# レイマーチング1から5

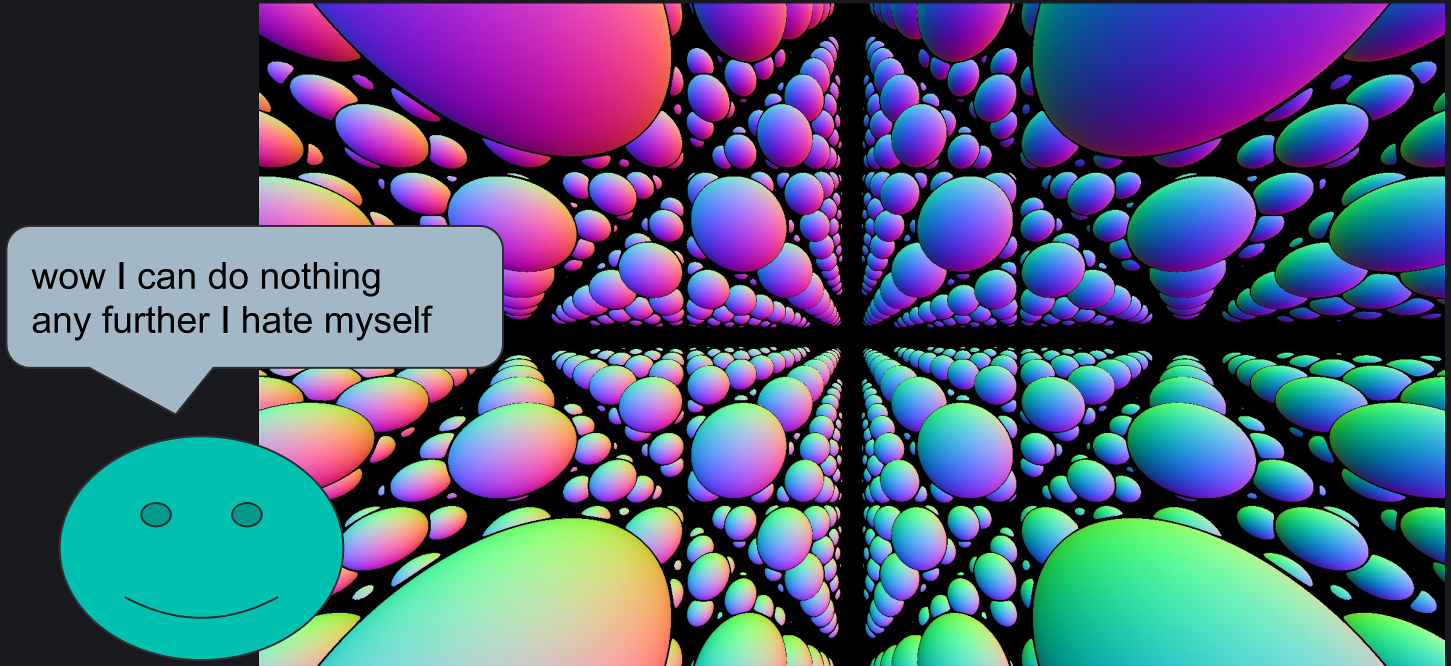
（命名: @kuyuri_iroha）

0b5vr

2021-12-11 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)**

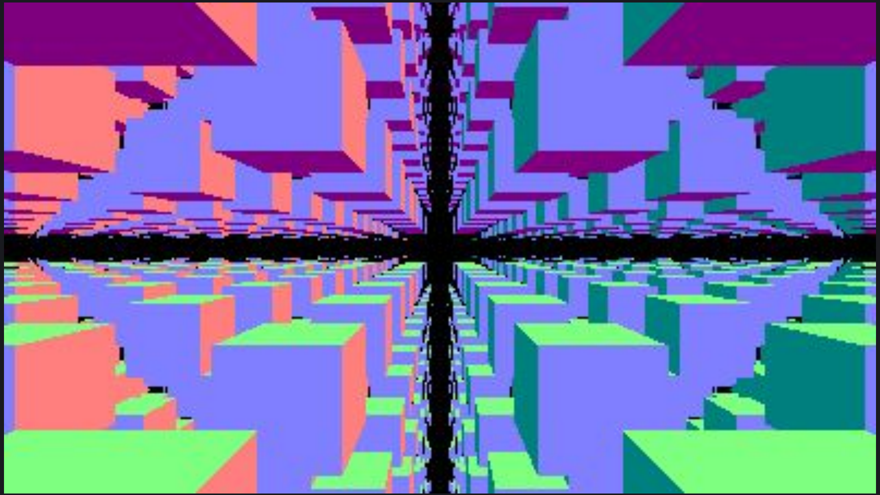
**(Definitely not exhaustive)**

# The basic structure of raymarcher code

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

# Topic: Camera

# Field of View (FOV)



define ro/rd

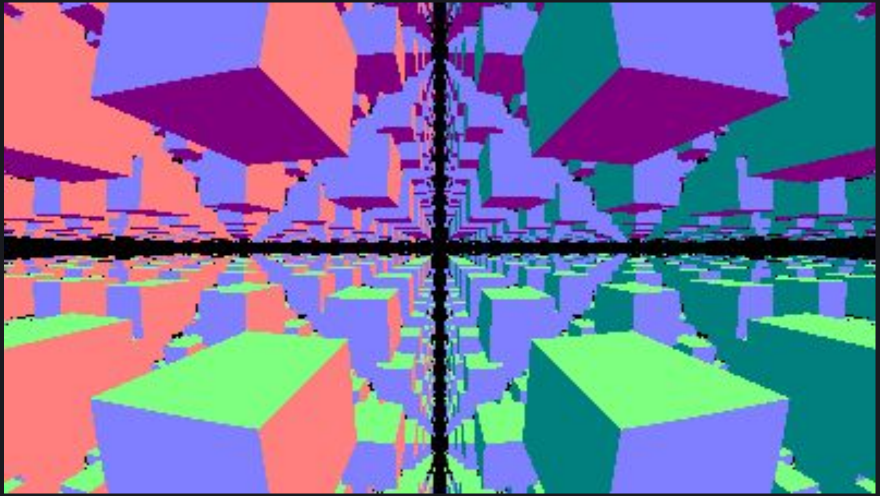
march the ray

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

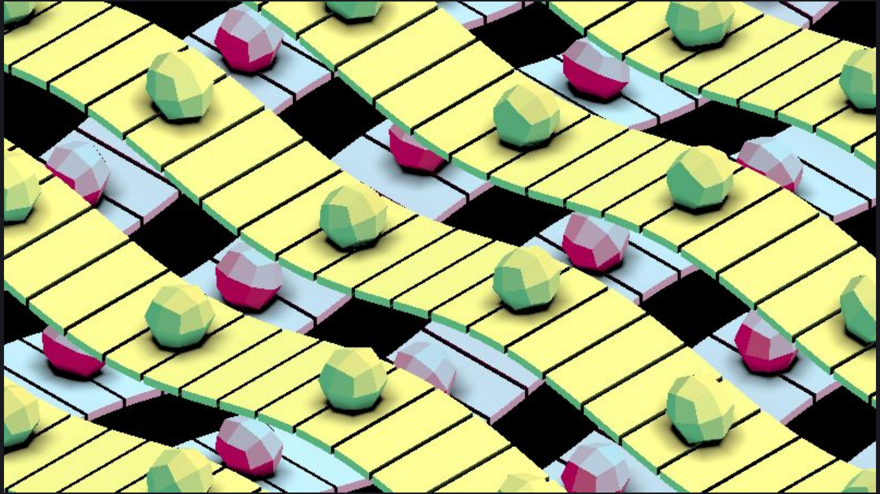
pick a color

**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](https://www.shadertoy.com/view/NtdXDH)
0b5vr, 2021

# Orthogonal Projection



define ro/rd

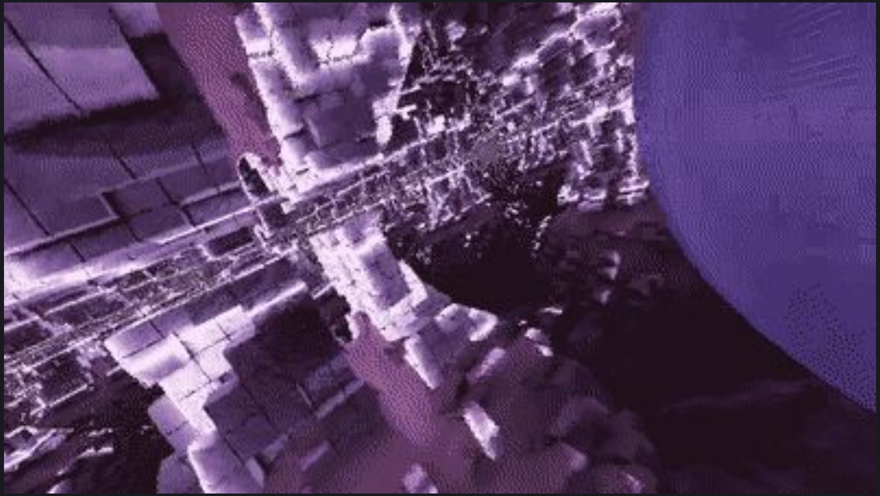
march the ray

pick a color

**You can even draw your scene without perspective projection**
**Very cute**

Weave Factory - [https://www.shadertoy.com/view/stSSzy](https://www.shadertoy.com/view/stSSzy)
Flopine, 2021

# Motion Blur



**add a random value to time**

**define ro/rd**

**march the ray**

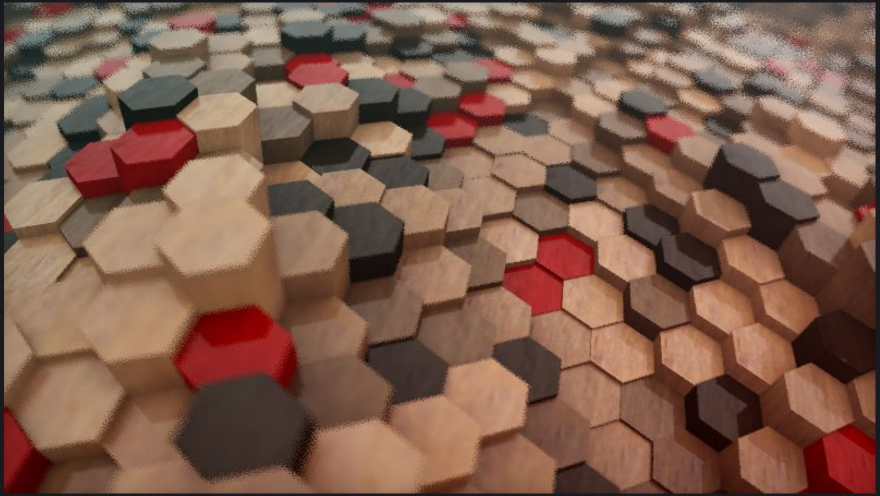
**pick a color**

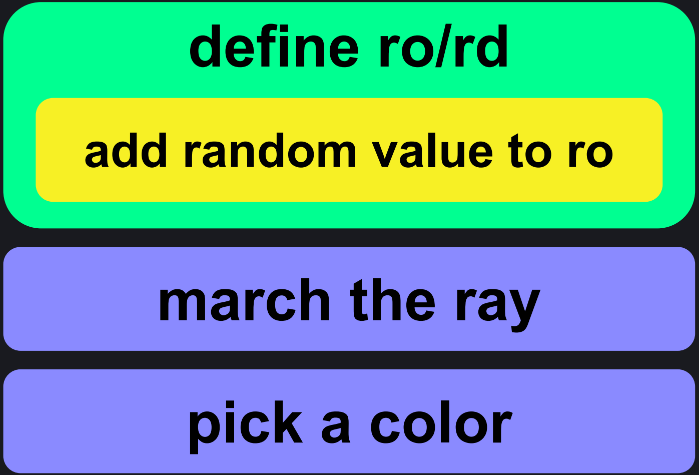
**Doing motion blur in a single pass??**
**Add a random value to `time` for each pixel, that’s it.**
**Might look noisy but it’s working, isn’t it?**

