レイマーチング1から5

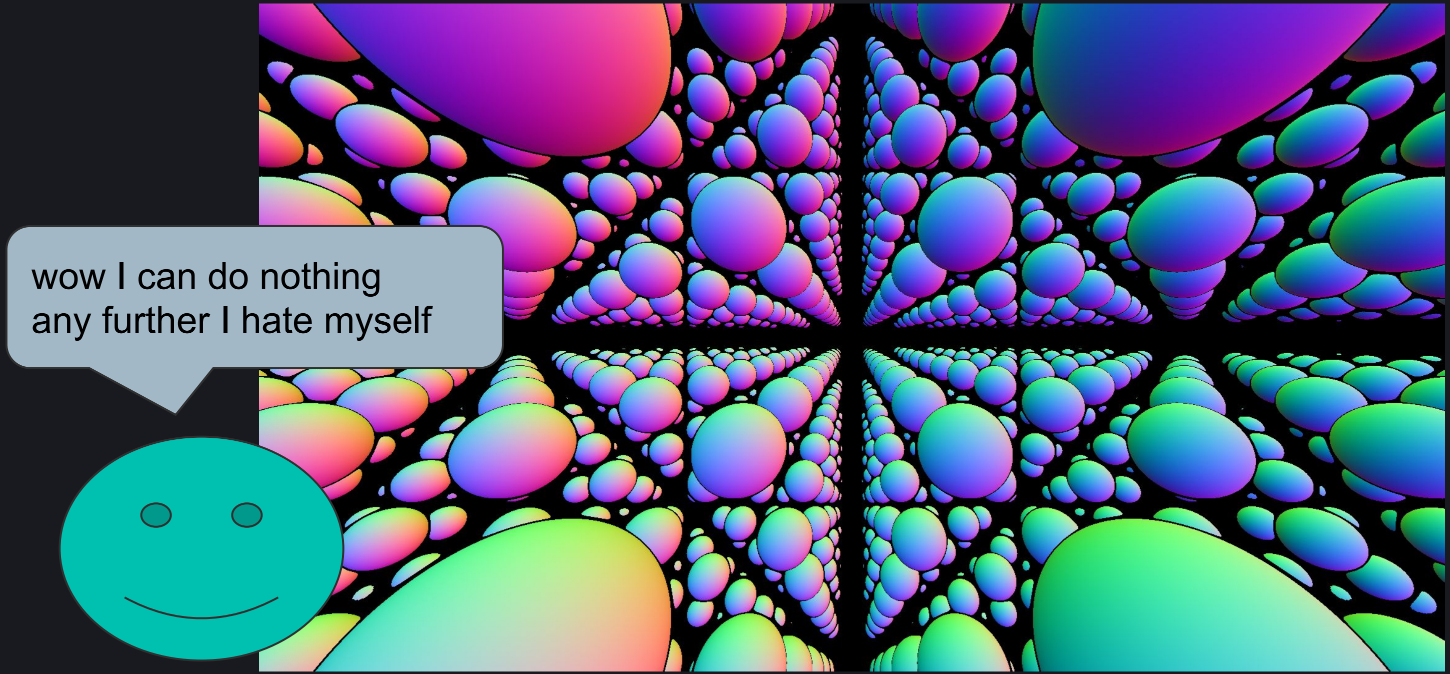
（命名: @kuyuri_iroha）

0b5vr

2021-12-04　TokyoDemoFest 2021

I will talk in Japanese because I suck at English

slides will be written in English



POV: You've finished your first sphere repetition using raymarching

if you're looking for a tutorial for this, this seminar is not for you, I'm sorry :(

This seminar is a collection of something you can do in raymarcher

(I’m not going to cover multi pass stuff this time)

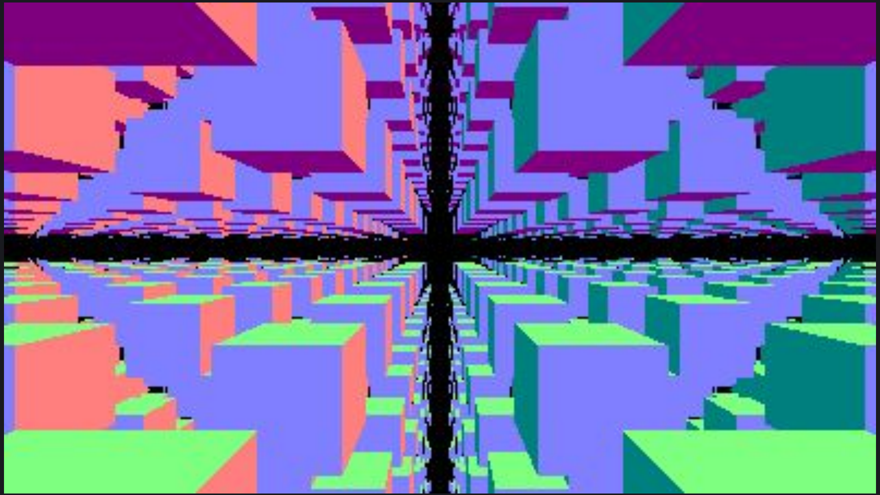
(Definitely not exhaustive)

The basic structure of raymarcher code

- define ro/rd
- march the ray
- pick a color

Topic: Camera

Field of View (FOV)



define ro/rd

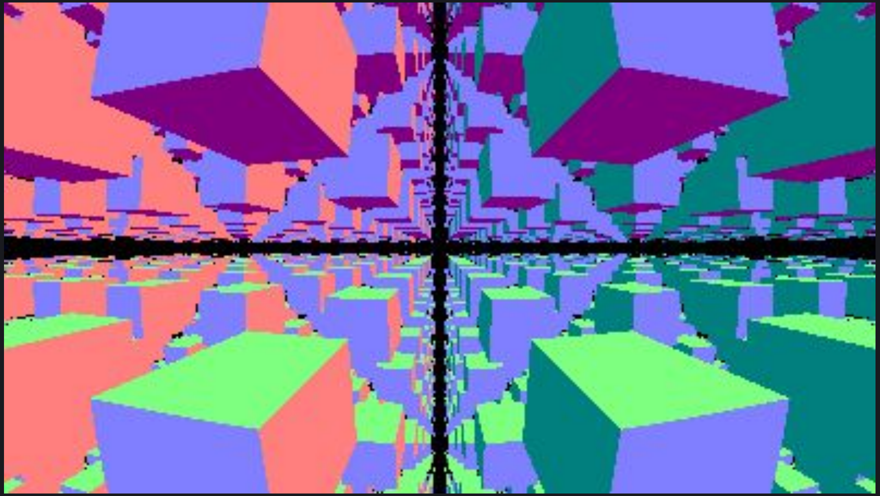
march the ray

pick a color

Use appropriate FOV for your scene
If you already have knowledge about camera in real world, that would be a good advantage

20211209_fov - https://www.shadertoy.com/view/ftdXDH
0b5vr, 2021

Fisheye / Distorted Perspective



define ro/rd

march the ray

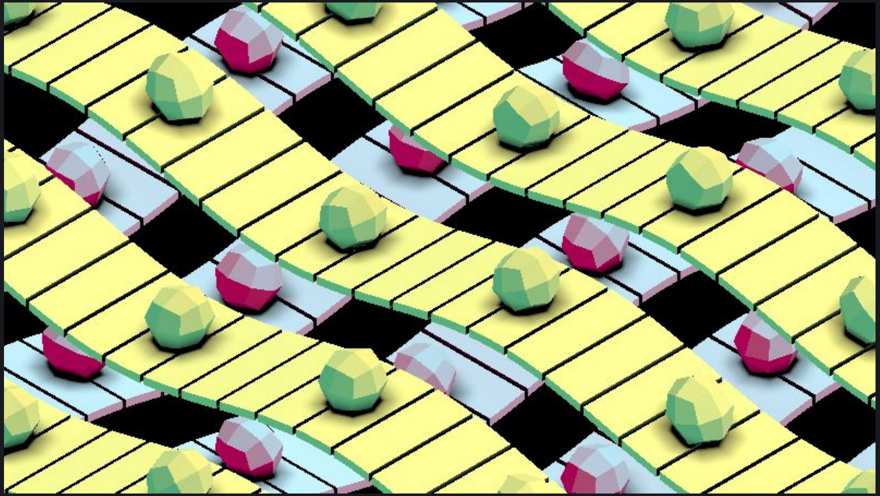
pick a color

Distort the perspective using the length from the center of the screen

```
rd = normalize( vec3( p, -1.0 + 0.5 * length( p ) ) );
```

20211209_fisheye - https://www.shadertoy.com/view/NtdXDH
0b5vr, 2021

Orthogonal Projection



define ro/rd

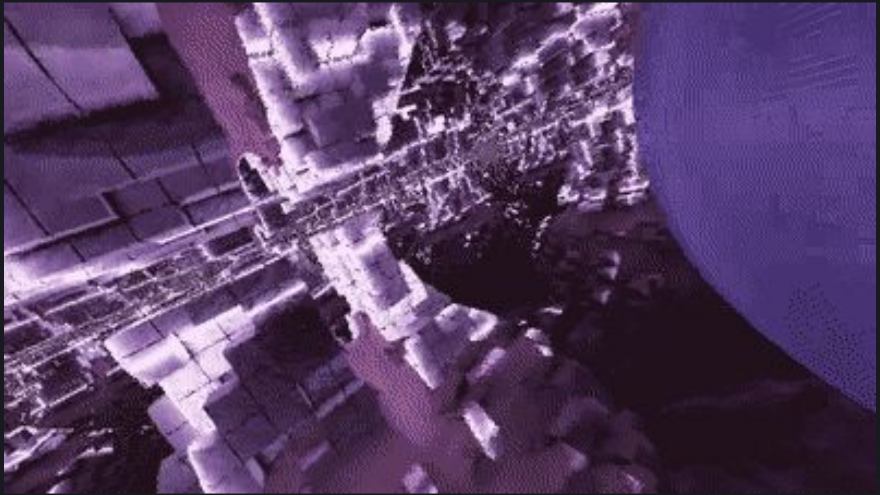
march the ray

pick a color

You can even draw your scene without perspective projection
Very cute

Weave Factory - https://www.shadertoy.com/view/stSSzy
Flopine, 2021

Motion Blur



add a random value to time

define ro/rd

march the ray

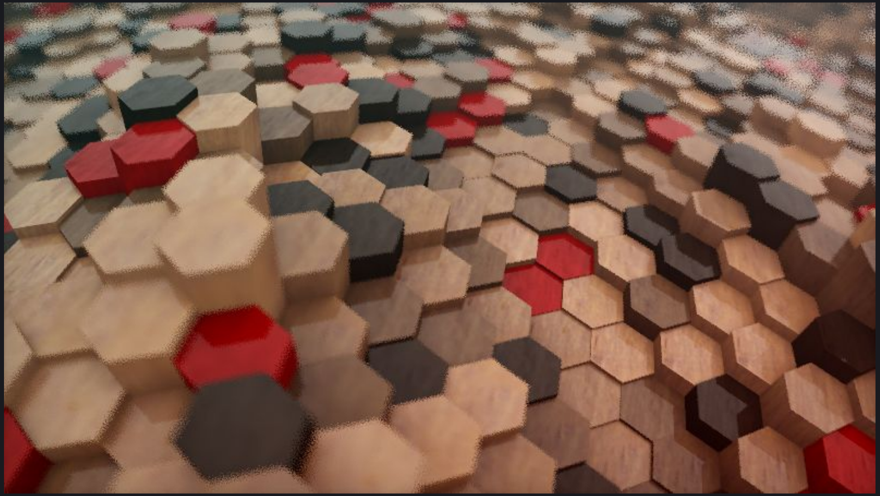
pick a color

Doing motion blur in a single pass??
Add a random value to `time` for each pixel, that's it.
Might look noisy but it's working, isn't it?

```
time += 0.01 * random();
```

