Introduction to Ray Tracing

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SIGGRAPH 2021

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Ray Tracing

Rajesh Sharma

Course Outline

-✔- Intro, Model, Sampling
-- Rays, Intersections
-- Scene, Recursion
-- Materials, BRDF
-- Importance Sampling, Lights
-- Systems View: Integrators, Accelerators
-- Wrap up, Learn more

Today

- Guest: Turner Whitted
- Recap, Q&A
- Rays
- Spheres
- Ray-Sphere Intersection
- Camera
- Ray Tracing Spheres

Housekeeping

- Link to today's slides and shaderToys:
  - Log in to your google drive
  - Google drive folder: https://bit.ly/3viTHez
  - Code: https://www.shadertoy.com/user/xarmalarma
- Use the chat to ask questions, help others
- After the lecture: @xarmalarma, #siggraph2021

Turner Whitted

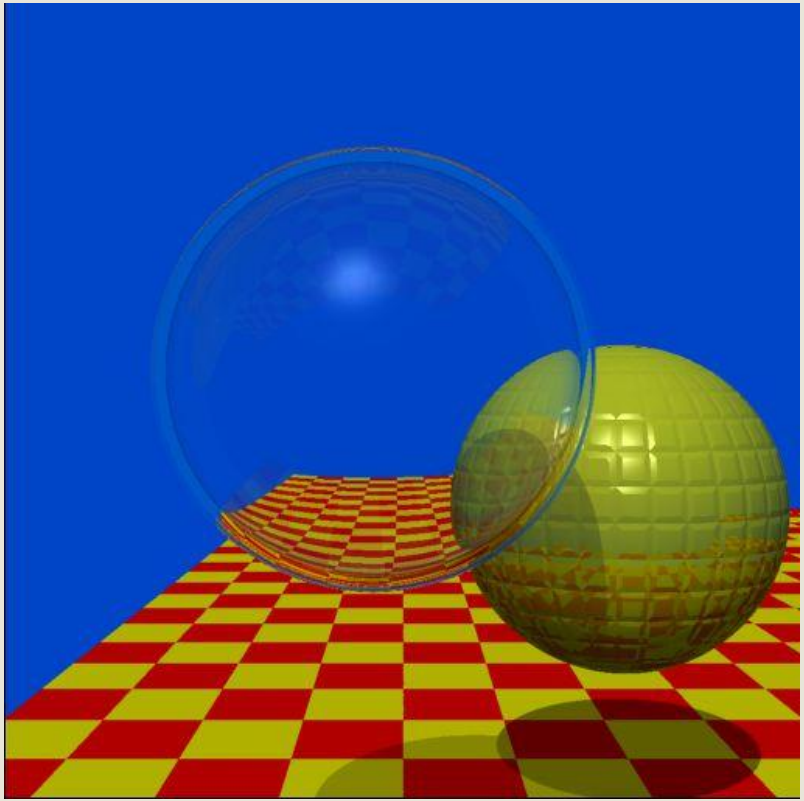
Turner Whitted was the first to apply the concept of ray tracing to global illumination in computer graphics.

The simple and elegant ray tracing algorithm formed the basic grounding for the majority of frames rendered in software by anyone, anywhere over a period of more than thirty years in computer graphics.

Turner went on from this remarkable insight to publish visionary and groundbreaking papers in a wide variety of fields with a remarkable set of collaborators. These papers cover topics as diverse as shaders , procedural graphics, graphics hardware, novel sensors, sensor arrays, and many other topics.