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

2nd stage BOSS - [https://www.pouet.net/prod.php?which=66962](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

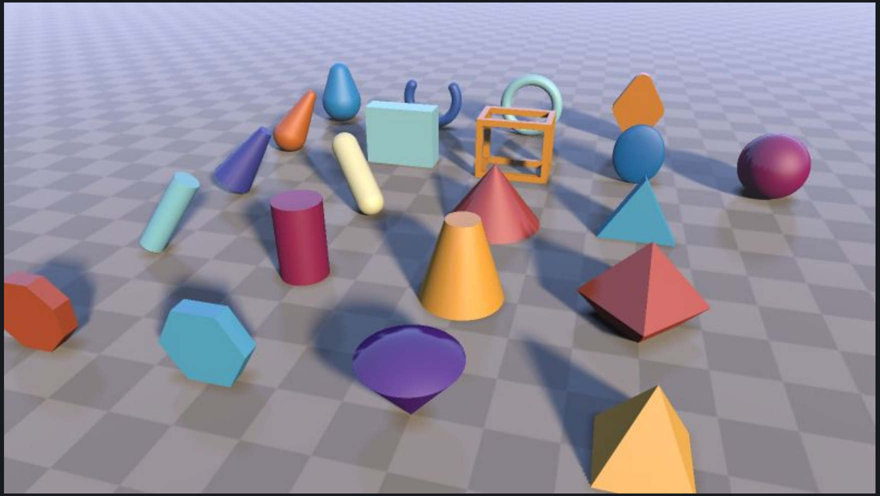
The same goes for the depth of field

```
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

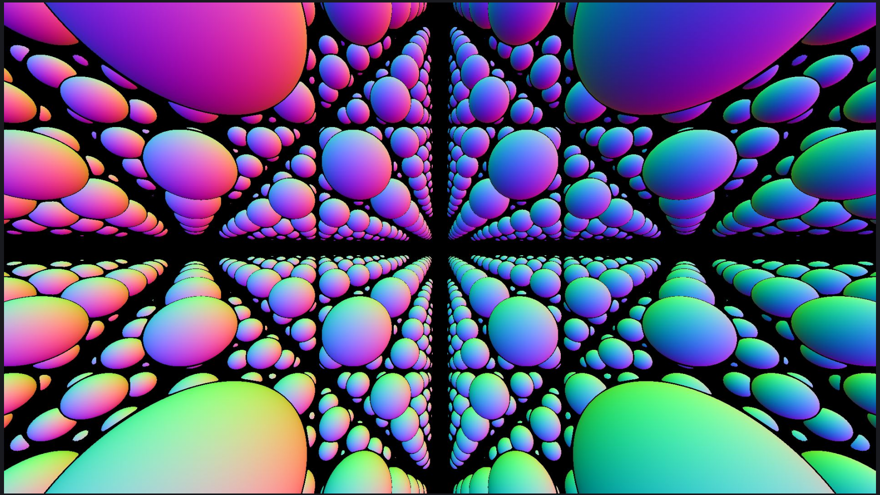
march the ray

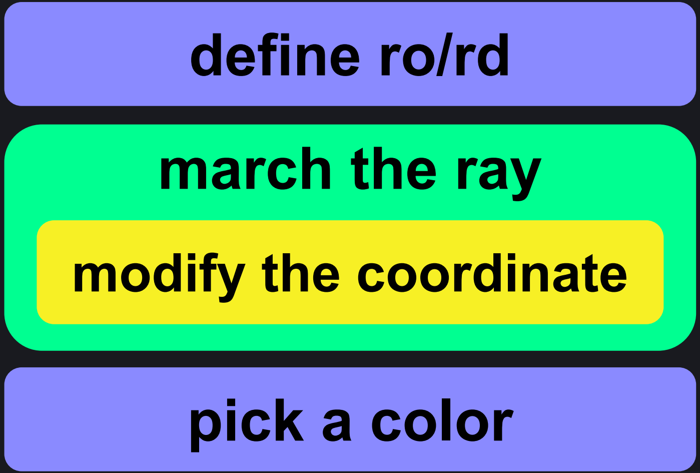
pick a color

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

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

# Repetition





define ro/rd

march the ray

modify the coordinate

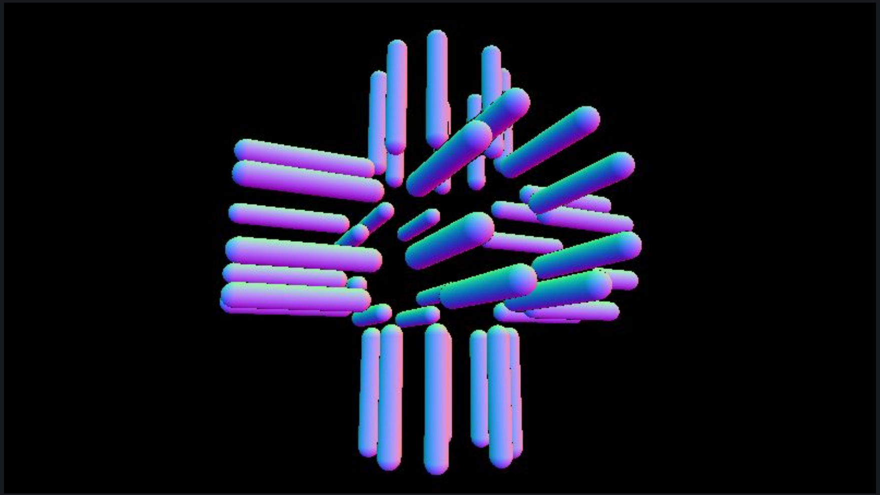
pick a color

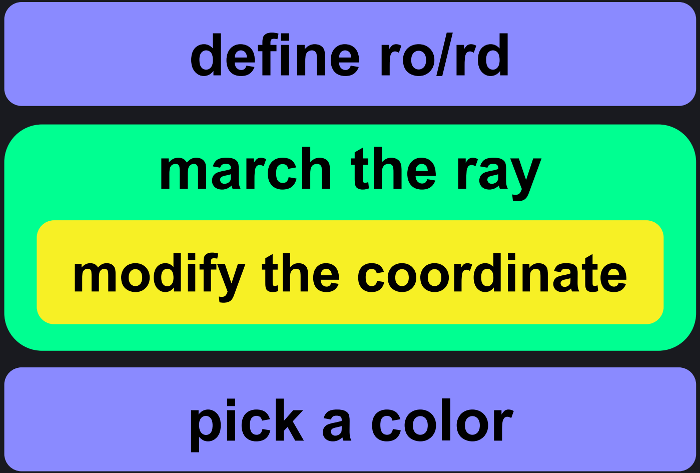
**Inside the distance function, repeat the coordination system and make a thing appear many times**

