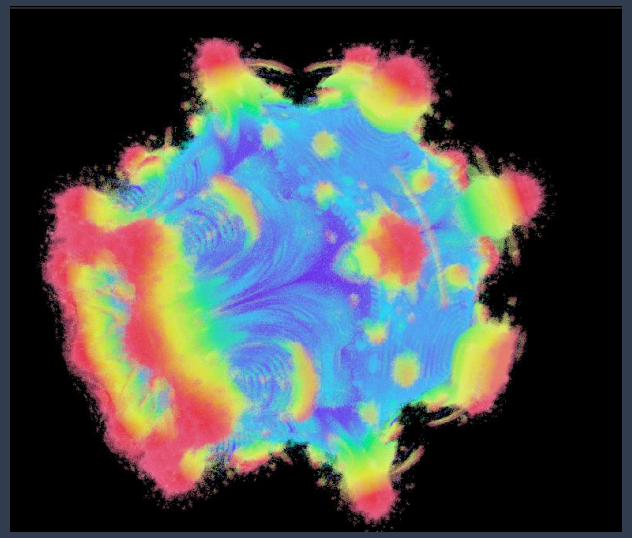
By DI Yang, GeometryFractal HDA

Difficulties facing in make volumetricFractal HDA

1. Not enough resolution for render
2. the higher resolution, the slower reaction from computer

Write materials using CVEX language to add details

02 Implementation Process



By DI Yang, VolumeFractal HDA

Implementation in houdini

Implemented in VEX:

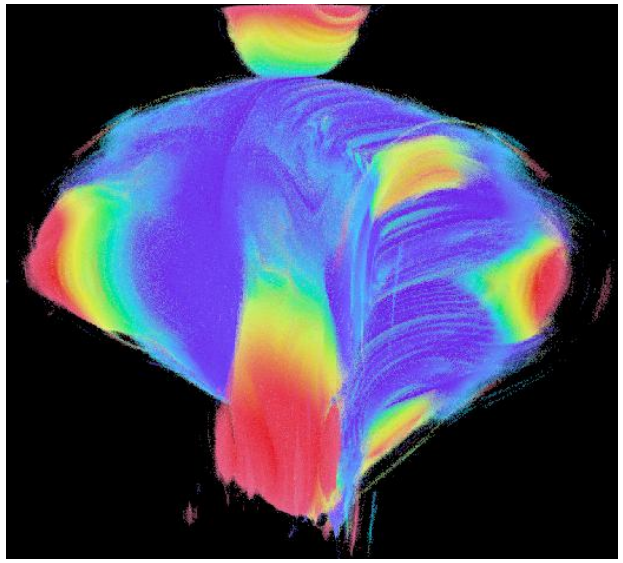
```
vector v = @P;
for(int i=0; i<iteration; i++){
    float r = length(v);
    float phi = atan2(v.y, v.x);
    float theta = atan2(sqrt(v.x * v.x + v.y*v.y), v.z);

    float vr = pow(r, n);
    float vx = sin(n * theta) * cos(n * phi);
    float vy = sin(n * theta) * sin(n * phi);
    float vz = cos(n * theta);

    v = set(vx, vy, vz) * vr + P0;

    if(length(v) > 10){
        @density = 0.0;
    }
```

Implemented in CEVX:

```
for(int i=0; i<iteration; i++){
    float r = length(v);
    float phi = atan2(v.y, v.x);
    float theta = atan2(sqrt(v.x * v.x + v.y*v.y), v.z);

    float vr = pow(r, n);
    float vx = sin(n * theta) * cos(n * phi);
    float vy = sin(n * theta) * sin(n * phi);
    float vz = cos(n * theta);

    v = set(vx, vy, vz) * vr + P0;
    $temperature = length(v);

    if(length(v) > 100){
        $density = 0.0;
    }
    else
    {
        $density = 1.0;
    }
```