2nd stage BOSS - https://www.pouet.net/prod.php?which=66962
0x4015 & YET11, 2016

Depth of Field (DoF)



define ro/rd

add random value to ro

march the ray

pick a color

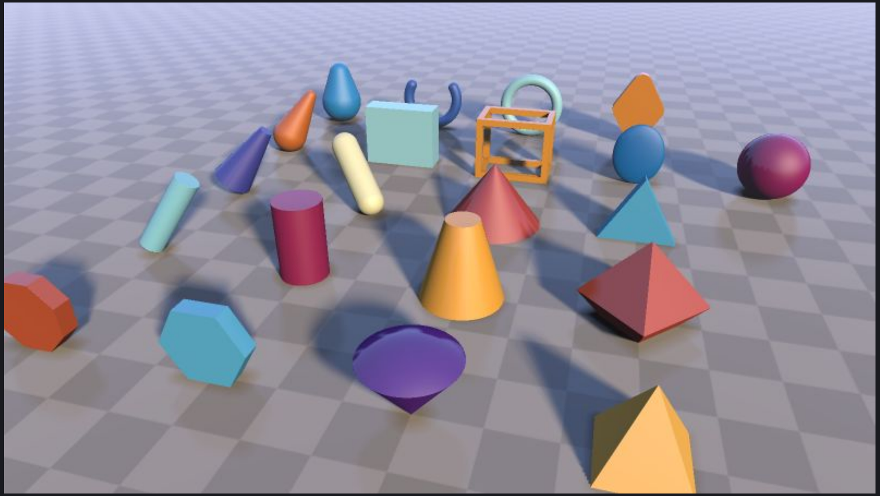
The same goes for the depth of field

```
vec3 fp = ro + rd * 5.0;
ro.xy += 0.1 * someAppropriateRandom();
rd = normalize( fp - ro );
```

Hexagon Grid Traversal - 3D - https://www.shadertoy.com/view/WtSfWK
Inigo Quilez, 2020

Topic: Geometries

Primitives



define ro/rd

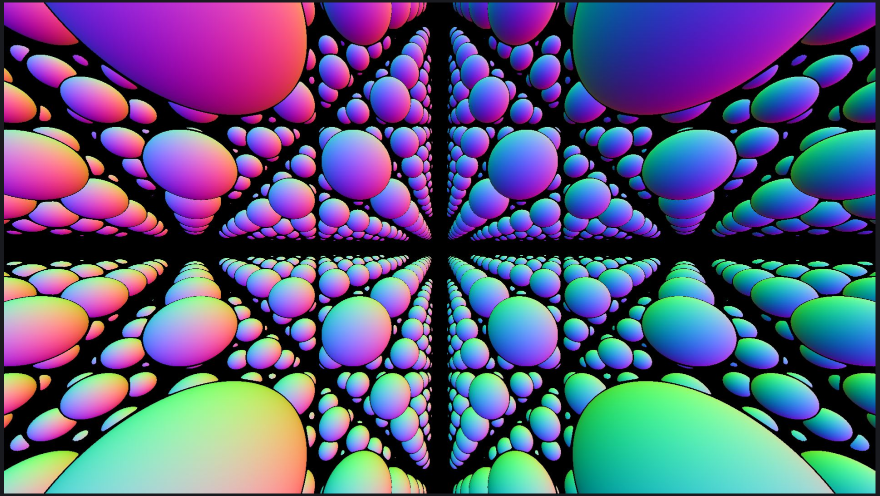
march the ray

pick a color

Understand primitives as many as possible!
They will eventually become your weapons
See: https://www.iquilezles.org/www/articles/distfunctions/distfunctions.htm

Raymarching - Primitives - https://www.shadertoy.com/view/Xds3zN
Inigo Quilez, 2013

Repetition



define ro/rd

march the ray

modify the coordinate

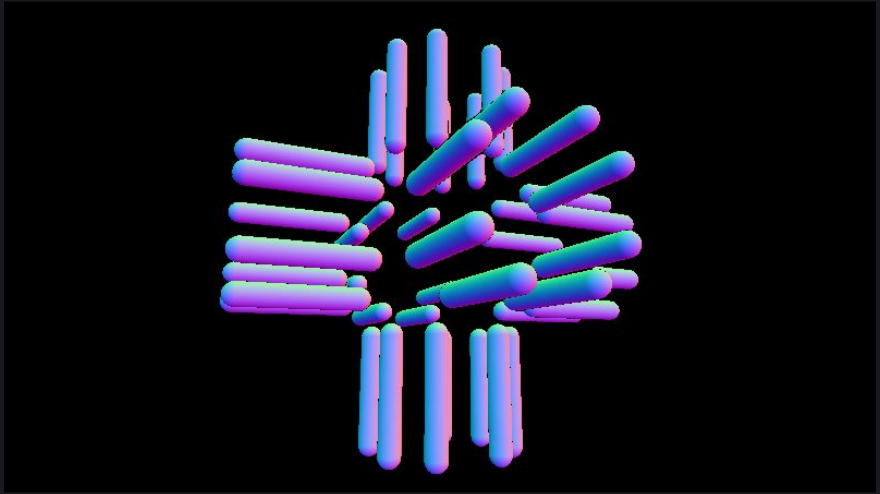
pick a color

Inside the distance function, repeat the coordination system and make a thing appear many times

```
p = mod( p, 5.0 ) - 2.5;
```

20211204_sphere repetition - https://www.shadertoy.com/view/7l3Xzn
0b5vr, 2021

Fold



define ro/rd

march the ray

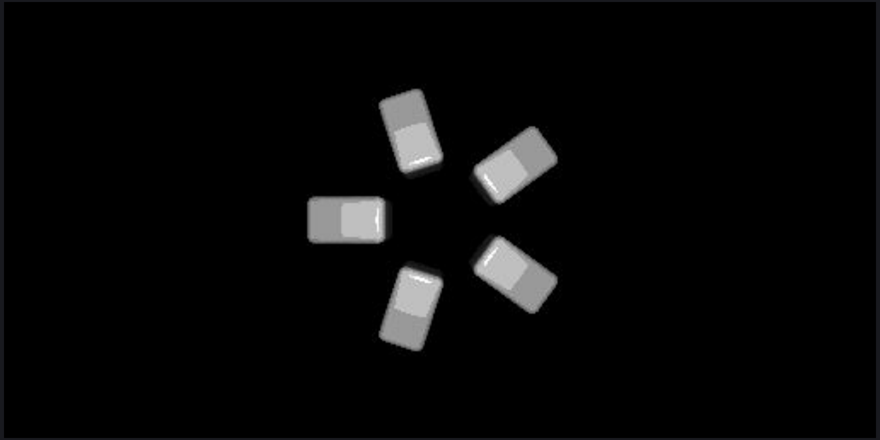
modify the coordinate

pick a color

"Fold" the coordinate using various tools like `abs` or `swizzle`
gaz's article explains the technique very well:
https://neort.io/product/bvcrf5s3p9f7gigeevf0

20211209_fold - https://www.shadertoy.com/view/flcXDH
0b5vr, 2021

Polar Mod (pmod) / Fold Rotate



define ro/rd

march the ray

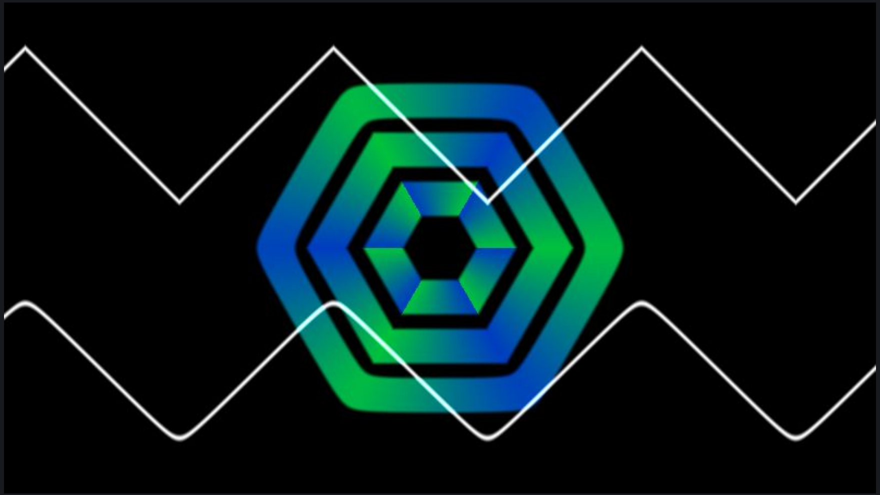
modify the coordinate

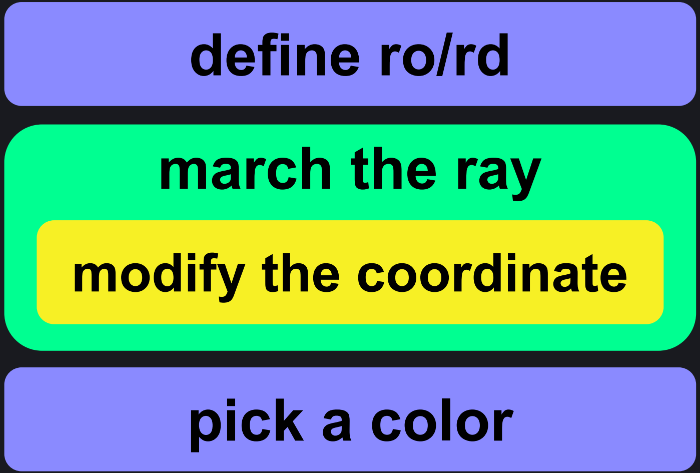
pick a color

Repeat the coordinate in theta axis of a polar coordinate
→ They will be duplicated in a circle

SDF for raymarching (距離関数のスキル) - https://neort.io/product/bvcrf5s3p9f7gigeevf0
gaz, 2020