```
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

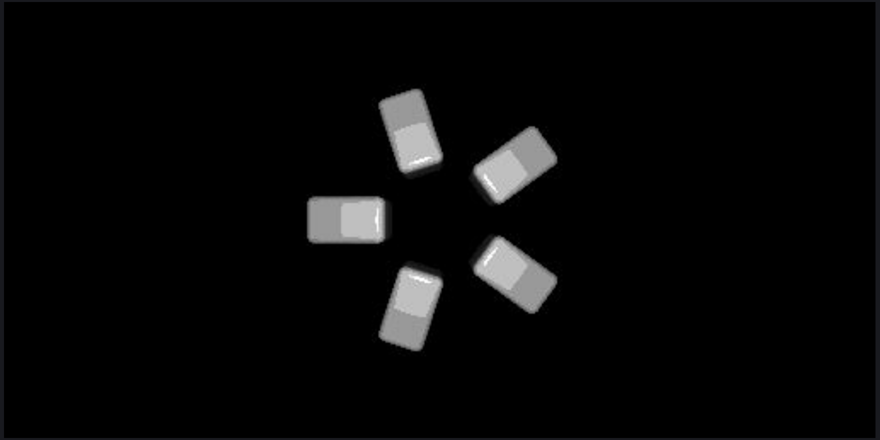
modify the coordinate

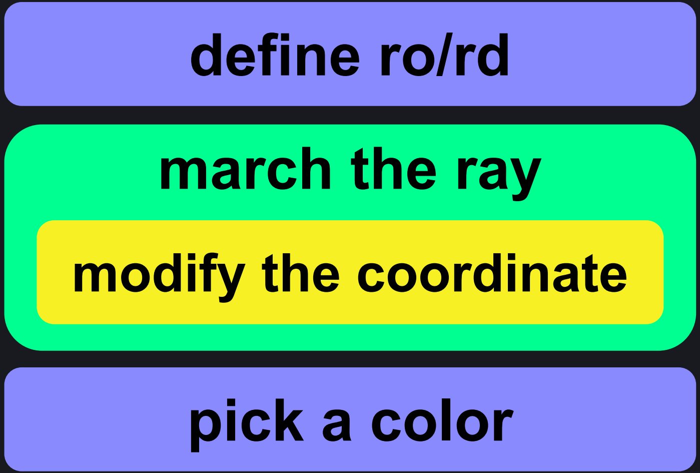
pick a color

“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

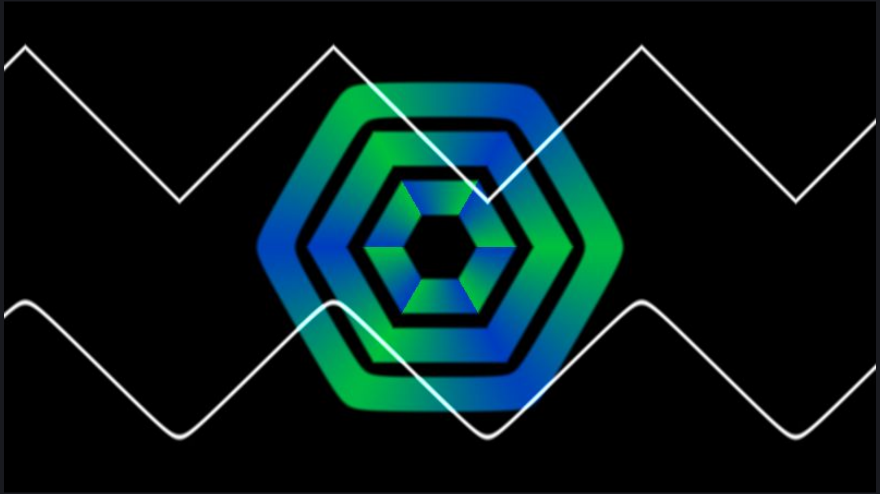


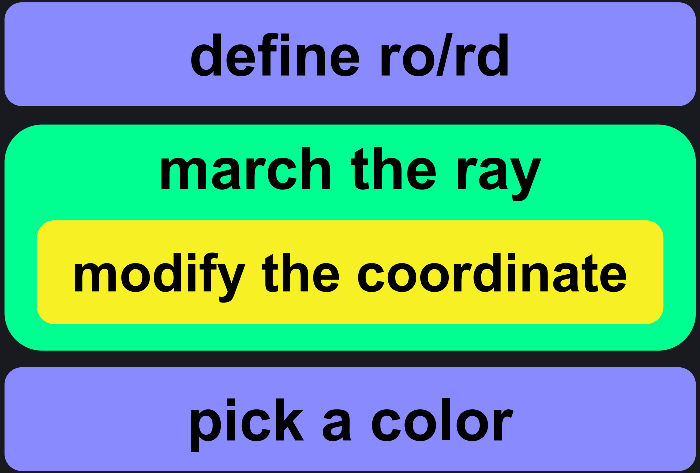


**Repeat the coordinate in theta axis of a polar coordinate**
**→ They will be duplicated in a circle**

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

# Polar Smooth Fold





define ro/rd

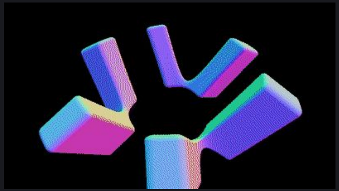
march the ray

modify the coordinate

pick a color

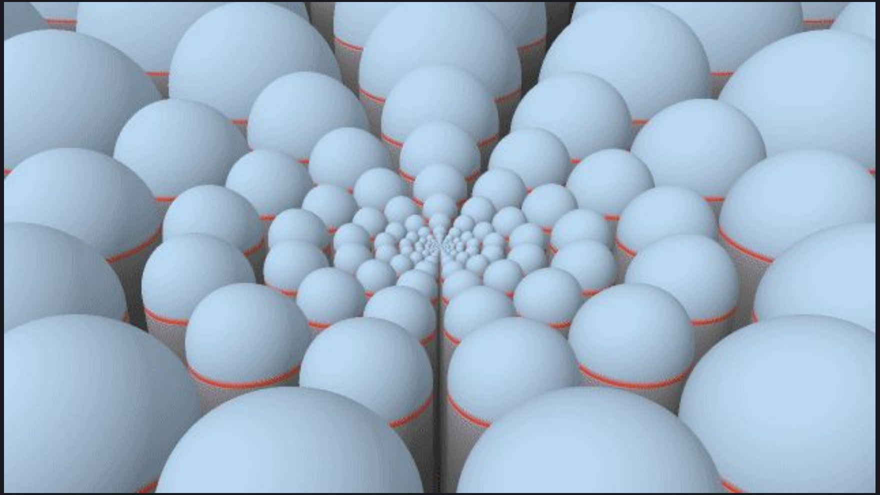
**Fold rotate but smoother**

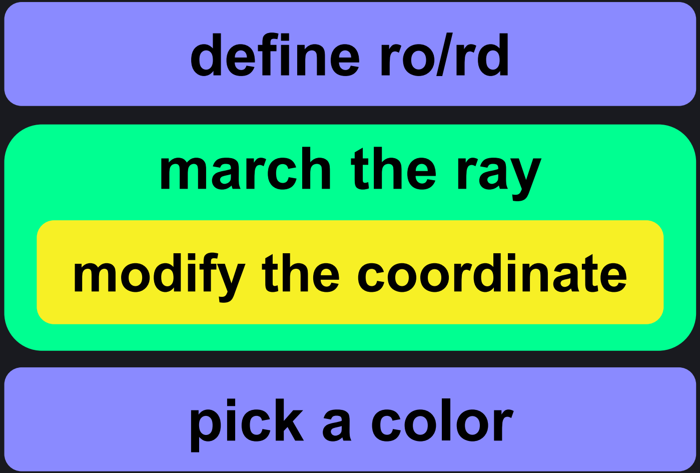
I tried this tech →
https://www.shadertoy.com/view/NttSD4



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

# Log-polar Mapping / Log-spherical Mapping 🔥





define ro/rd

march the ray

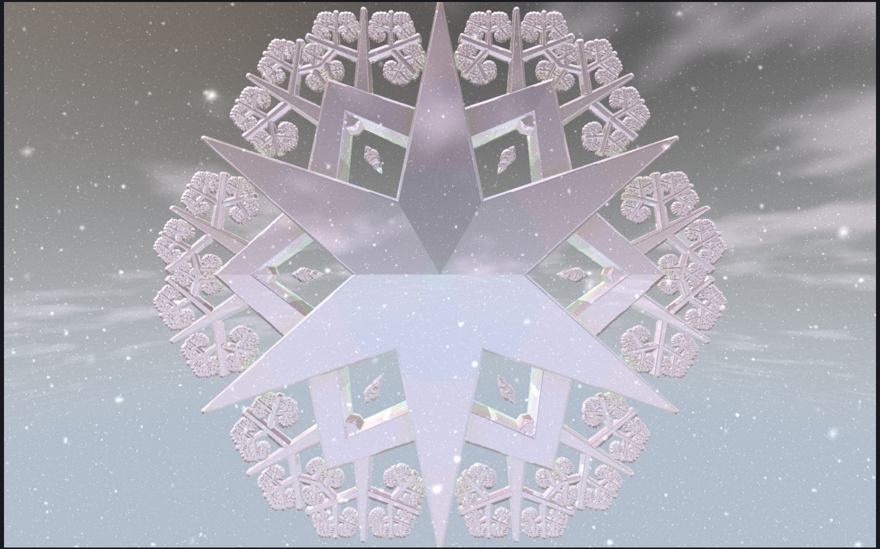
modify the coordinate

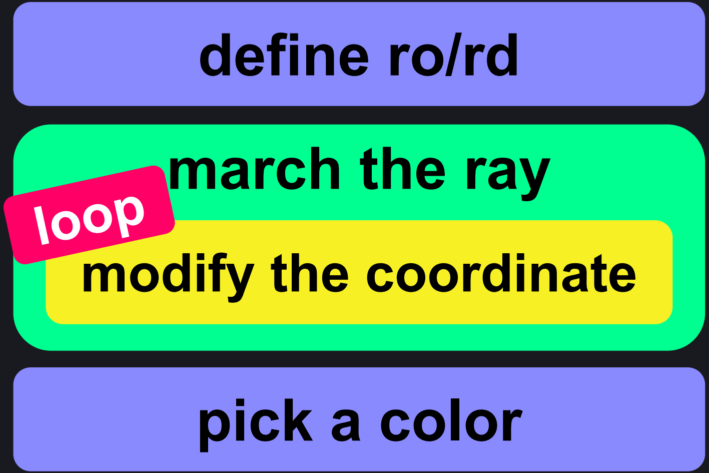
pick a color

**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/](https://www.osar.fr/notes/logspherical/)
Pierre Cusa, 2019

# IFS (Iterated function system)





define ro/rd

march the ray

loop

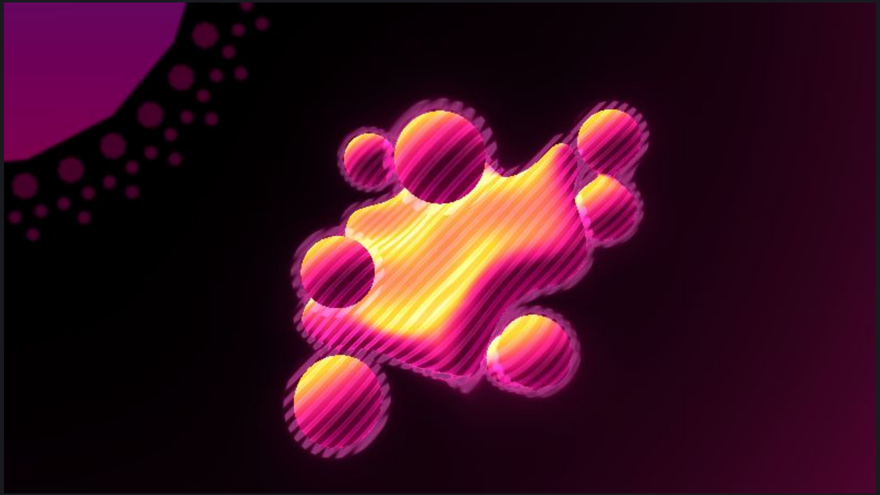
modify the coordinate

pick a color

**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

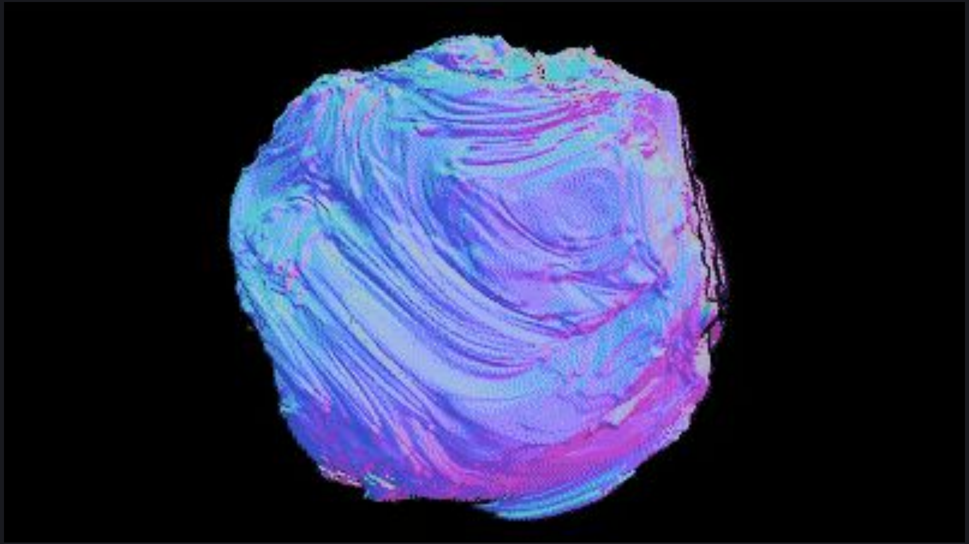
march the ray

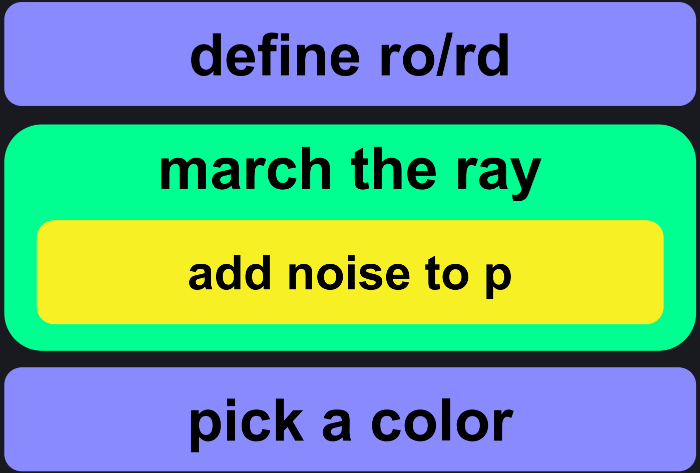
pick a color

**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](https://www.shadertoy.com/view/7tcGWB)
Tater, 2021

# Domain Warping

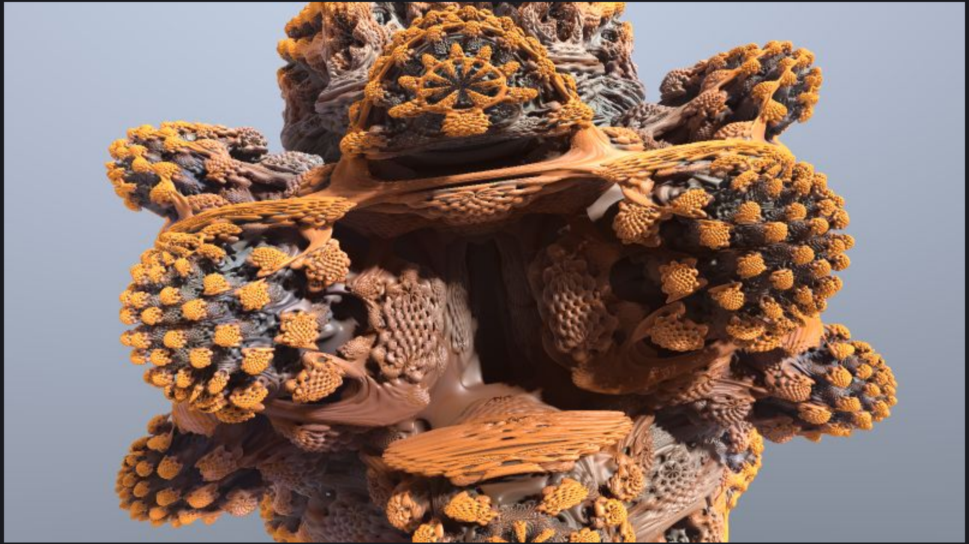




**Warp the coordination using noises inside of distance function!**
**You can use various noises (and not-noises) for domain warping**