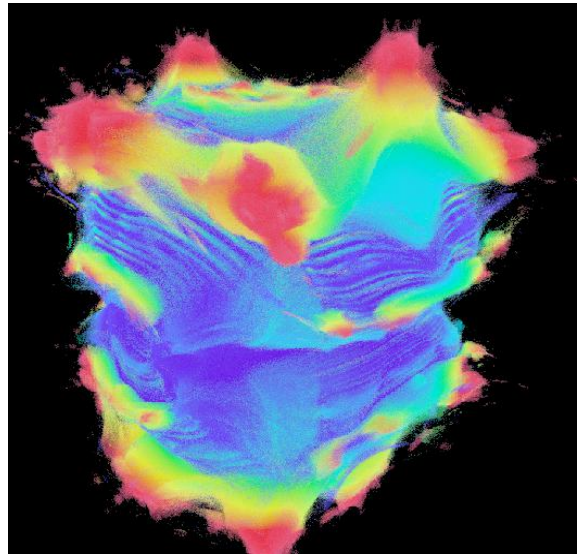
02 Implementation Process

Cubic formula



Change the “Fractal Type” to Cubic formula

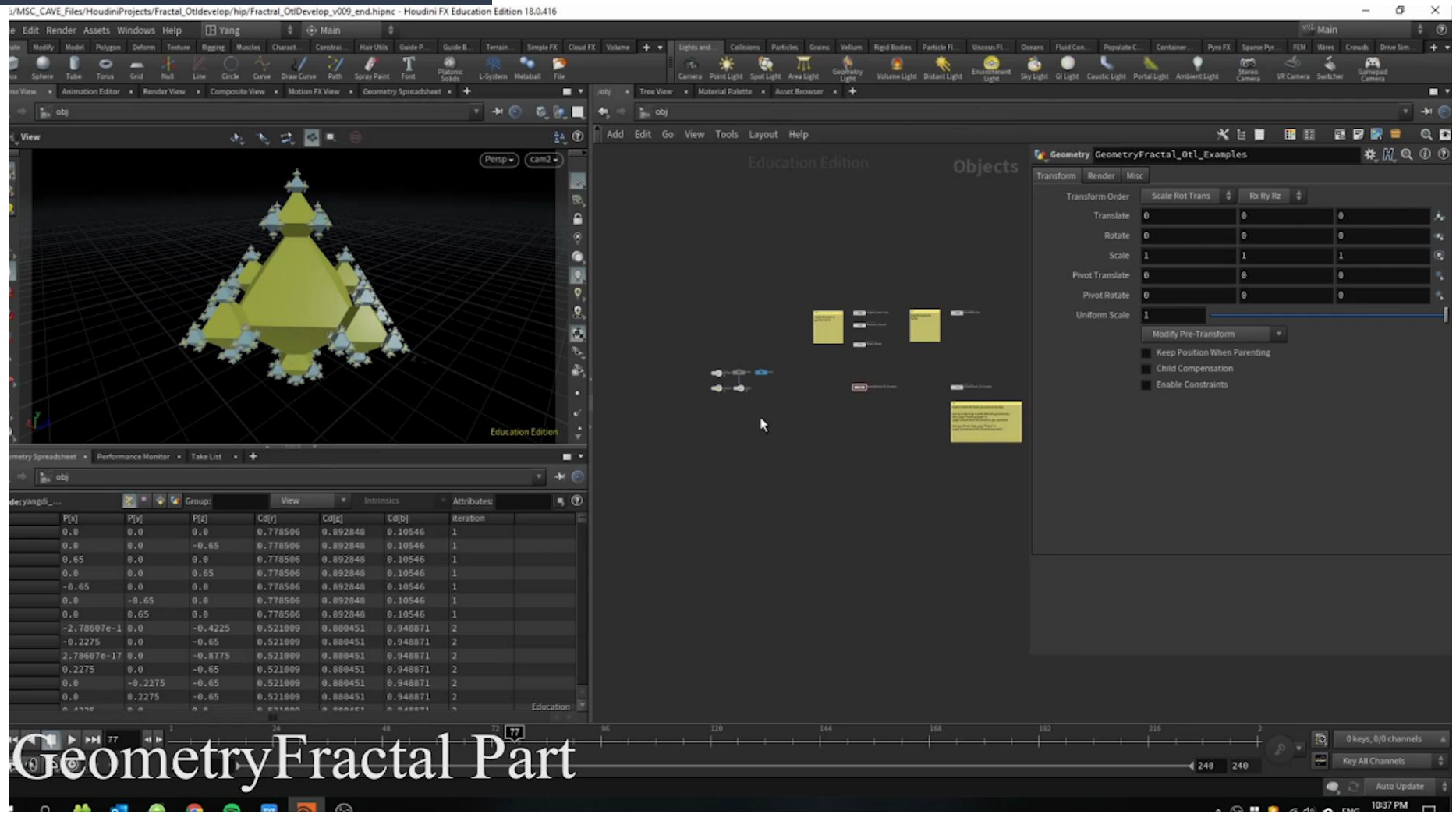
Quintic formula



Change the “Fractal Type” to Quintic formula

02 Implementation Process

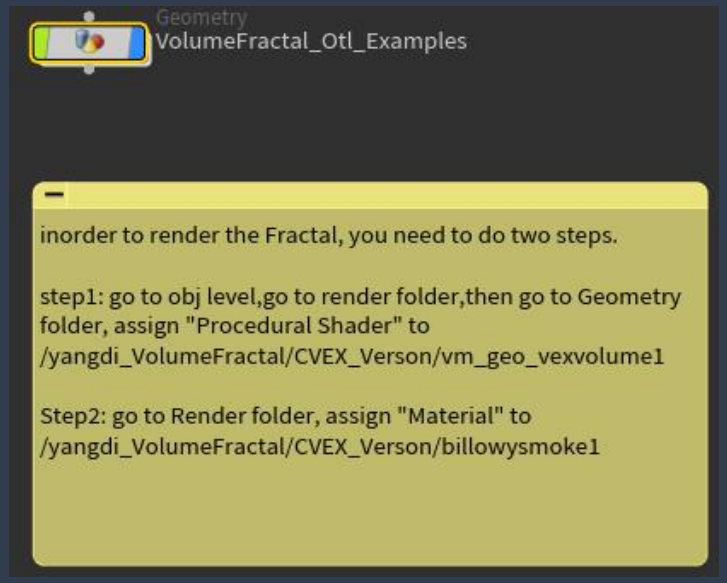
Fractal HDA ShowReel



PART 03

Conclusions and Deficiencies

03 Conclusions And Deficiencies



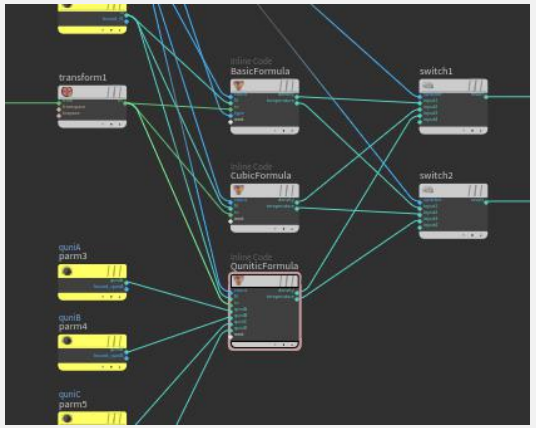
The example of the utility
By DI Yang, VolumeFractal HDA

VolumeFractal HDA