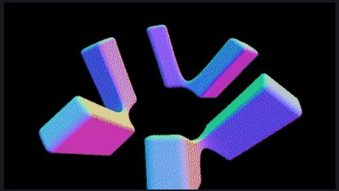
Polar Smooth Fold





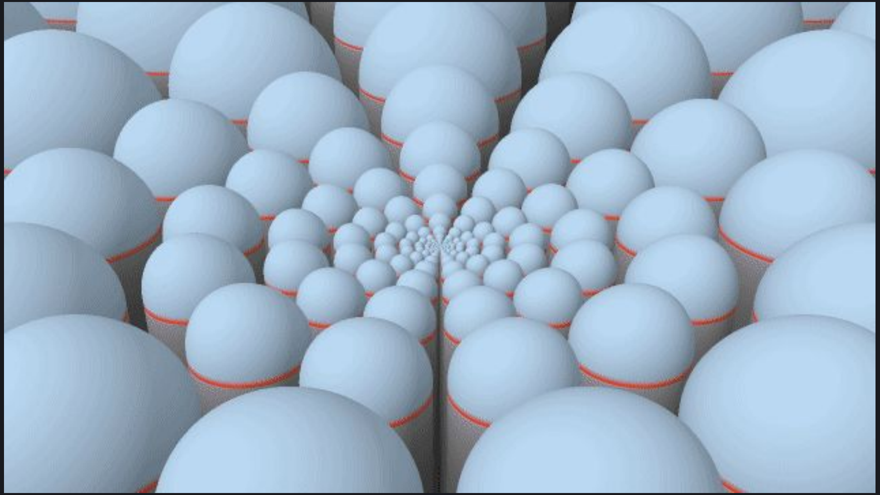
Fold rotate but smoother

I tried this tech →
https://www.shadertoy.com/view/NttSD4



polarSmoothFold2 - https://www.shadertoy.com/view/7sKGzR
gaz, 2020

Log-polar Mapping / Log-spherical Mapping



define ro/rd

march the ray

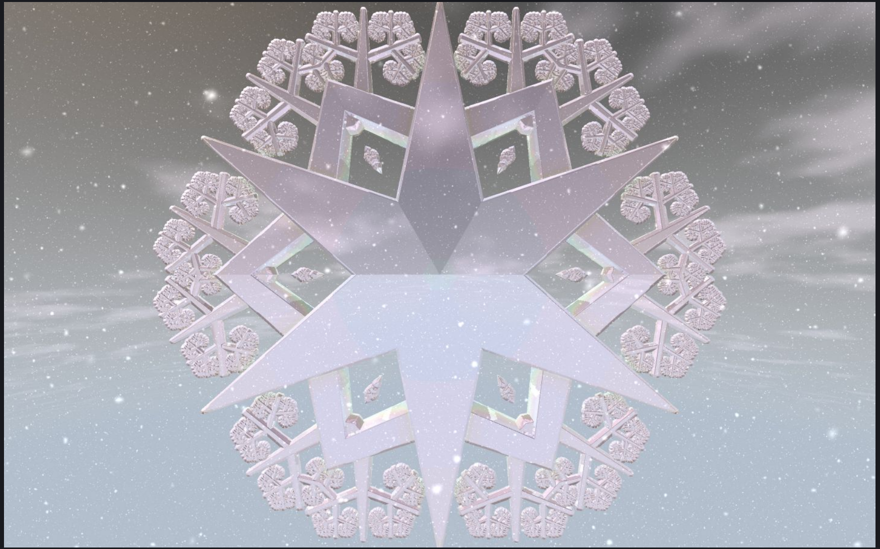
modify the coordinate

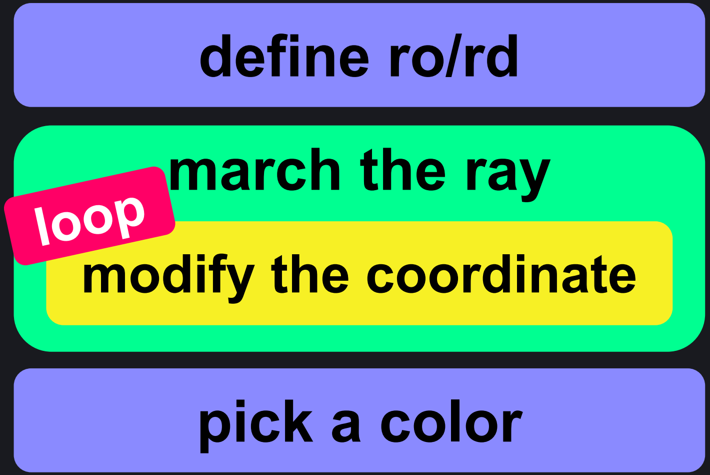
pick a color

Now the coordinate system is (log-radius, theta) instead of (radius, theta)
Pierre Cusa's article about log-spherical mapping is defo worth read (link below)

Log-spherical Mapping in SDF Raymarching - https://www.osar.fr/notes/logspherical/
Pierre Cusa, 2019

IFS (Iterated function system)

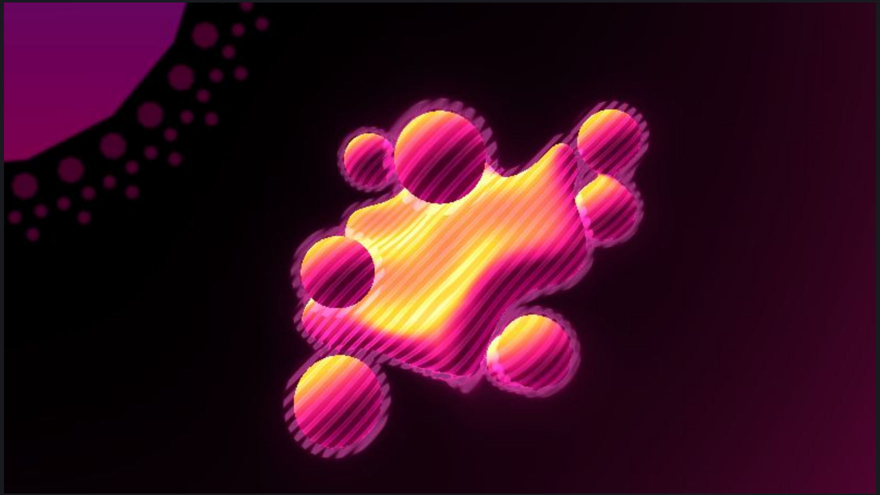




It ACTUALLY IS NOT AN IFS. You can achieve IFS-like shapes by folding the coordinate system recursively

距離関数のfold（折りたたみ）による形状設計 - https://gam0022.net/blog/2017/03/02/raymarching-fold/
gam0022, 2017

Smooth Minimum (smin)



define ro/rd

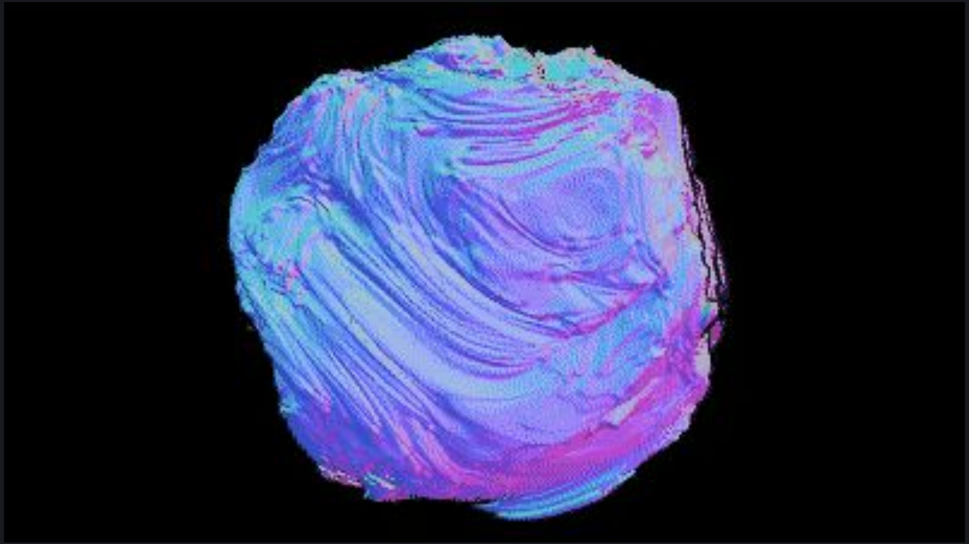
march the ray

pick a color

Take a minimum of two distance functions = union
Take a smooth minimum of two distance functions = smooth union
Best for metaballs

Hyper Dough - https://www.shadertoy.com/view/7tcGWB
Tater, 2021

Domain Warping

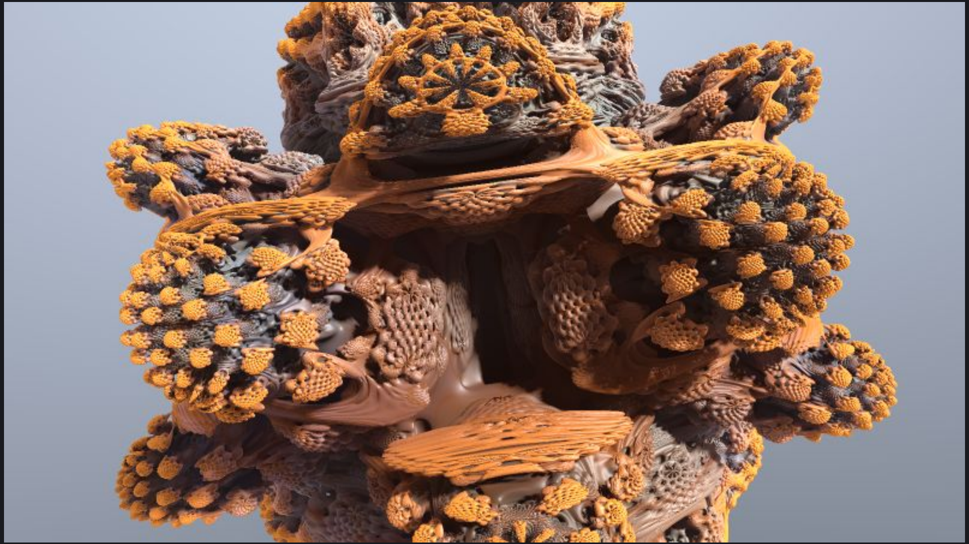


- define ro/rd
- march the ray
  - add noise to p
- pick a color

Warp the coordination using noises inside of distance function!
You can use various noises (and not-noises) for domain warping

20211209_domain warping - https://www.shadertoy.com/view/7ltXD8
0b5vr, 2021

Mandelbulb



define ro/rd

march the ray

do quaternion funnies
I guess

pick a color

(I’m not understanding how it works. I can’t explain!)