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

# Mandelbulb



define ro/rd

march the ray

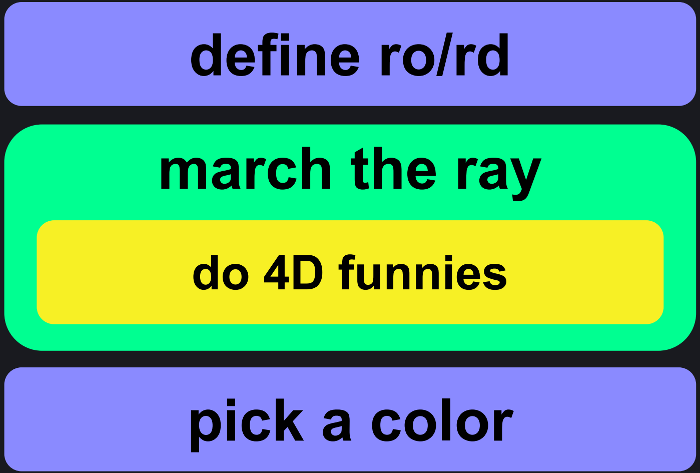
do quaternion funnies
I guess

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

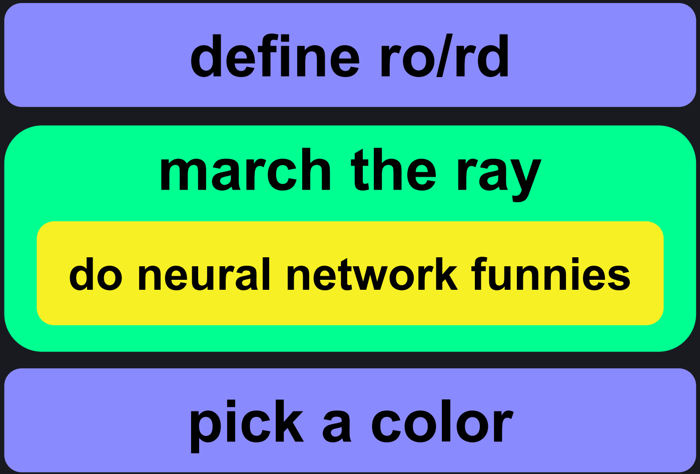
# 4D Stereographic Projection 🔥



**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

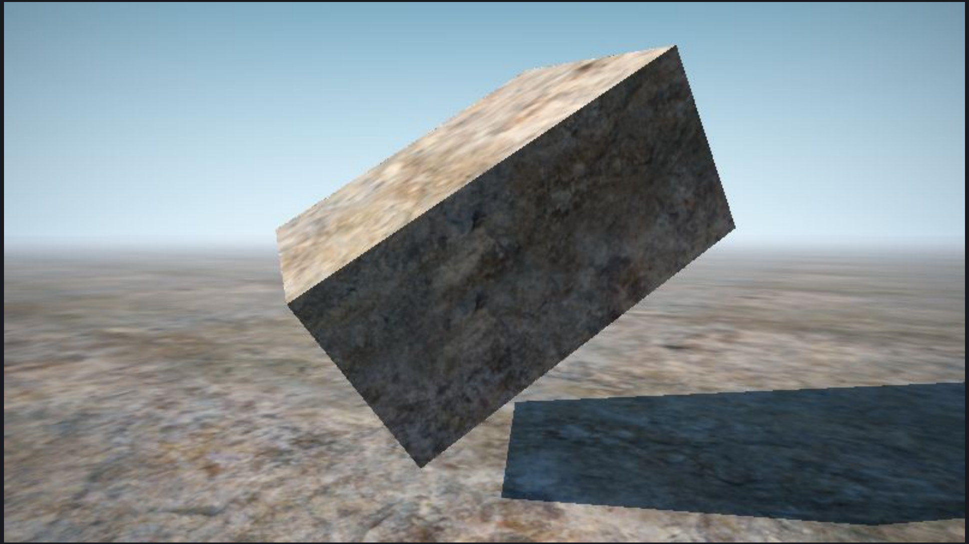
pick a color

**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~~

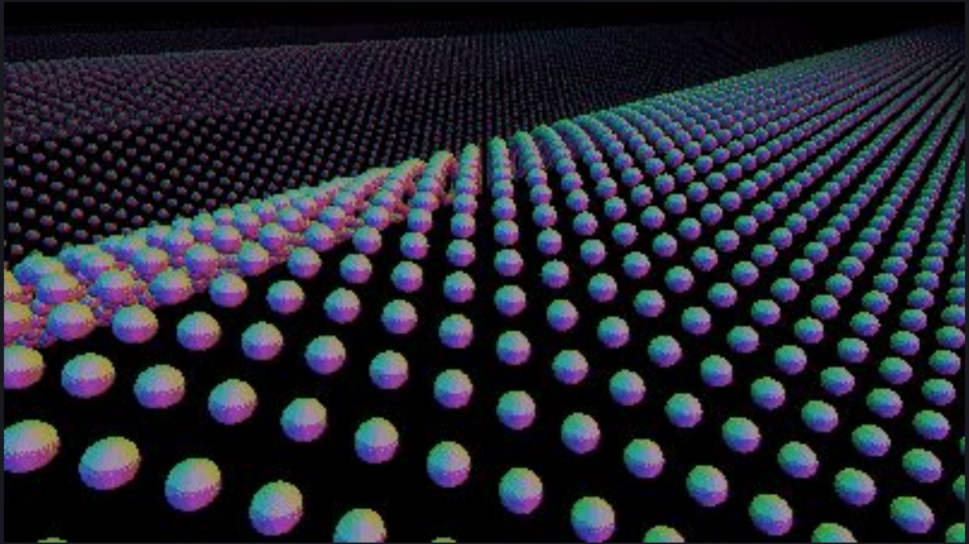
find ray intersection

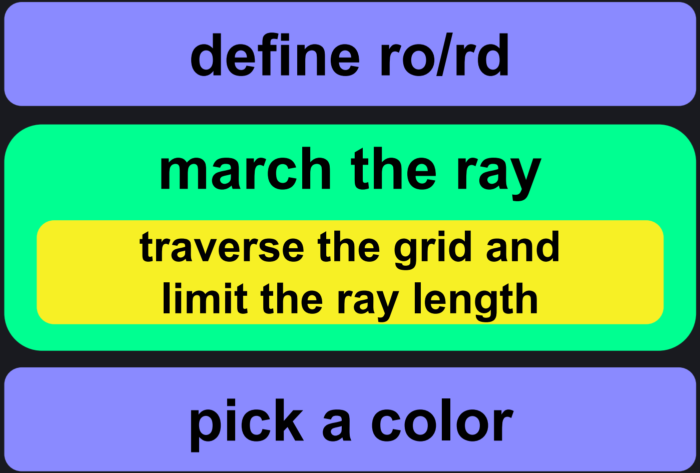
pick a color

**“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](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

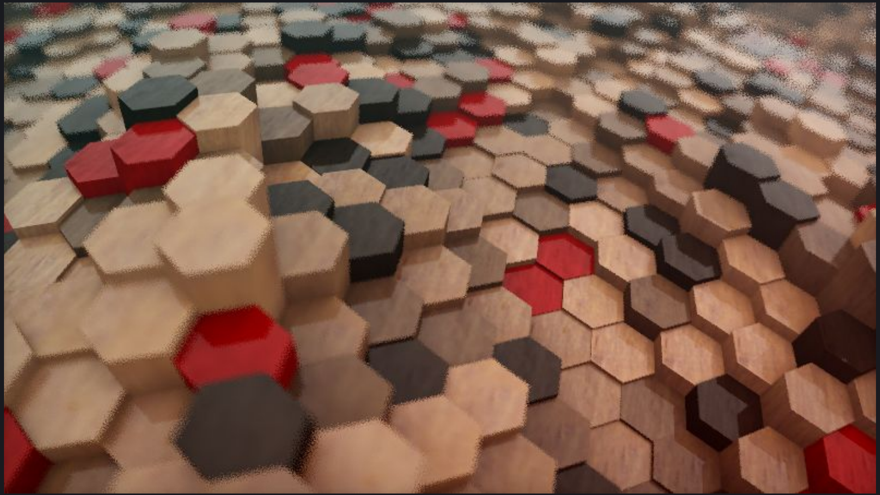
pick a color

**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

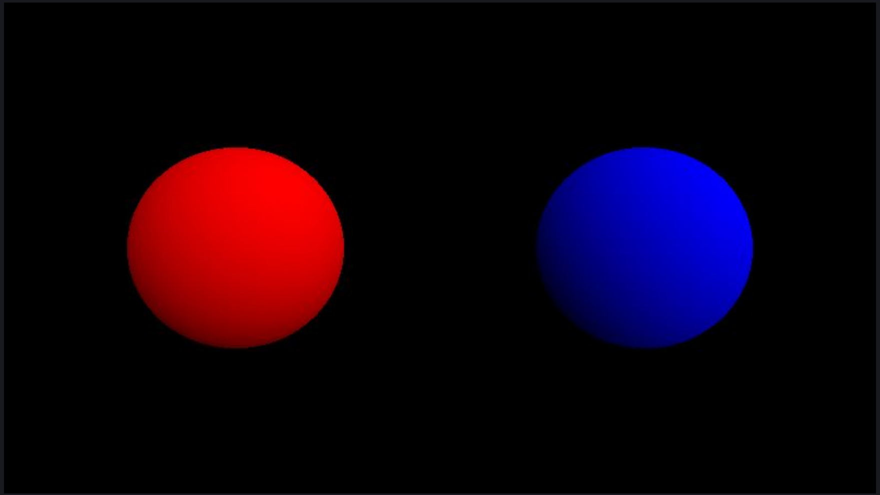
pick a color

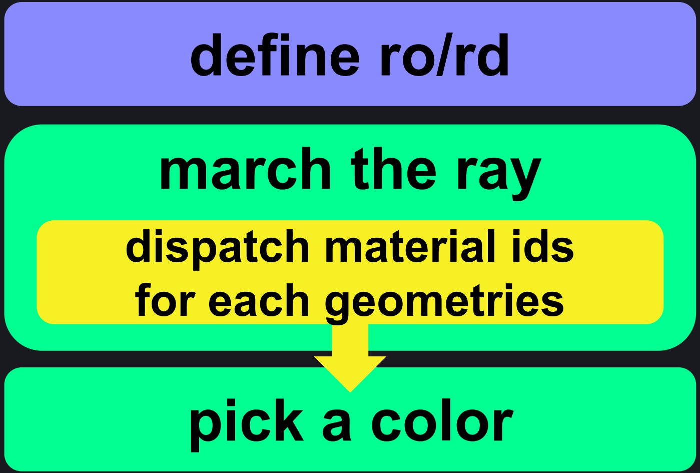
**You can even traverse the hexagonal grid!**

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

# Topic: Rendering

# Materials





define ro/rd

march the ray

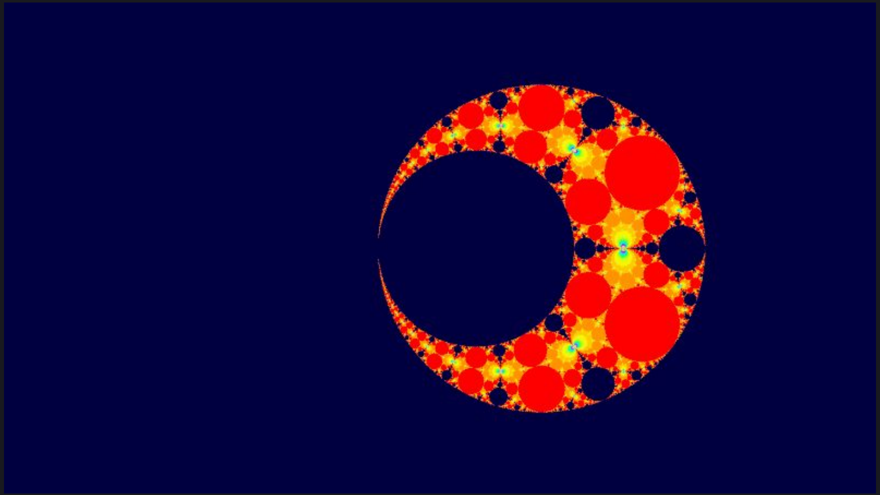
dispatch material ids
for each geometries