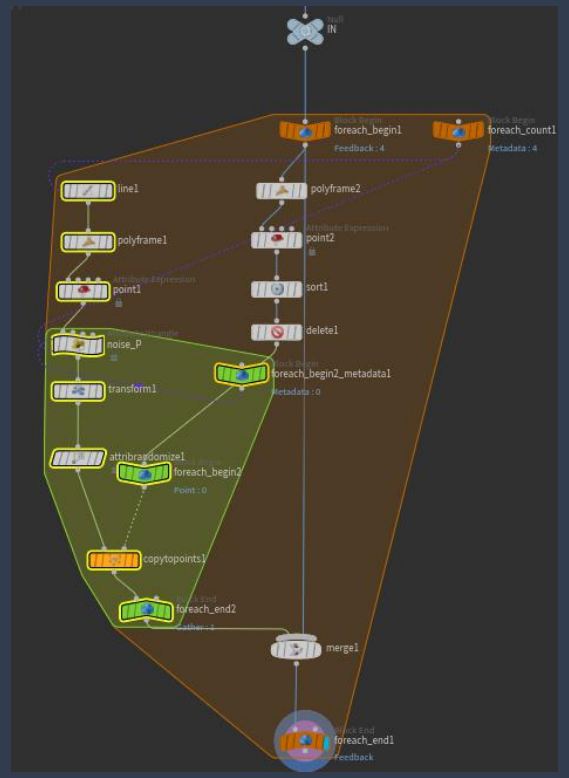
HDA of VolumeFractal is very difficult to use, seeing in Figure left, very unfriendly for Artists.

The design of interoperability between CVEX and VEX is very bad:

- almost the same but can not directly copy
- need manually import parameters



03 Conclusions And Deficiencies



The example of the Utility
By DI Yang, VolumeFractal HDA

GeometryFractal HDA

The scope of application is too small.

need to modify the node-tree when making other effects.

Find the Instance functions.