Mandelbulb - https://www.iquilezles.org/www/articles/mandelbulb/mandelbulb.htm
Inigo Quilez, 2009

4D Stereographic Projection 🔥

define ro/rd

march the ray

do 4D funnies

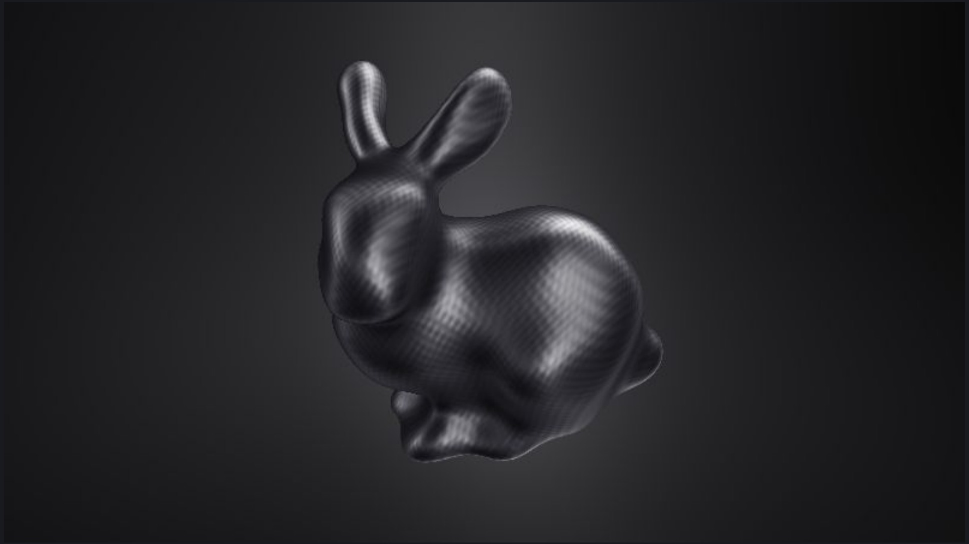
pick a color

Project 3D geometries into 4D, rotate, and project back to 3D
tdhooper have made a great write-up about this technique in Shadertoy 👇
https://www.shadertoy.com/view/fdfSDH

Inside, the new Outside! - https://www.instagram.com/p/CNQCz5YH9PH/
tdhooper, 2021

Neural Network

🔥🔥



define ro/rd

march the ray

do neural network funnies

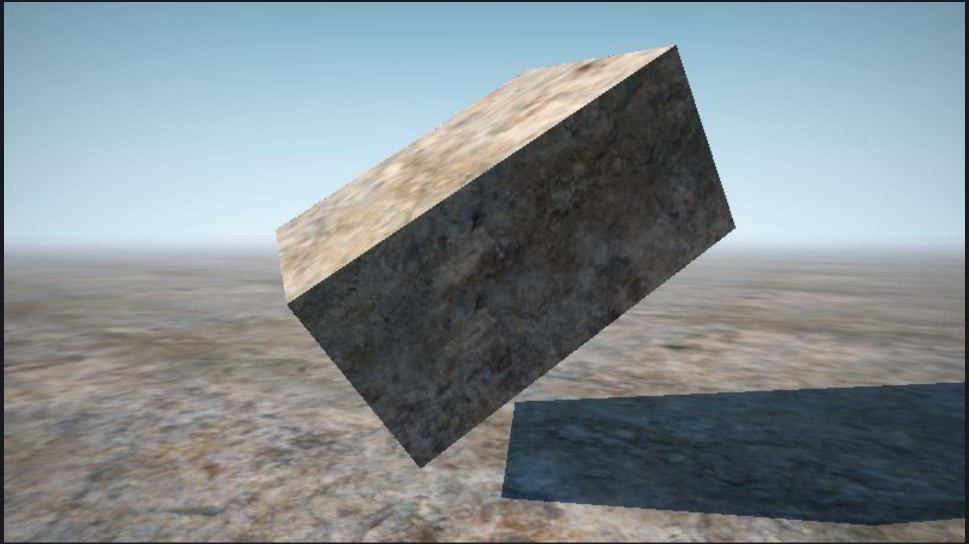
pick a color

Let neural network generate an SDF out of 3D models (???????)
Blackle’s tutorial explains how to do this by yourself using Jupyter Notebook:
https://www.youtube.com/watch?v=8pwXpfi-0bU

Neural Stanford Bunny (5 kb) - https://www.shadertoy.com/view/wtVyWK
Blackle, 2021

Topic: Raycasting

Raycasting / Intersection



define ro/rd

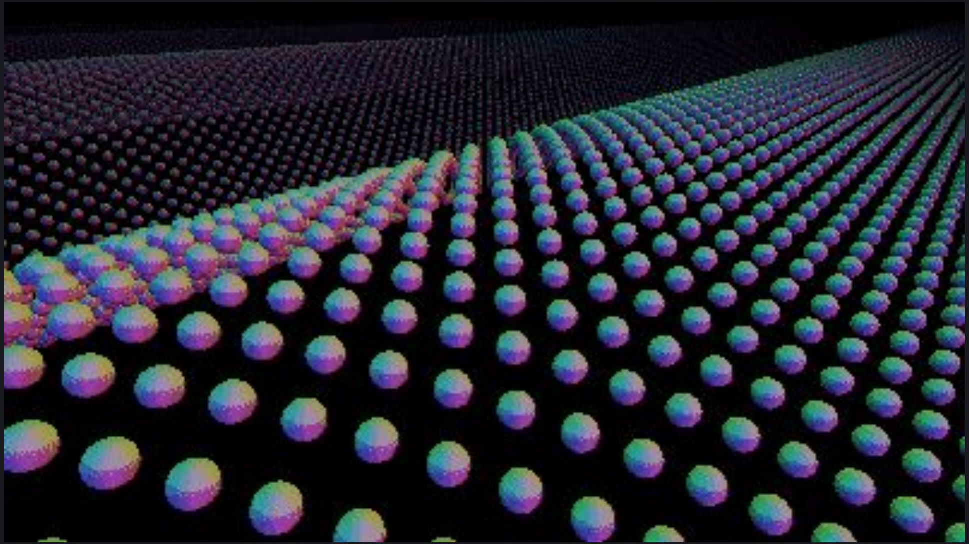
~~march the ray~~
find ray intersection

pick a color

“What?! I’m already casting rays for intersections using raymarching!” Sometimes using a classic raycaster along with raymarcher gives you a massive performance improvement

Box - intersection - https://www.shadertoy.com/view/ld23DV
Inigo Quilez, 2014

Grid Traversal



define ro/rd

march the ray

traverse the grid and limit the ray length

pick a color

Traverse the grid to make rays not overshoot grid regions
Remember this when you are trying to tile things in grid

20211210_grid traversal - https://www.shadertoy.com/view/stdXWH
0b5vr, 2021

Quadtree / Octree Grid Traversal

🔥

define ro/rd

march the ray

traverse the grid and limit the ray length

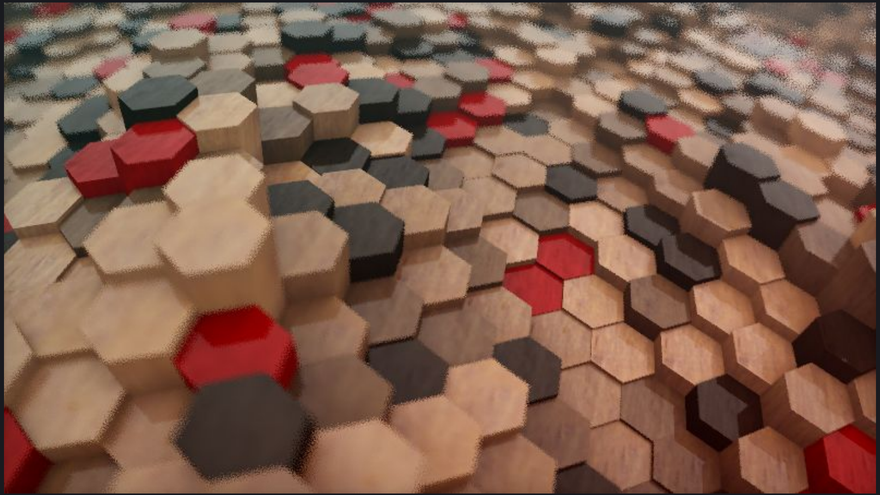
pick a color

Quadtree and octree can be achieved by a simple expansion of grid traversal (The shader above doesn't use any raymarcher though...)

20211031_Shader Royale (0b5vr) - https://www.shadertoy.com/view/7td3zn
0b5vr, 2021

Hexagonal Grid Traversal

🔥🔥



define ro/rd

march the ray

traverse the grid and
limit the ray length

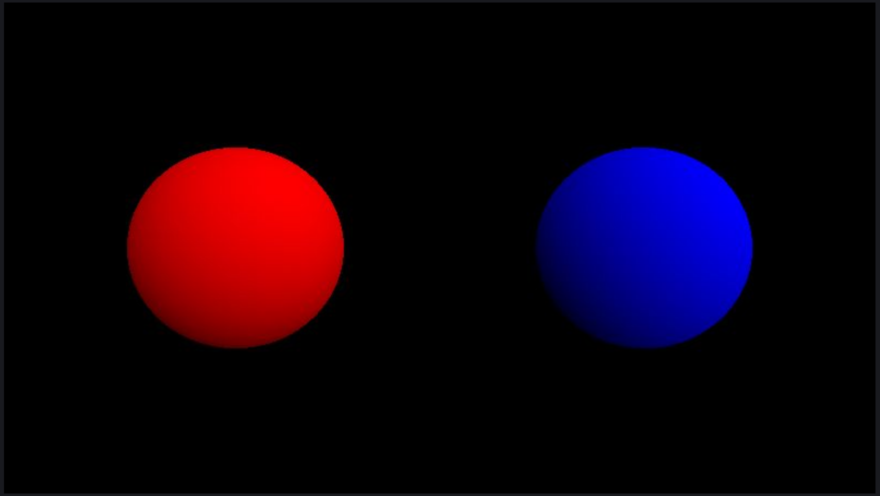
pick a color

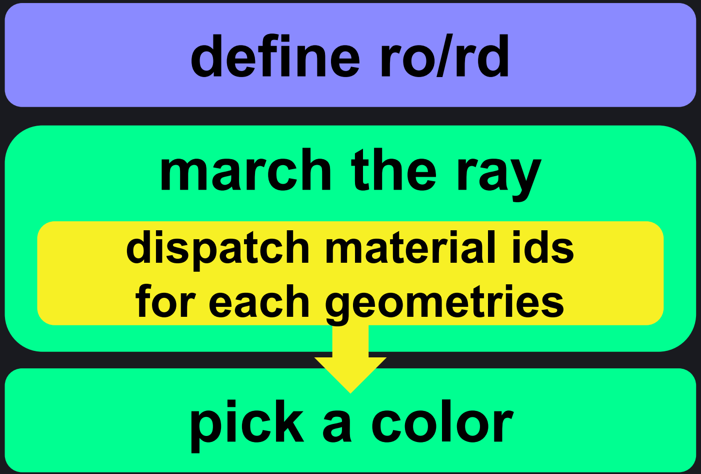
You can even traverse the hexagonal grid!