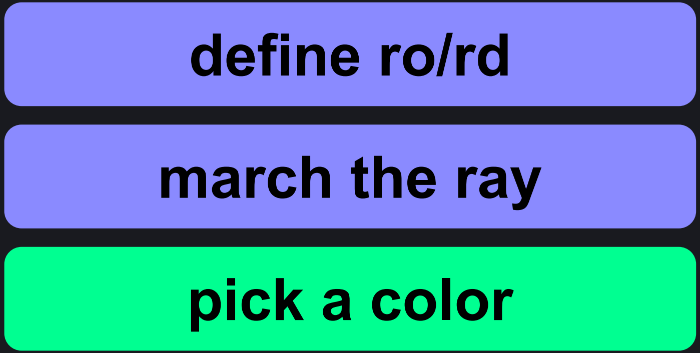
pick a color

**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

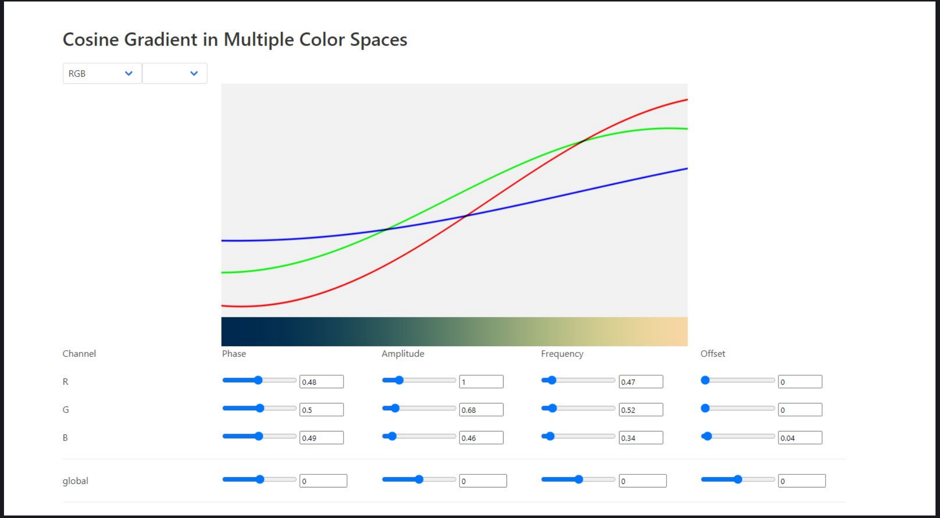
march the ray

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**

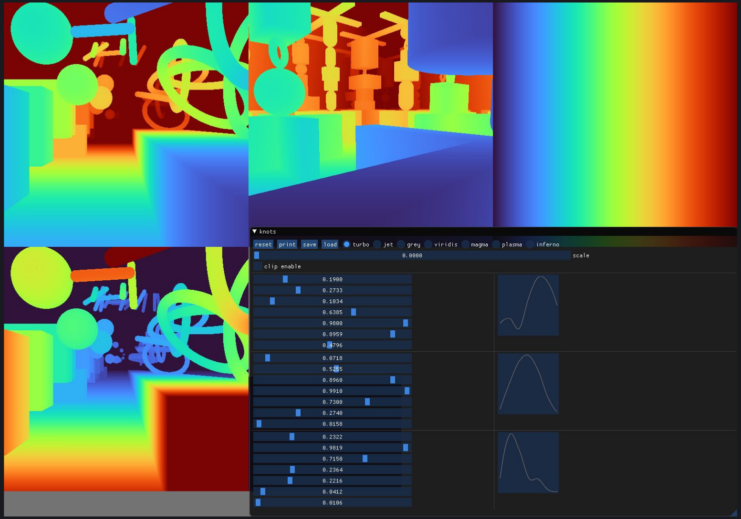
**march the ray**

**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
□ clip enable
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