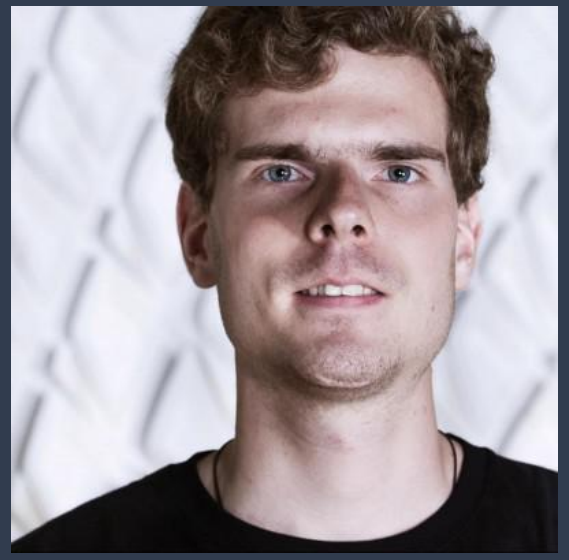
Can combine two HDAs together

instance VEX function

Creates an instance transform matrix.

```
                    vectorvector
matrix  instance(P, N)
                    vectorvectorvector
matrix  instance(P, N, scale)
                    vectorvectorvector  vector
matrix  instance(P, N, scale, pivot)
                    vectorvectorvector  vector4  vector
matrix  instance(P, N, scale, rotate, up)
                    vectorvectorvector  vector4  vectorvector
matrix  instance(P, N, scale, rotate, up, pivot)
                    vectorvectorvector  vector4  vector4
matrix  instance(P, N, scale, rotate, orient)
                    vectorvectorvector  vector4  vector4  vector
matrix  instance(P, N, scale, rotate, orient, pivot)
```

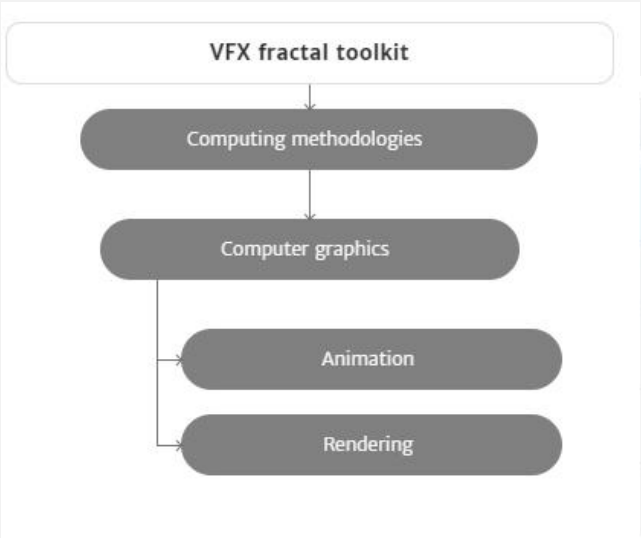
03 Conclusions And Deficiencies

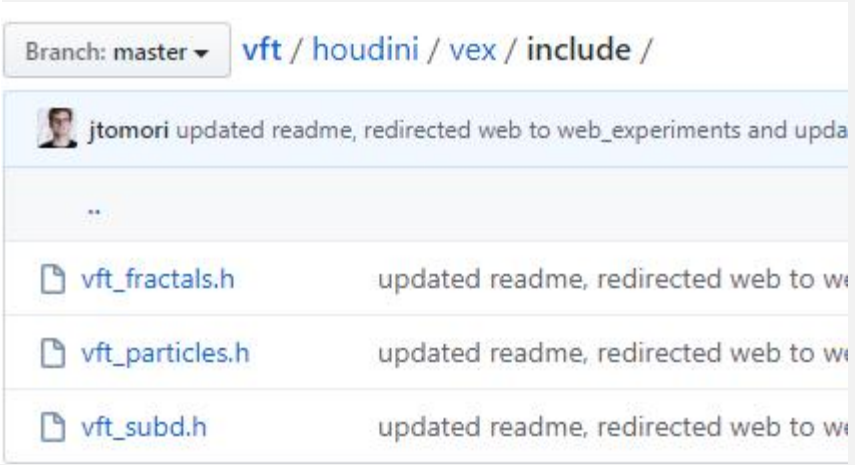


Juraj Tomori The Author of VFX Fractal Toolkit
https://jtomori.github.io/

VFX fractal toolkit

It contains tools written in OpenCL, OSL, Blink, Python, VEX and JavaScript intended to be used in Houdini, Arnold, Nuke or a web browser.





PART 04

References

04 References

Coding Challenge #2, by Daniel Shiffman: Menger Sponge Fractal, https://www.youtube.com/watch?v=LG8ZK-rRkXo

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3D Fractals in VFX : http://www.cgbreak.com/news/articles/3d-fractals-in-vfx/

Mandelbulb 3D Tutorials, by Don Whitaker : https://www.youtube.com/playlist?list=PL67453435CBFEDB49

How to make a Mandelbulb, By Matt Ebb (3D World): https://www.creativebloq.com/how-to/make-a-mandelbulb.

Fractal tutorials , by Julius Horsthuis : http://www.julius-horsthuis.com/tutorials

What are Fractals? by Fractal Fundation: https://fractalfoundation.org/

Fractal, From Wikipedia: https://en.wikipedia.org/wiki/Fractal

Mandelbulb,From Wikipedia: https://en.wikipedia.org/wiki/Mandelbulb

PART 05

Q&A

Thank You for Listening

BLUE SIMPLE GRADUATION THESIS DEFENSE PPT TEMPLATE