Hexagon Grid Traversal - 3D - https://www.shadertoy.com/view/WtSfWK
Inigo Quilez, 2020

Topic: Rendering

Materials

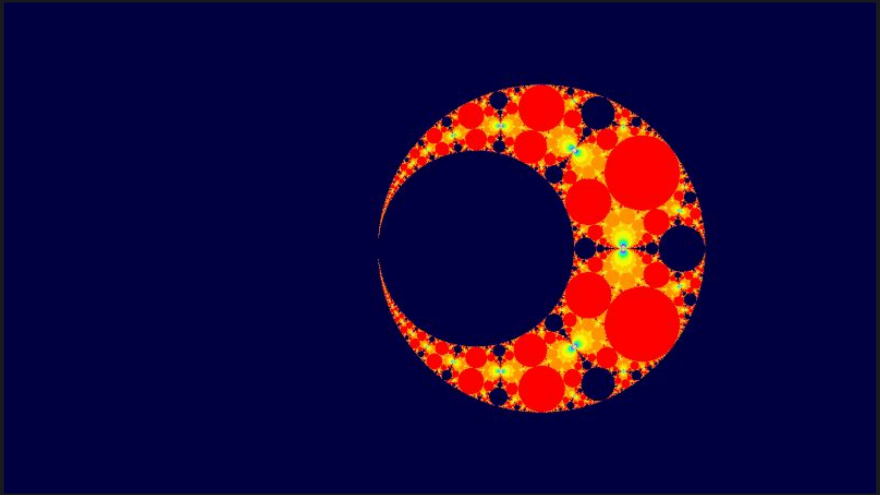




Use two materials at the same time!
There are various way to achieve the figure above
but you should try dispatching material ids for each geometries

20211210_materials - https://www.shadertoy.com/view/NtdXD4
0b5vr, 2021

HSV Color



define ro/rd

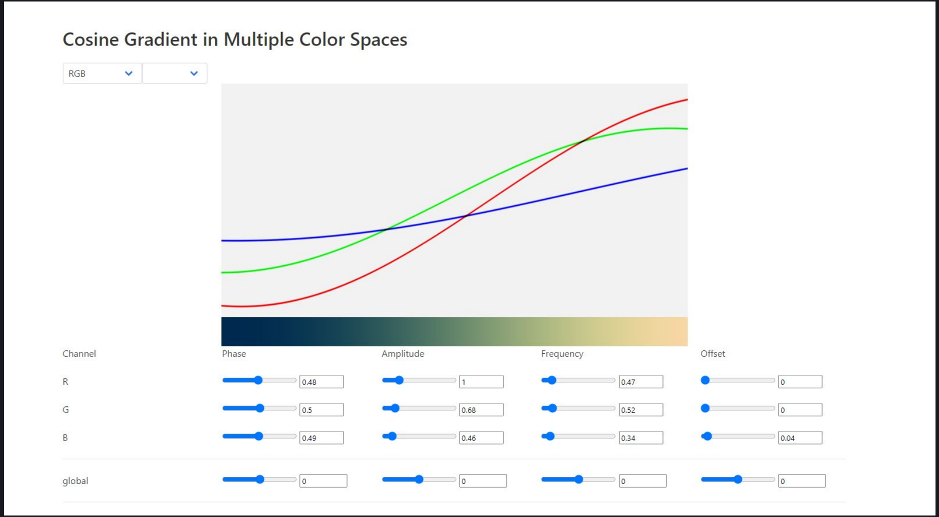
march the ray

pick a color

Color stuff using a scalar value
If you are familiar with painting tools such as Photoshop / Illustrator, this might be a best pick for you

[TDF2018] Morph - https://www.shadertoy.com/view/MlGfDG
soma_arc, 2018

Cosine Gradient


Cosine Gradient in Multiple Color Spaces

RGB

Channel	Phase	Amplitude	Frequency	Offset
R	0.48	1	0.47	0
G	0.5	0.68	0.52	0
B	0.49	0.46	0.34	0.04
global	0	0	0	0

define ro/rd

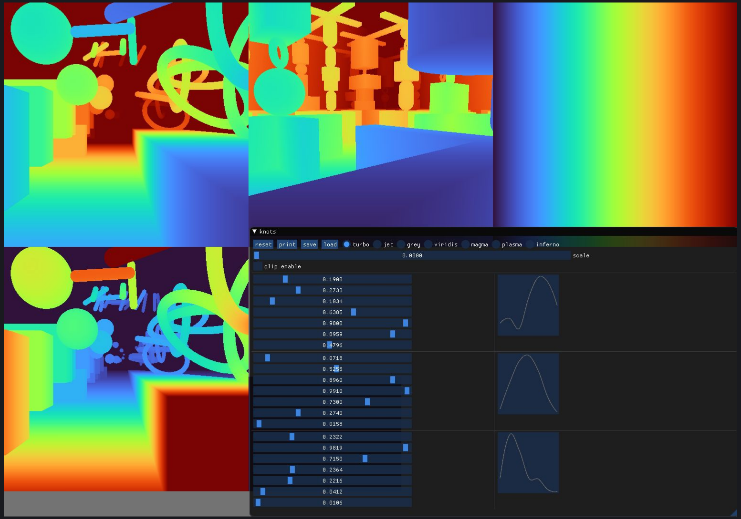
march the ray

pick a color

A gradient made of sinewave
sp4ghet made a webtool that lets you design sinewave gradient and generate a GLSL code out of it

grad - Cosine Gradient in Multiple Color Spaces - https://sp4ghet.github.io/grad/
sp4ghet, 2019

Turbo Gradient



```
0.0000 scale
0.1900
0.2733
0.1034
0.6385
0.9800
0.8959
0.4796
0.0718
0.5255
0.8960
0.9910
0.7300
0.2740
0.0158
0.2322
0.9819
0.7150
0.2364
0.2216
0.0412
0.0106
```

define ro/rd

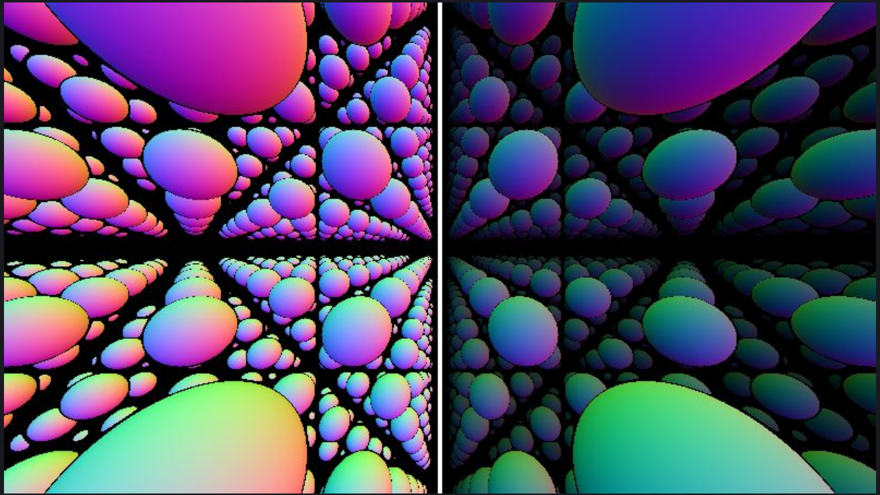
march the ray

pick a color

A gradient that is smooth, band free, and color blind friendly
Useful to visualize depth or anything that is a real number between 0 and 1
You might want to use them on your development stage

Turbo, An Improved Rainbow Colormap for Visualization - https://ai.googleblog.com/2019/08/turbo-improved-rainbow-colormap-for.html
Google LLC., 2019

Distance Fog



define ro/rd

march the ray

pick a color

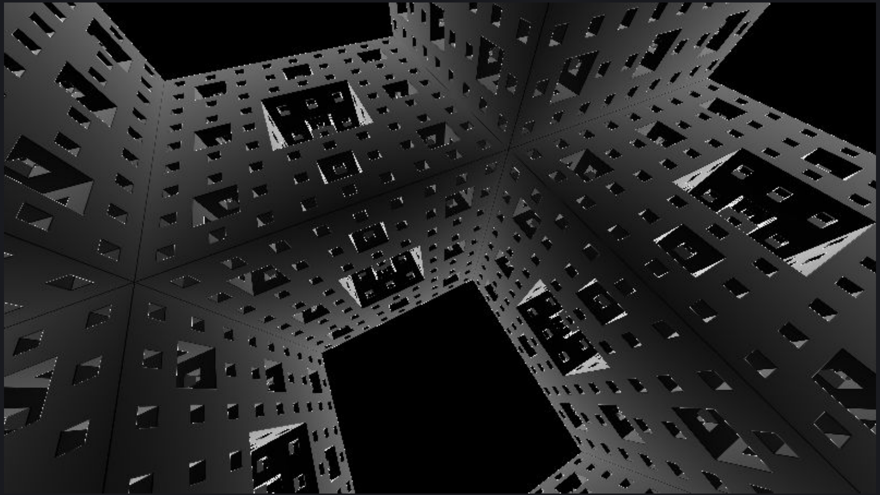
use ray length

Use ray length to enhance the perception based on distance

```
color *= exp( -0.1 * rl );
```

20211210_distance fog - https://www.shadertoy.com/view/NtdSD4
0b5vr, 2021

Fresnel / Rim Lighting



define ro/rd

march the ray

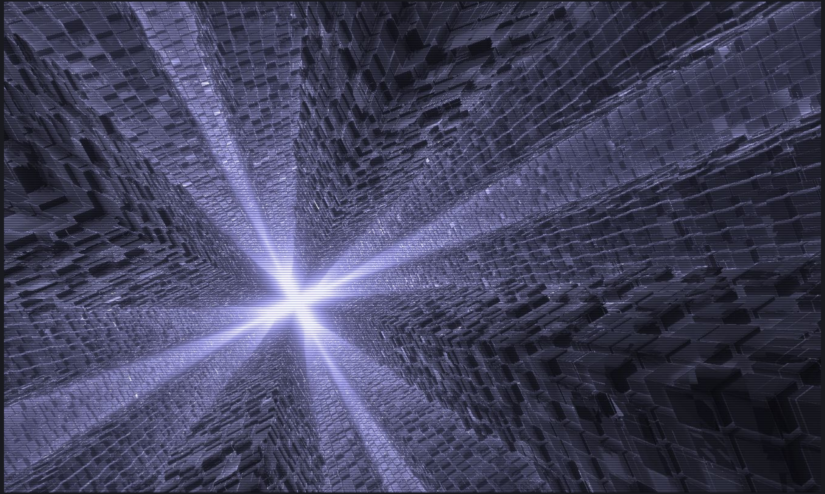
pick a color

use rd and N

Surfaces of geometries reflects more rays at the grazing angle
Easier way to use fresnel = just do rim lighting (the figure above)
Harder way to use fresnel = use in PBR (to be introduced later)