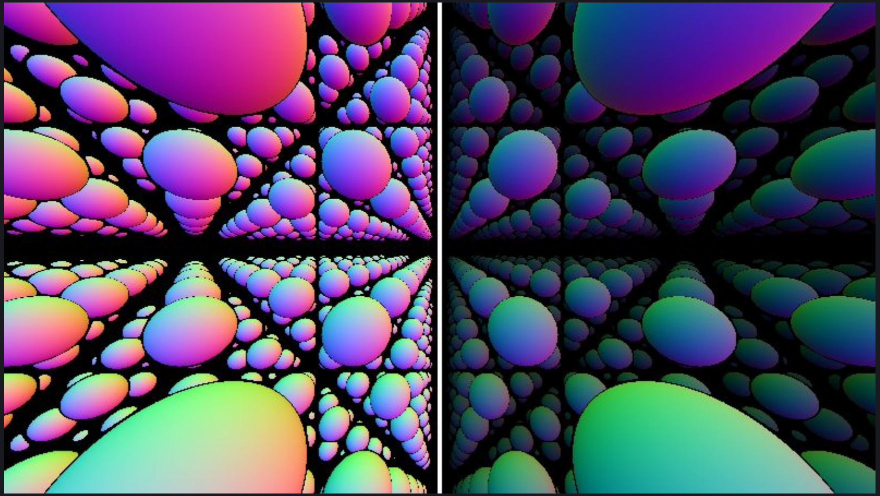
march the ray

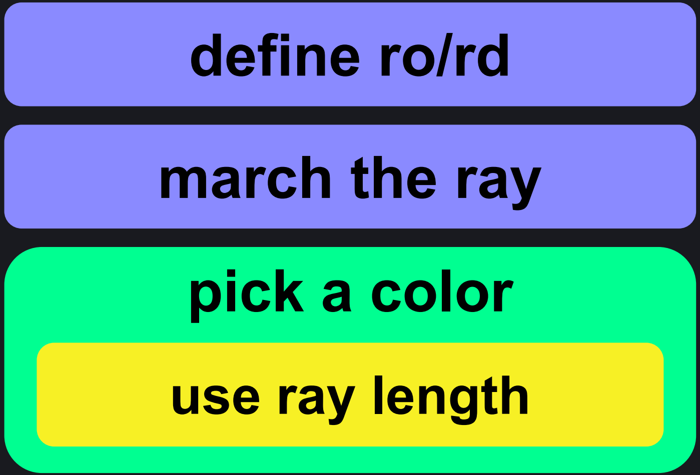
pick a color

**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

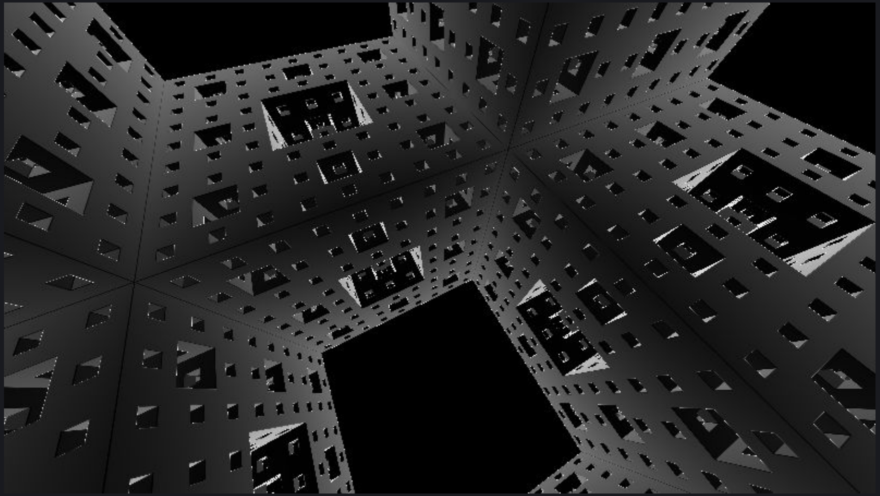
use ray length

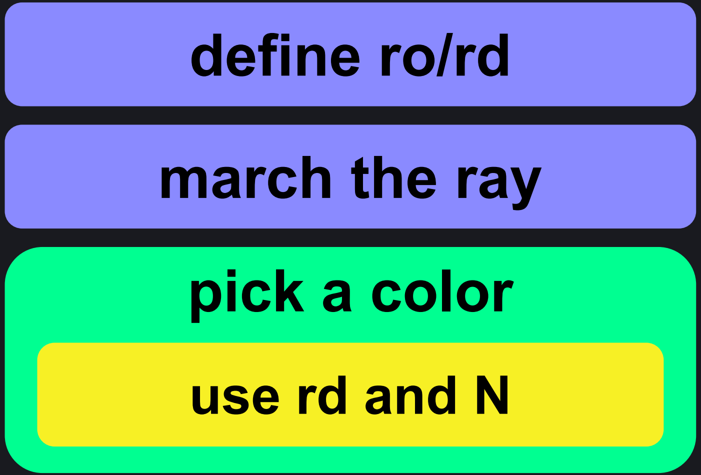
**Use ray length to enhance the perception based on distance**

```
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

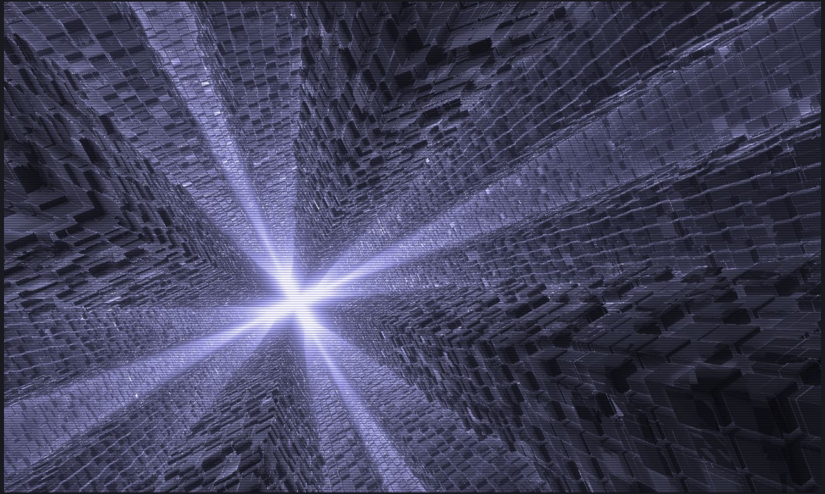
pick a color

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



Glowing edges are cool

define ro/rd

march the ray

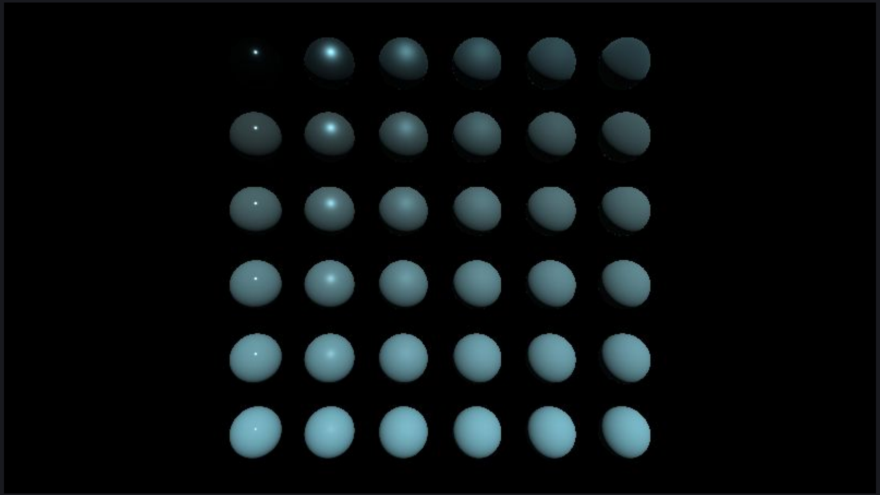
pick a color

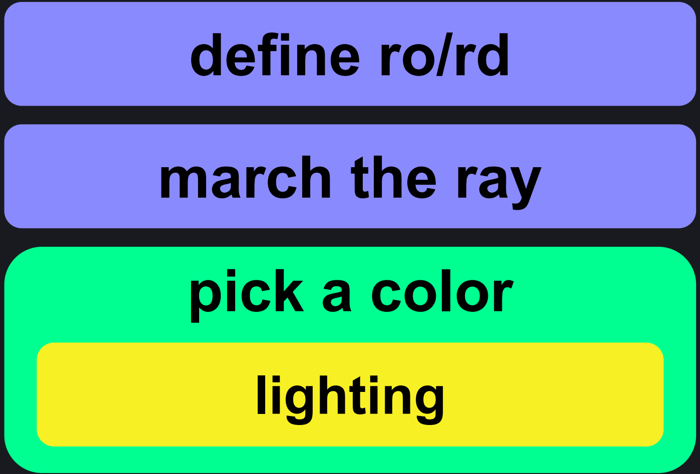
pick dFdx/dFdy of N*

*There are various ways to get edges

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

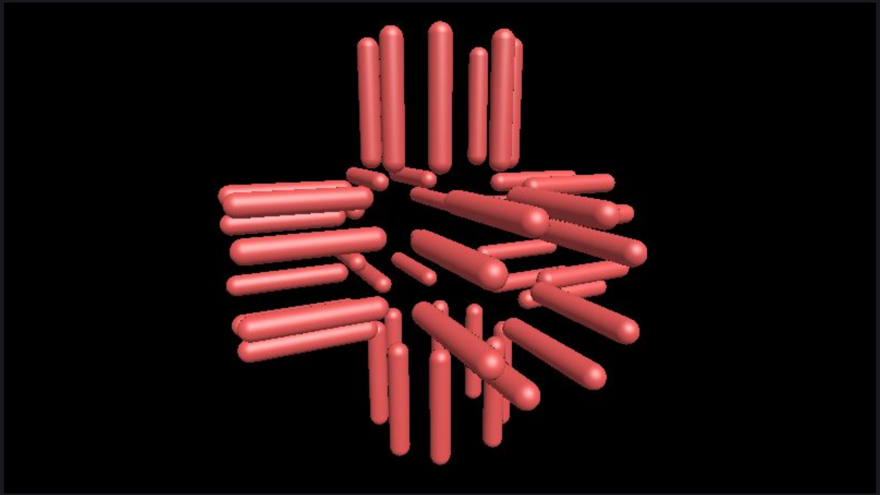
pick a color

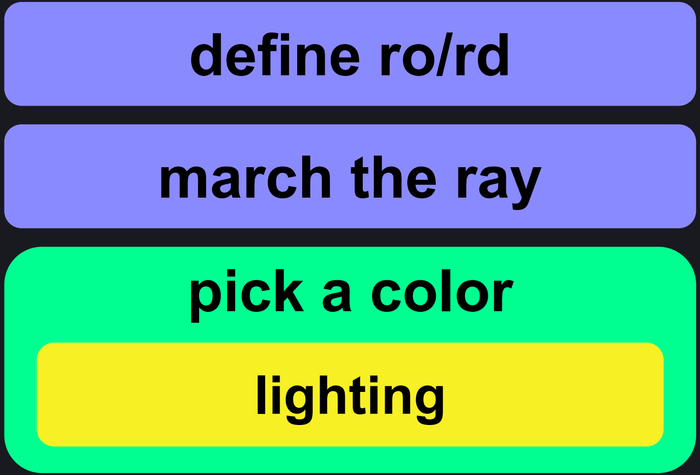
lighting

**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

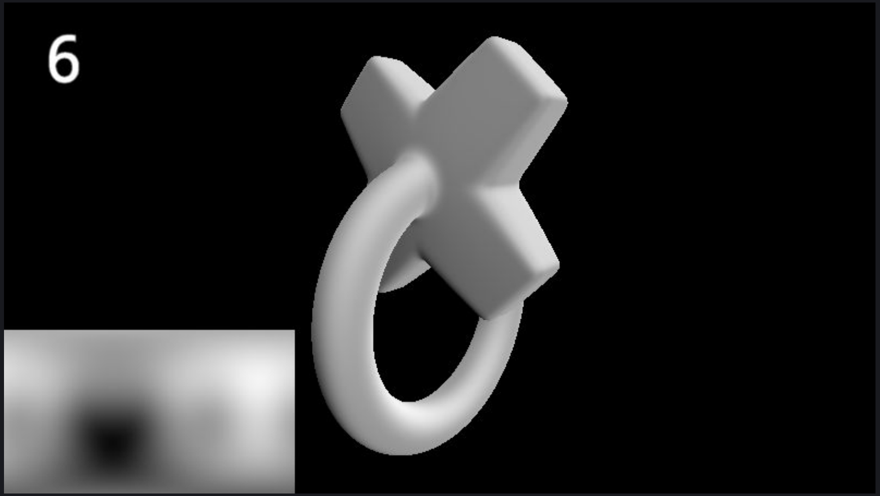


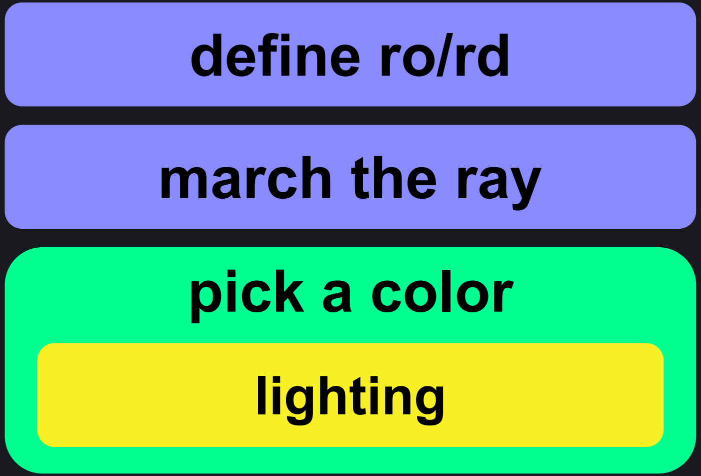


**Wait, Phong is actually good enough! (according to sp4ghet)**
**Best for live coding**

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

# Fake IBL




define ro/rd

march the ray

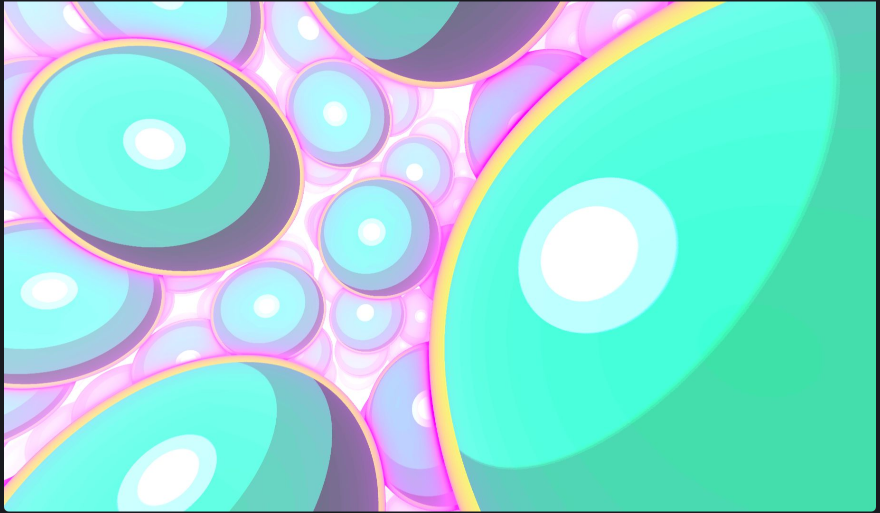
pick a color

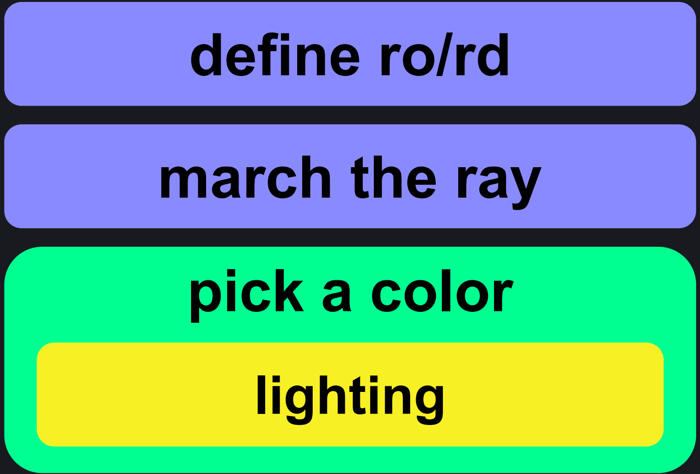
lighting

**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

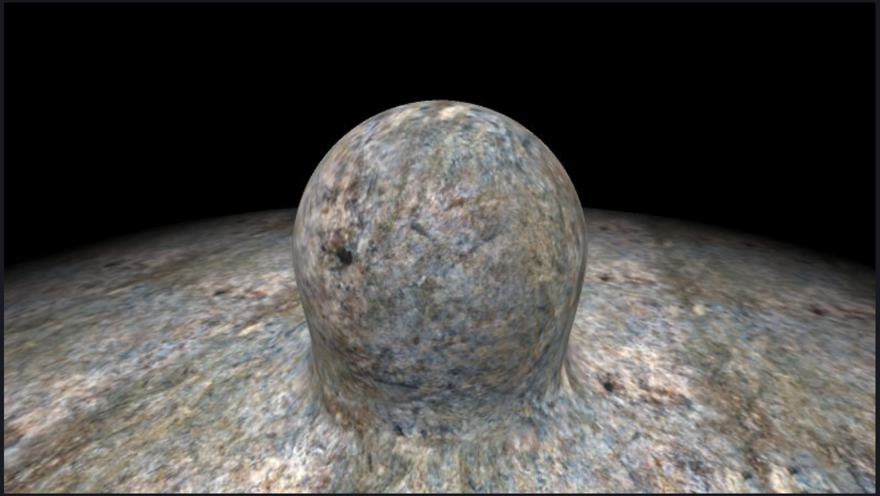