20211210_rim lighting - https://www.shadertoy.com/view/NttXD4
0b5vr, 2021

Edge Detection



define ro/rd

march the ray

pick a color

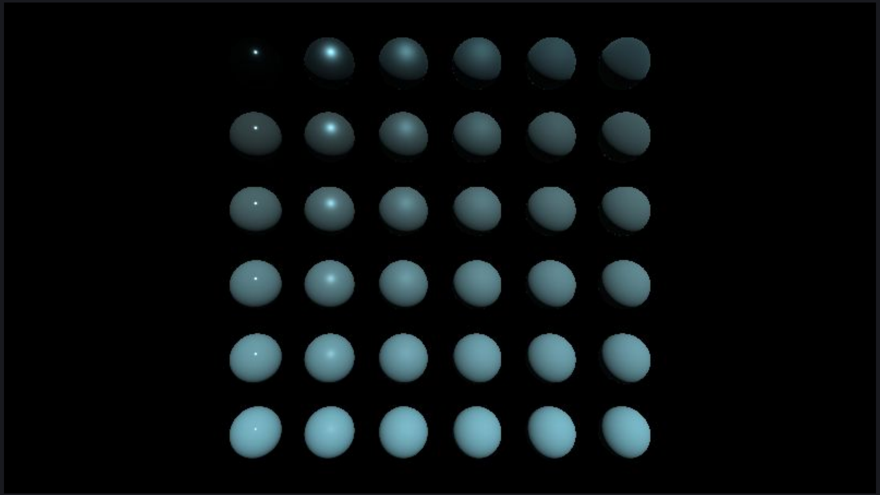
pick dFdx/dFdy of N*

*There are various ways to get edges

Glowing edges are cool

raymarching for games - https://i-saint.hatenablog.com/entry/2013/08/20/003046
i-saint, 2013

Physically Based Rendering (PBR) 🔥



define ro/rd

march the ray

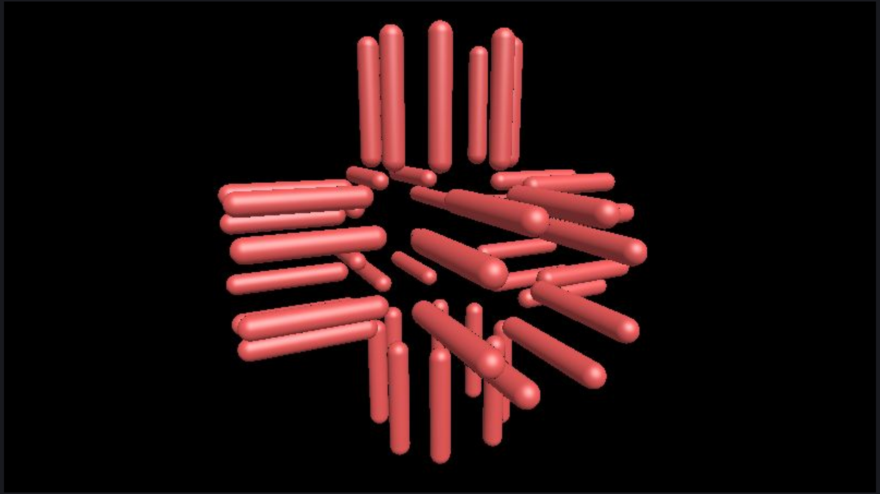
pick a color

lighting

Shade stuff using physically based theories!
Definitely not for live coding considering time budget
but you should try if you want to render things realistically

20211210_pbr - https://www.shadertoy.com/view/NldXD4
0b5vr, 2021

Phong Reflection Model



define ro/rd

march the ray

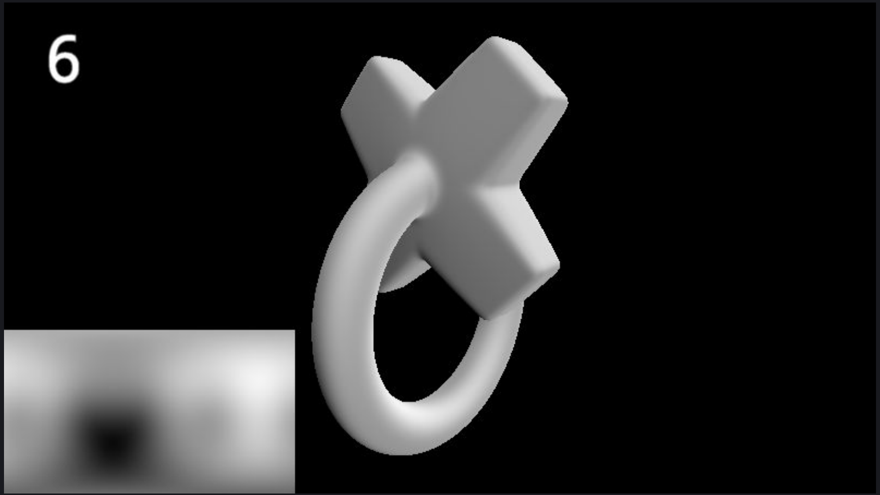
pick a color

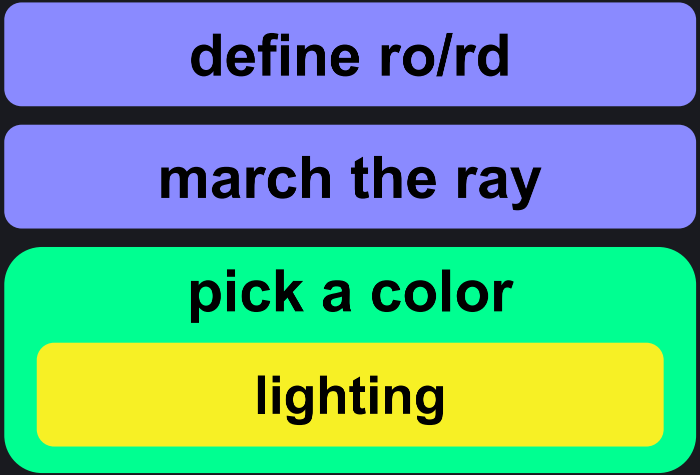
lighting

Wait, Phong is actually good enough! (according to sp4ghet)
Best for live coding

20211210_phong - https://www.shadertoy.com/view/fltSDN
0b5vr, 2021

Fake IBL

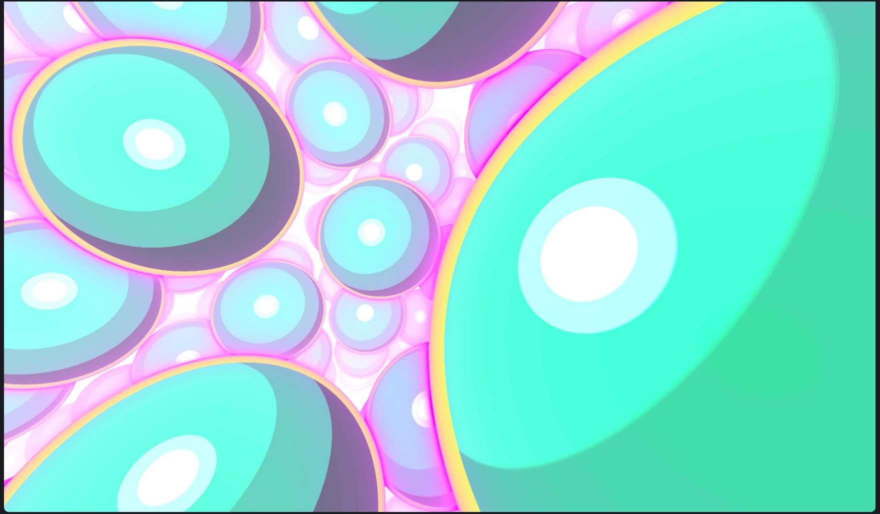




Blackle introduced a way to imitate image based lighting using simple equations
Achieve studio like lighting for free I guess

Quick Lighting Tech - https://www.shadertoy.com/view/ttGfz1
Blackle, 2021

Toon Shading



define ro/rd

march the ray

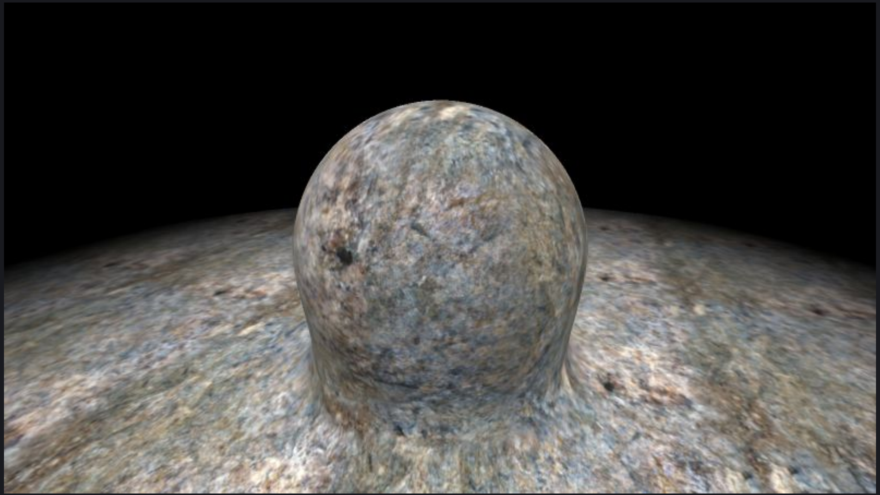
pick a color

lighting

You don’t have to stick to physically legit stuff of course!

Toon Balls - https://www.shadertoy.com/view/lsGBWh
setchi, 2018

Triplanar Mapping



define ro/rd

march the ray

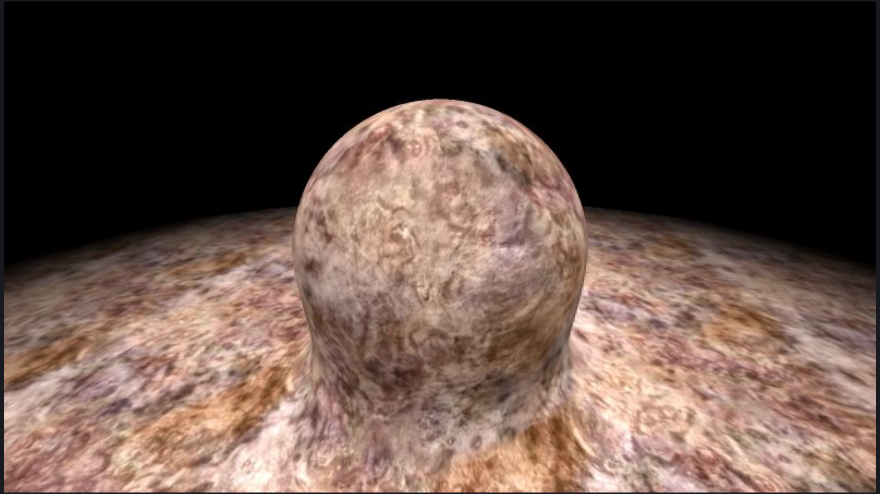
pick a color

map a texture

Map a texture without defining UVs!
Project textures from three sides parallel to each axes and blend them

Box mapping (aka triplanar) - https://www.shadertoy.com/view/MtsGWH
iq, 2015

Biplanar Mapping



define ro/rd

march the ray

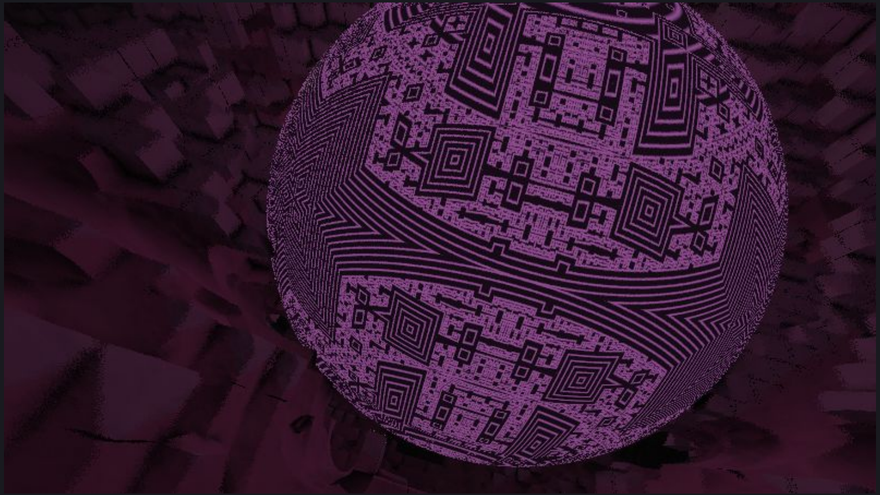
pick a color

map a texture

iq introduced a way to map a texture with only two texture fetches instead of three

Biplanar mapping - https://www.shadertoy.com/view/ws3Bzf
iq, 2020

Procedural Textures



define ro/rd

march the ray

pick a color

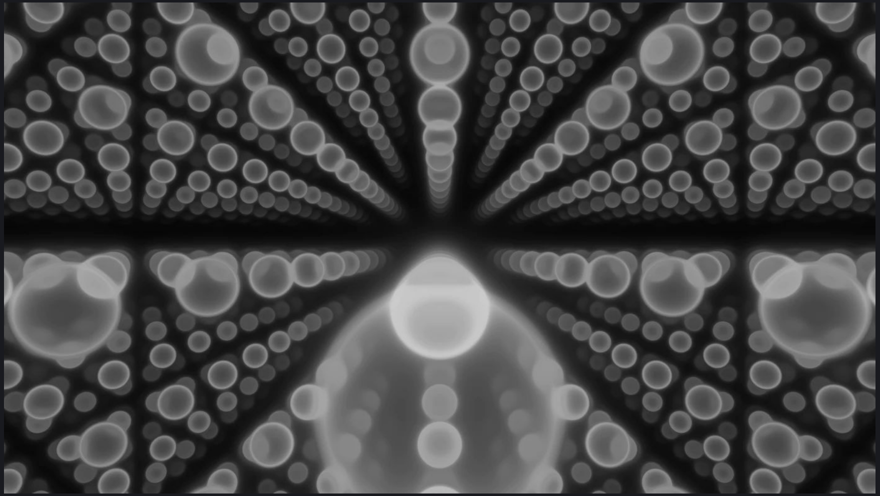
generate a texture

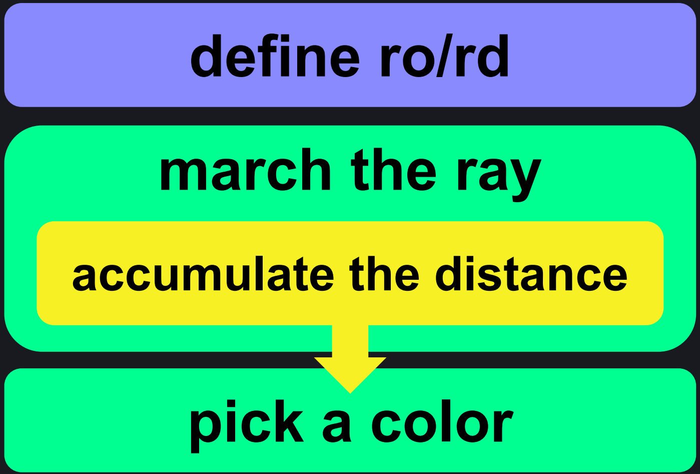
Draw complex patterns using ray position!
Procedural texturing environments such as Blender or Substance Designer might work as great inspirations for you

2nd stage BOSS - https://www.pouet.net/prod.php?which=66962
0x4015 & YET11, 2016

Topic: Ray Tricks

Phantom Mode

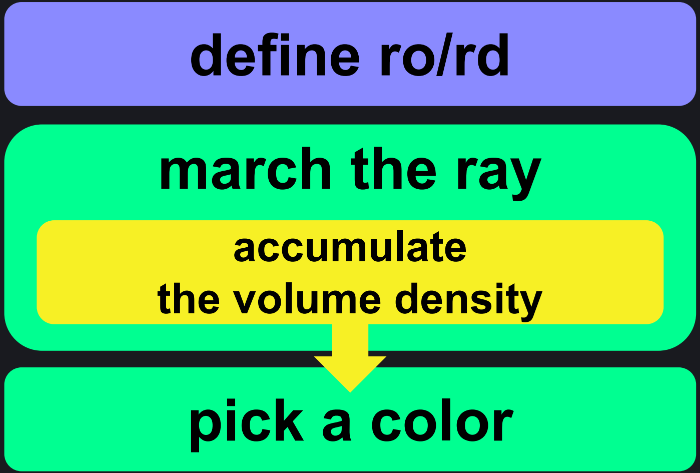




Make things look like X-Ray!
Instead of look for an intersection make it pass through geometries and accumulate `exp(-k * abs(distance))` for each loop

魔法使いになりたい人のためのシェーダーライブコーディング入門 - https://qiita.com/kaneta1992/items/21149c78159bd27e0860
kaneta, 2019

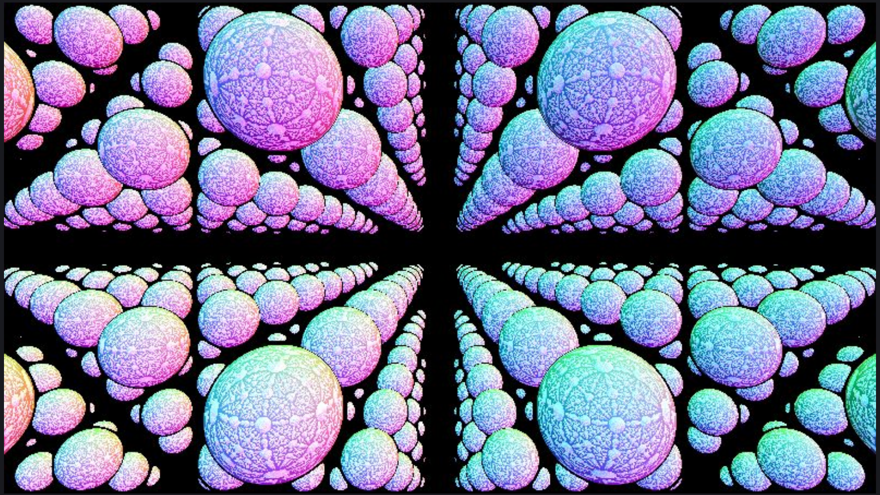
Volumetric Rendering

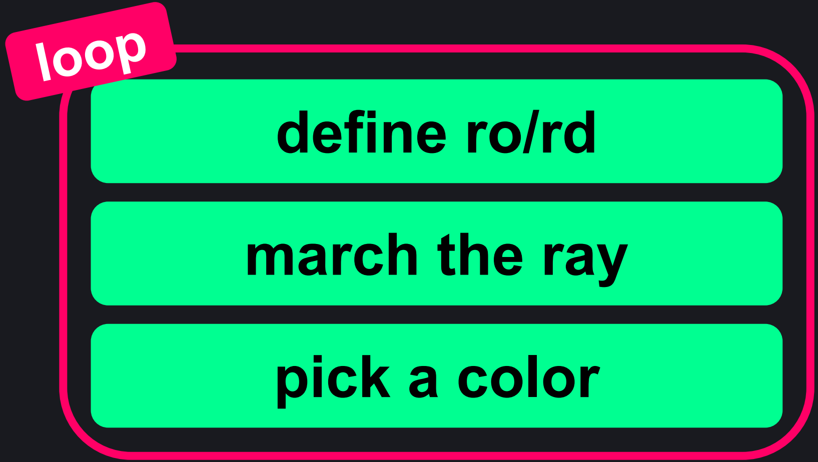


Now we are using a volume density function instead of a distance function
volume density is often defined using noises
March the ray at a constant step length, accumulate the density