pick a color

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

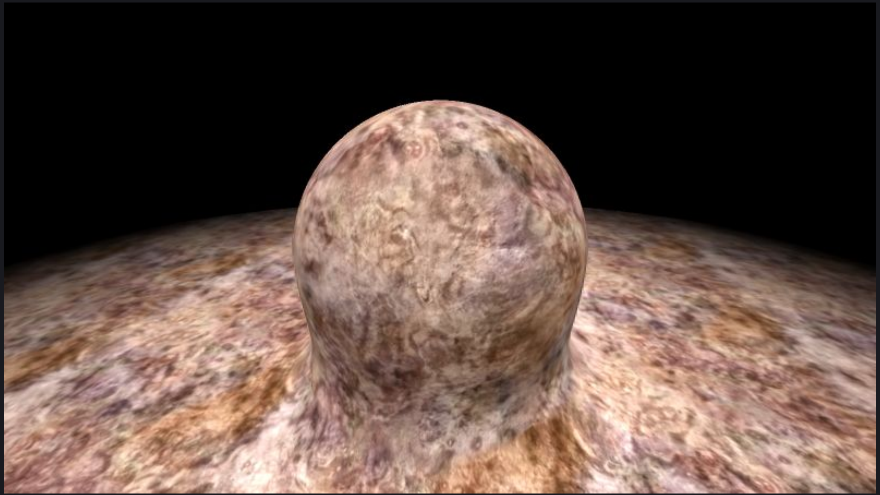
pick a color

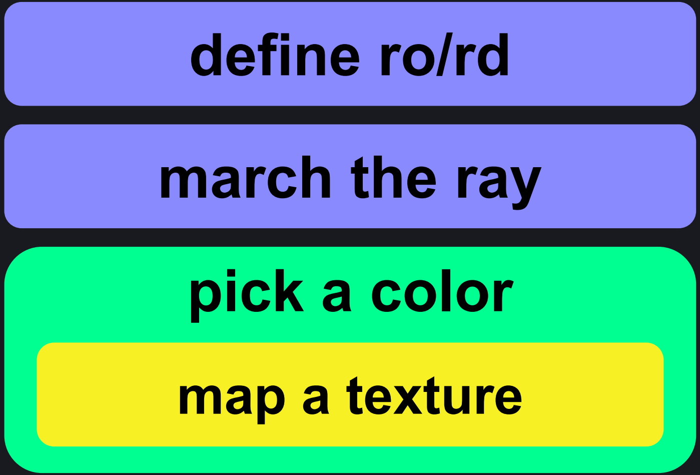
map a texture

**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

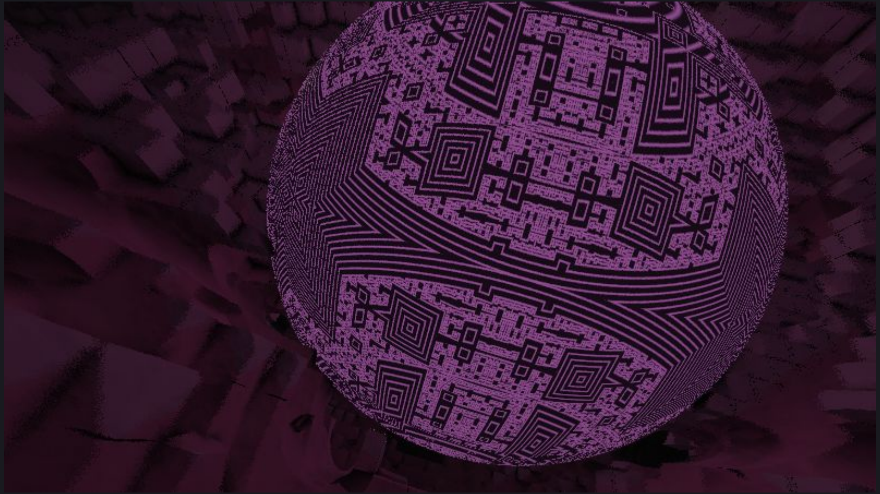
pick a color

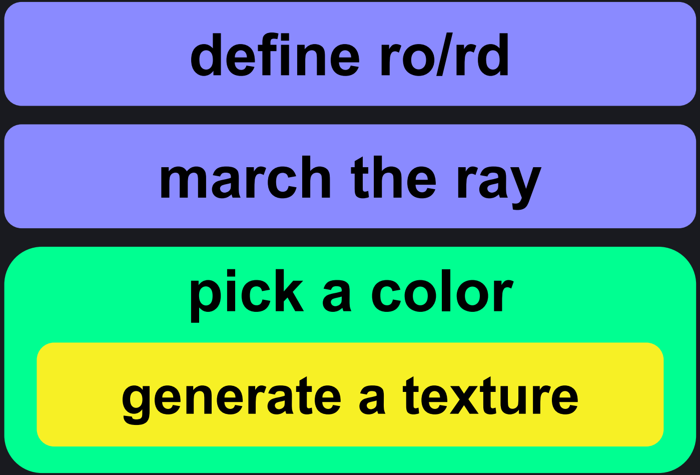
map a texture

**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

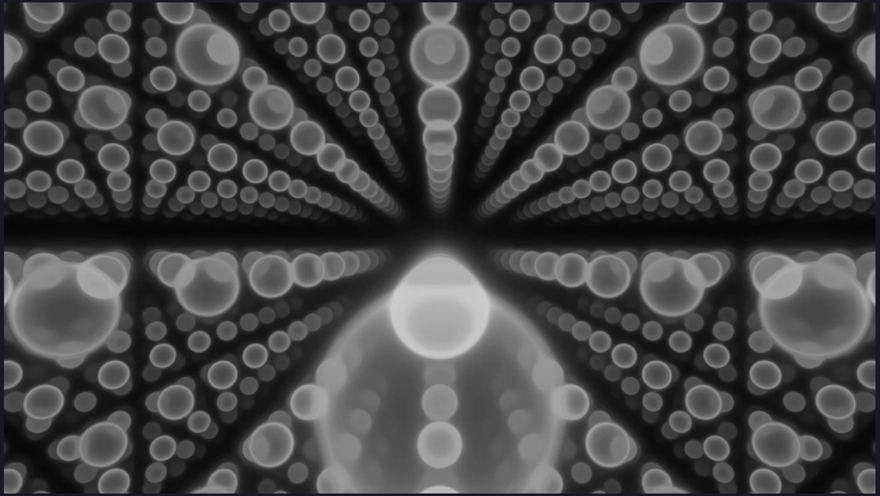
generate a texture

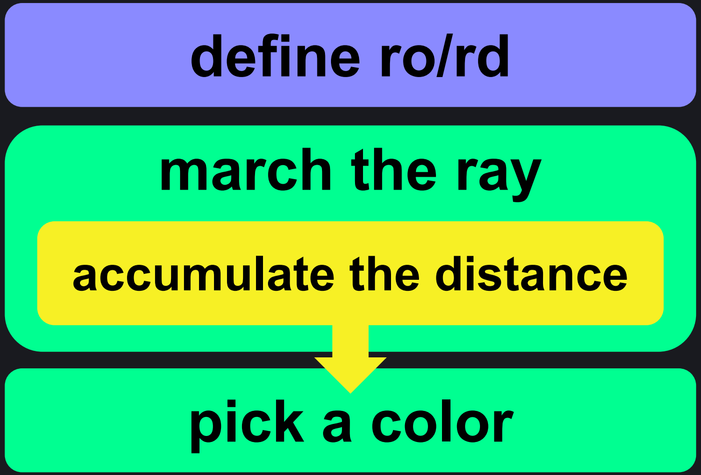
**Draw complex patterns using ray position!**
**Procedural texturing environments such as Blender or Substance Designer might work as great inspirations for you**

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

# Topic: Ray Tricks

# Phantom Mode

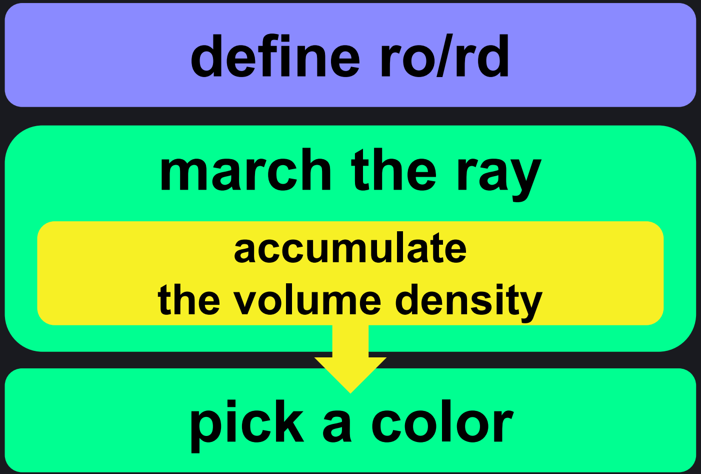




**Make things look like X-Ray!**
**Instead of look for an intersection make it pass through geometries and accumulate `exp(-k * abs(distance))` for each loop**

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



define ro/rd

march the ray

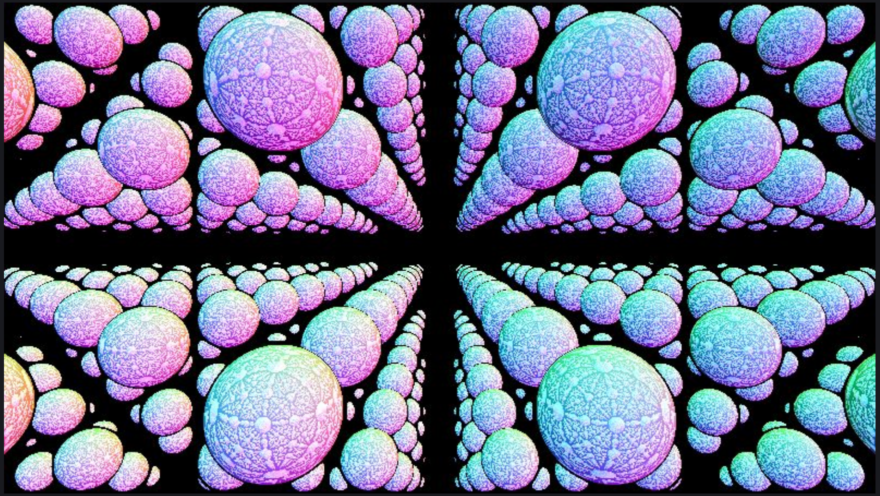
accumulate
the volume density

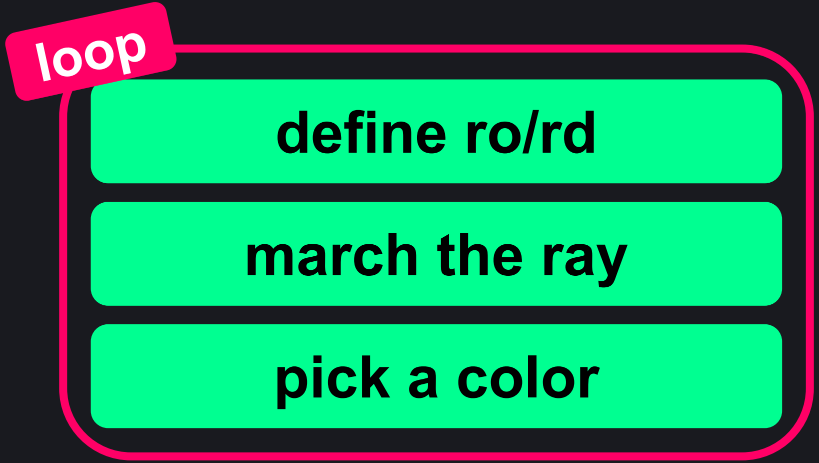
pick a color

**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](https://www.shadertoy.com/view/XslGRr)
Inigo Quilez, 2013

# Reflection

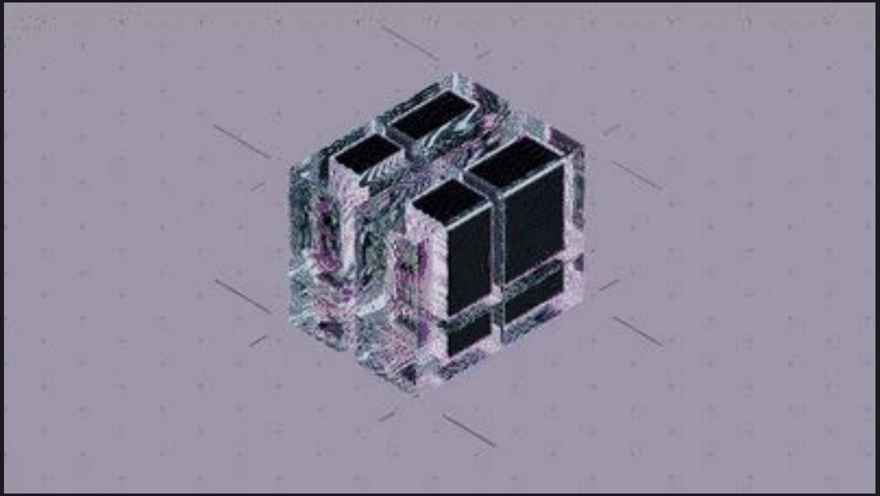


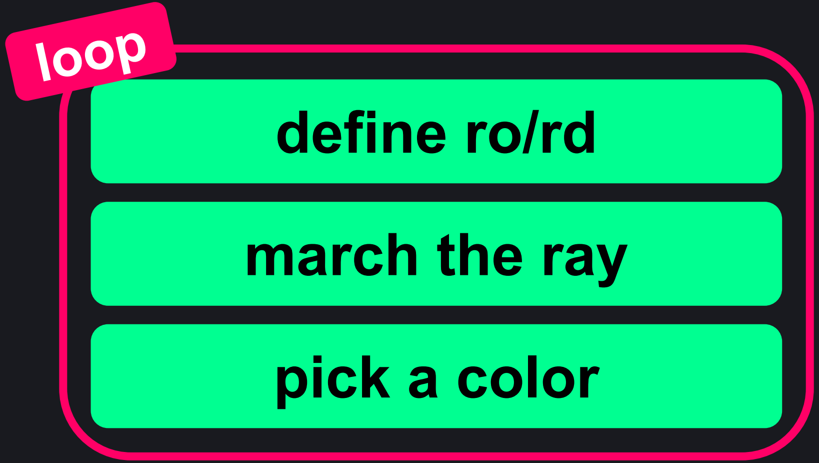