Clouds - https://www.shadertoy.com/view/XslGRr
Inigo Quilez, 2013

Reflection

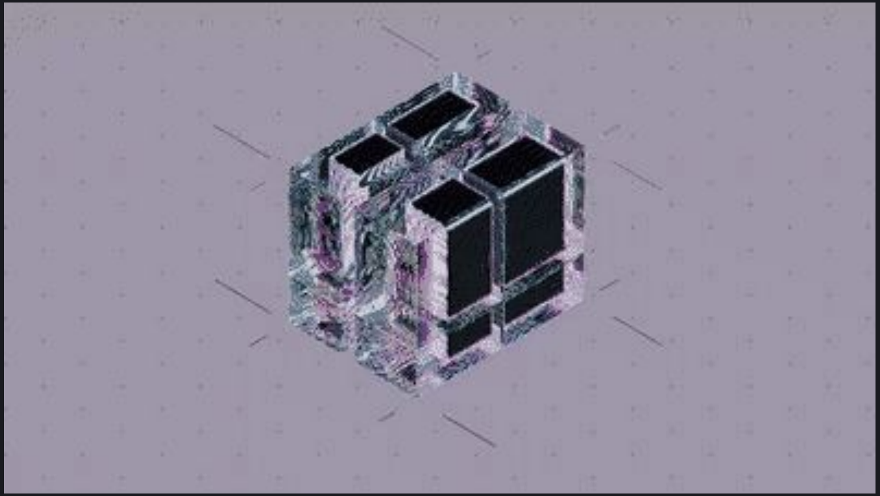


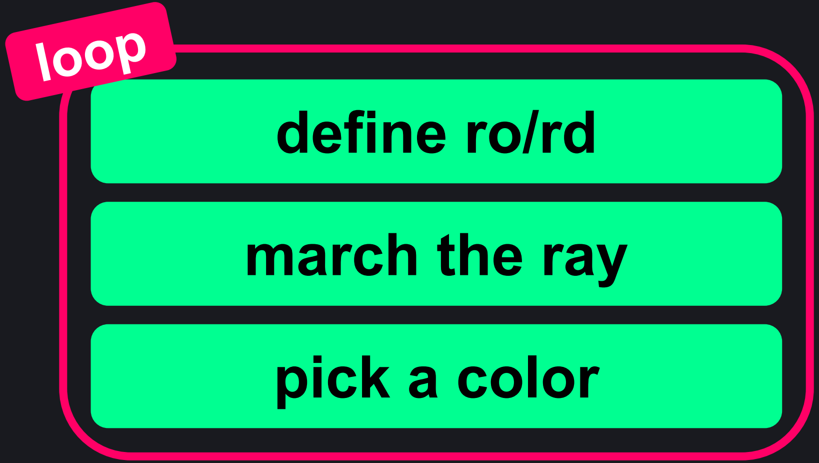


After the ray hits to surfaces, march the ray again from the surface

20211210_reflection - https://www.shadertoy.com/view/fttXD4
0b5vr, 2021

Refraction

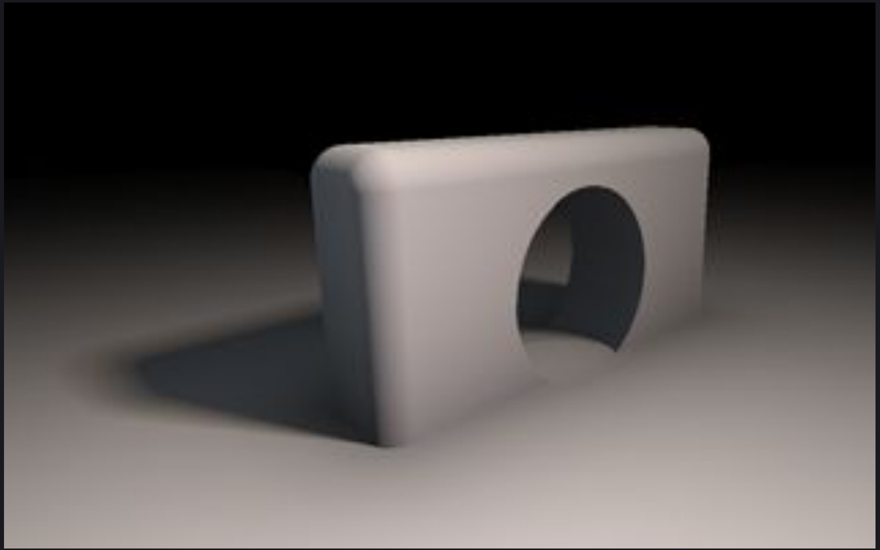


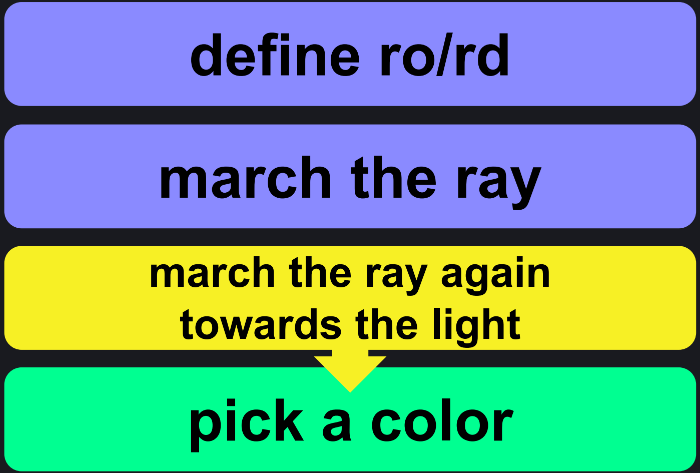


I just wanted to introduce tdhooper's new shader tbh

Shuffle box - https://www.shadertoy.com/view/7t3SW8
tdhooper, 2021

Shadowing

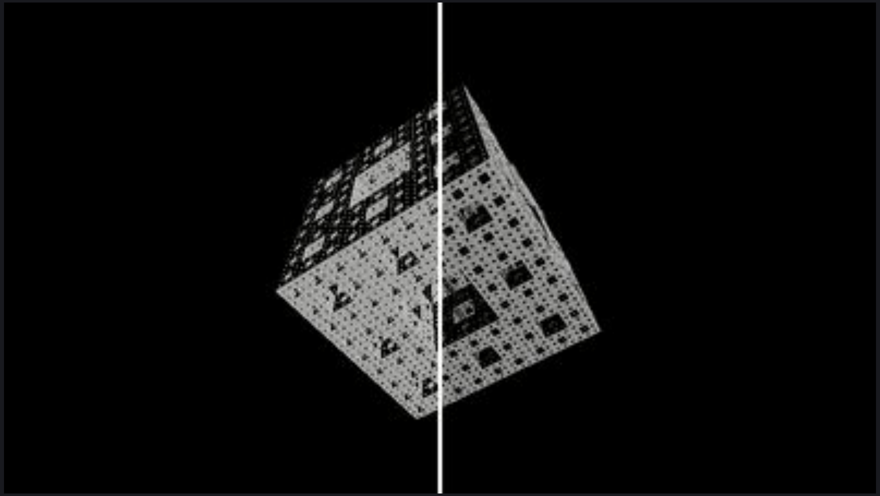




Make surfaces darker by obscurance
Soft shadows can be achieved easily in raymarched scenes!

soft shadows in raymarched SDFs - https://www.iquilezles.org/www/articles/rmshadows/rmshadows.htm
Inigo Quilez, 2010

Ambient Occlusion



Make surfaces darker by obscurance (2)
Perfect with complex geometries!

define ro/rd

march the ray

march the ray again
towards the surface normal*

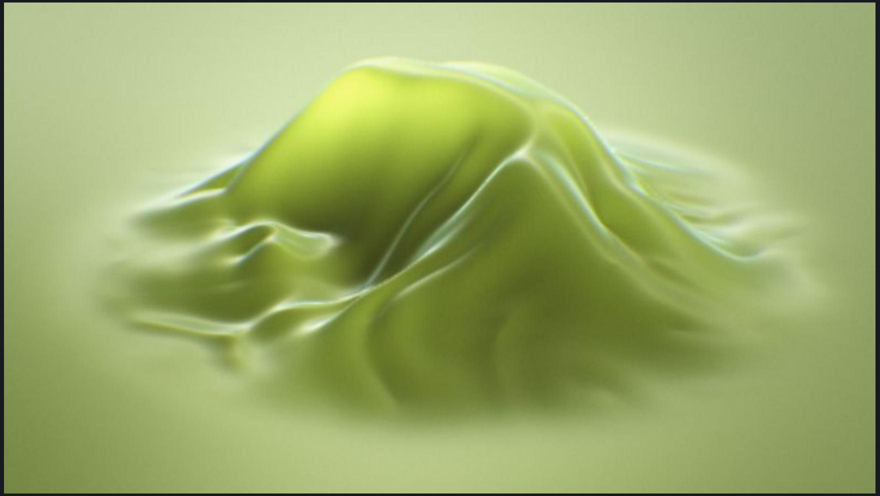
pick a color

*There are various ways
to achieve AO

20211209_menger sponge ao - https://www.shadertoy.com/view/ft3XDH
0b5vr, 2021

Subsurface Scattering

🔥🔥



define ro/rd

march the ray

march the ray again
towards the light*

pick a color

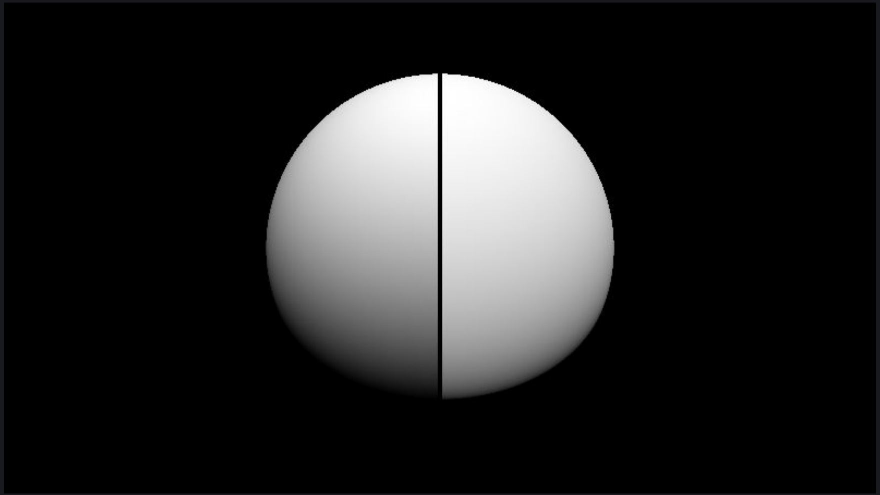
*There are various ways
to achieve SSS

Make rays scatter inside the surface
Useful to achieve human skins or gummy like feelings

Goo - https://www.shadertoy.com/view/llIBDM
noby, 2017

Topic: Post Processing

OETF



define ro/rd

march the ray

pick a color

modify the color

To make the output color physically linear, we have to use a function called OETF since our display does not emit input colors linearly

The famous `pow(color, vec3(0.4545))`

20211209_oetf - https://www.shadertoy.com/view/ft3SWH
0b5vr, 2021

Vignette

define ro/rd

march the ray

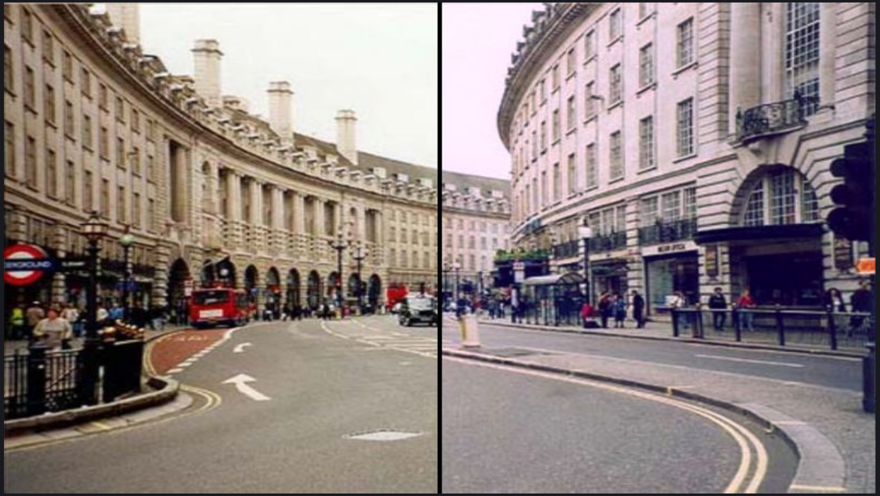
pick a color

modify the color

Unnecessarily make corners darker to make it cool

20211209_vignette - https://www.shadertoy.com/view/NtcSWH
0b5vr, 2021

Color Grading



define ro/rd

march the ray

pick a color

modify the color

Modify the output color at the very last part of the shader
There are various ways to do color grading
The above one simulates DaVinci Resolve, the famous color grading software

20211119_DaVinci Resolve - https://www.shadertoy.com/view/7tK3zW
0b5vr, 2021

Conclusion

Go https://www.shadertoy.com/

don’t be afraid! people are coding just for fun I believe :)

END