**After the ray hits to surfaces, march the ray again from the surface**

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

# Refraction





loop

define ro/rd

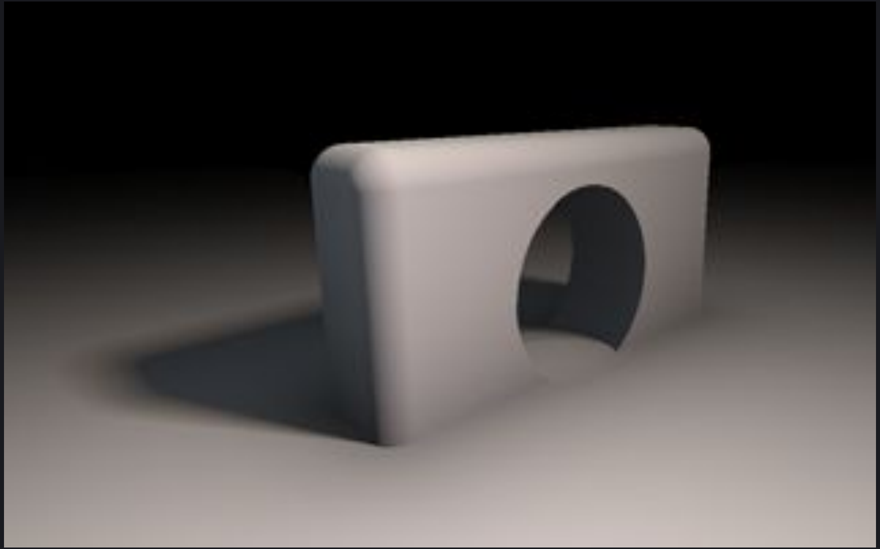
march the ray

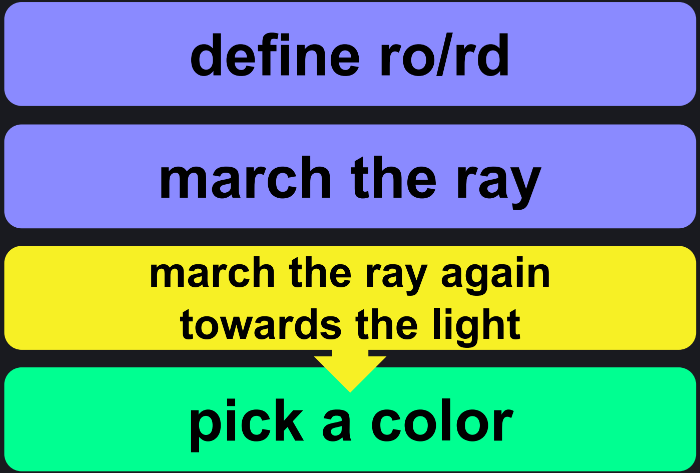
pick a color

**I just wanted to introduce tdhooper's new shader tbh**

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

# Shadowing





define ro/rd

march the ray

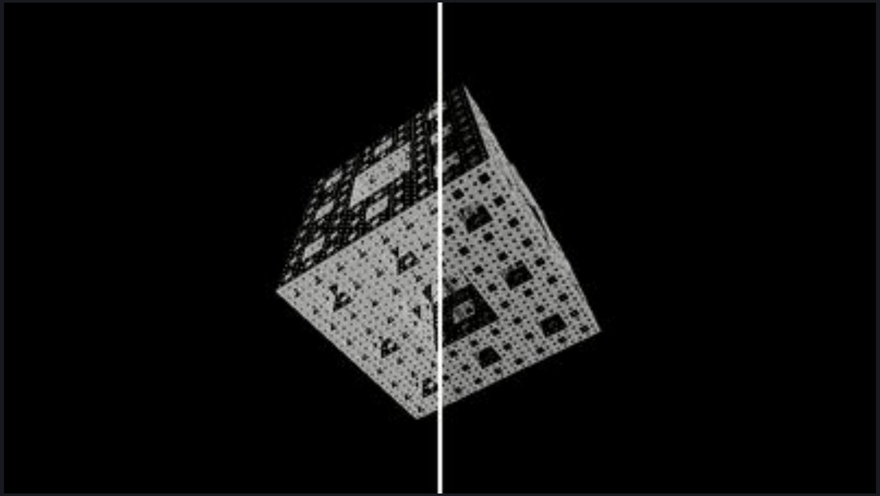
march the ray again
towards the light

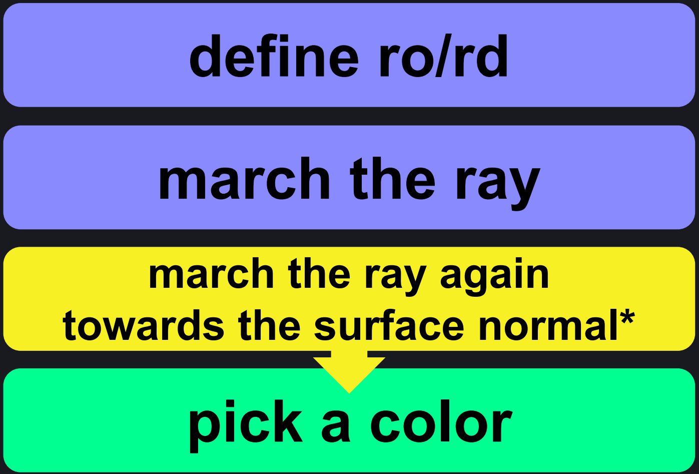
pick a color

**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





define ro/rd

march the ray

march the ray again
towards the surface normal*

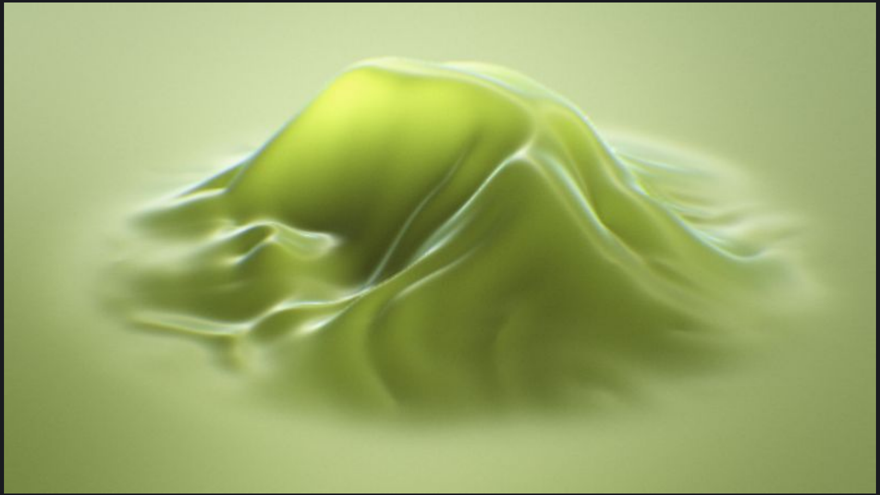
pick a color

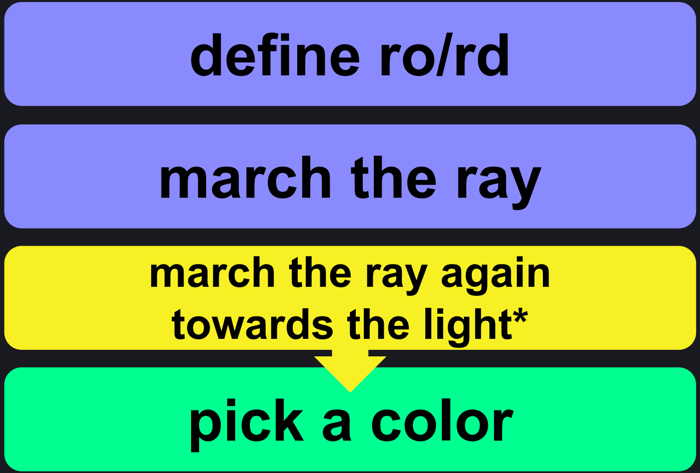
*There are various ways
to achieve AO

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

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

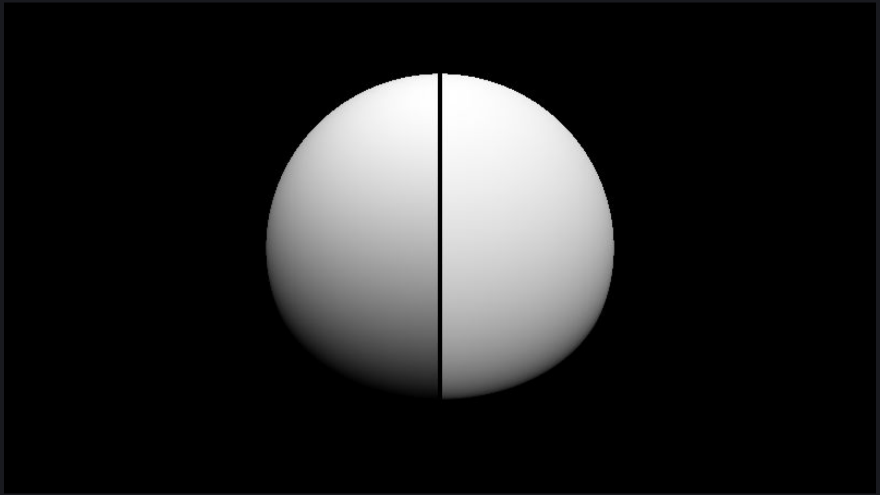
*There are various ways
to achieve SSS

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

Goo - [https://www.shadertoy.com/view/lllBDM](https://www.shadertoy.com/view/lllBDM)
noby, 2017

# Topic: Post Processing

# OETF



define ro/rd

march the ray

pick a color

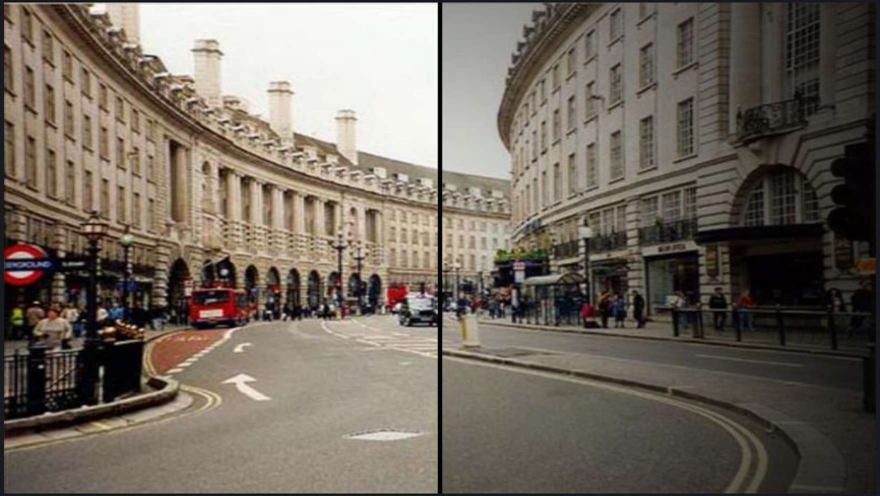
modify the color

**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](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