Turner Whitted

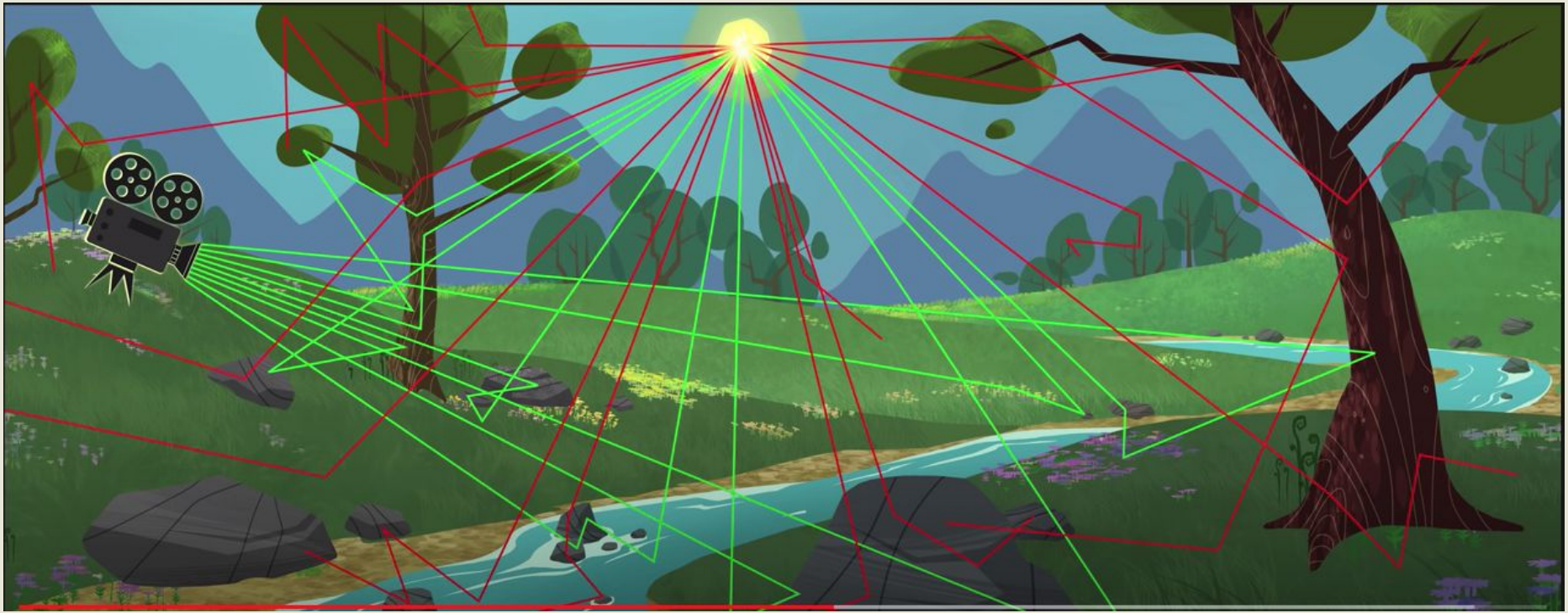
An Improved Illumination Model for Shaded Display -- *Graphics and Image Processing 1980*



What is Ray Tracing?

https://www.youtube.com/watch?v=frLwRLS_ZR0

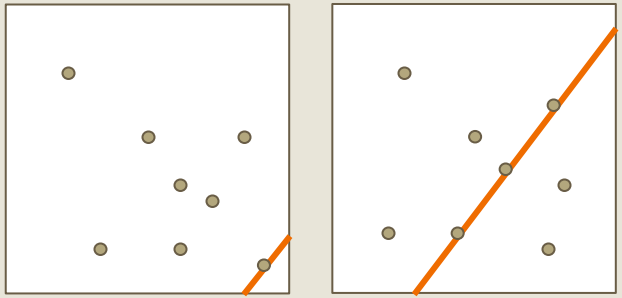
What is Ray Tracing?

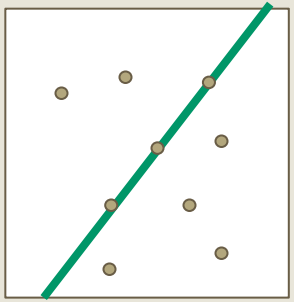


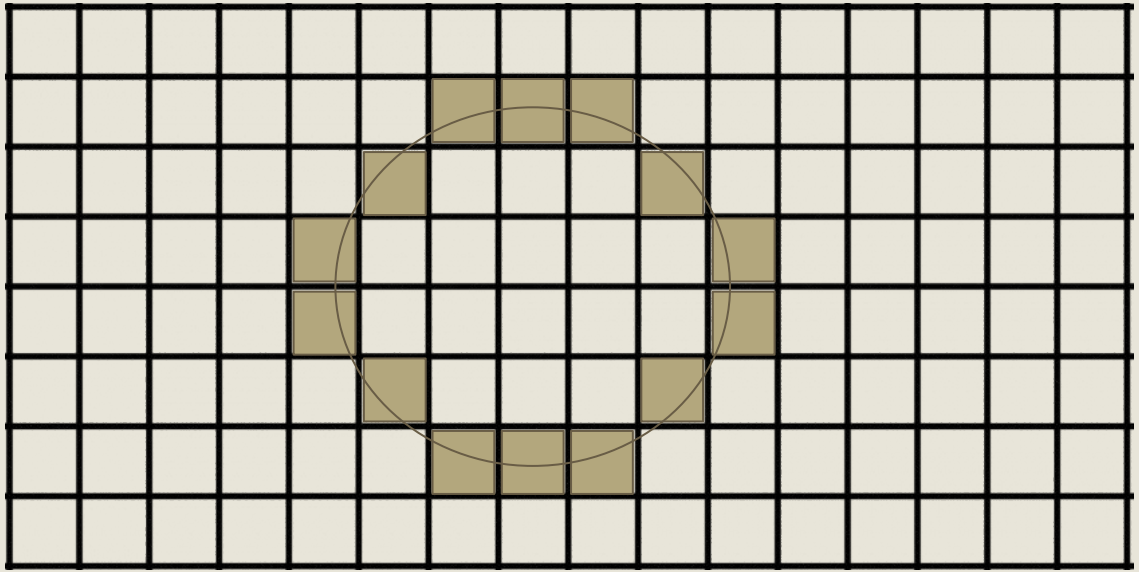
https://www.youtube.com/watch?v=frLwRLS_ZR0

Sampling

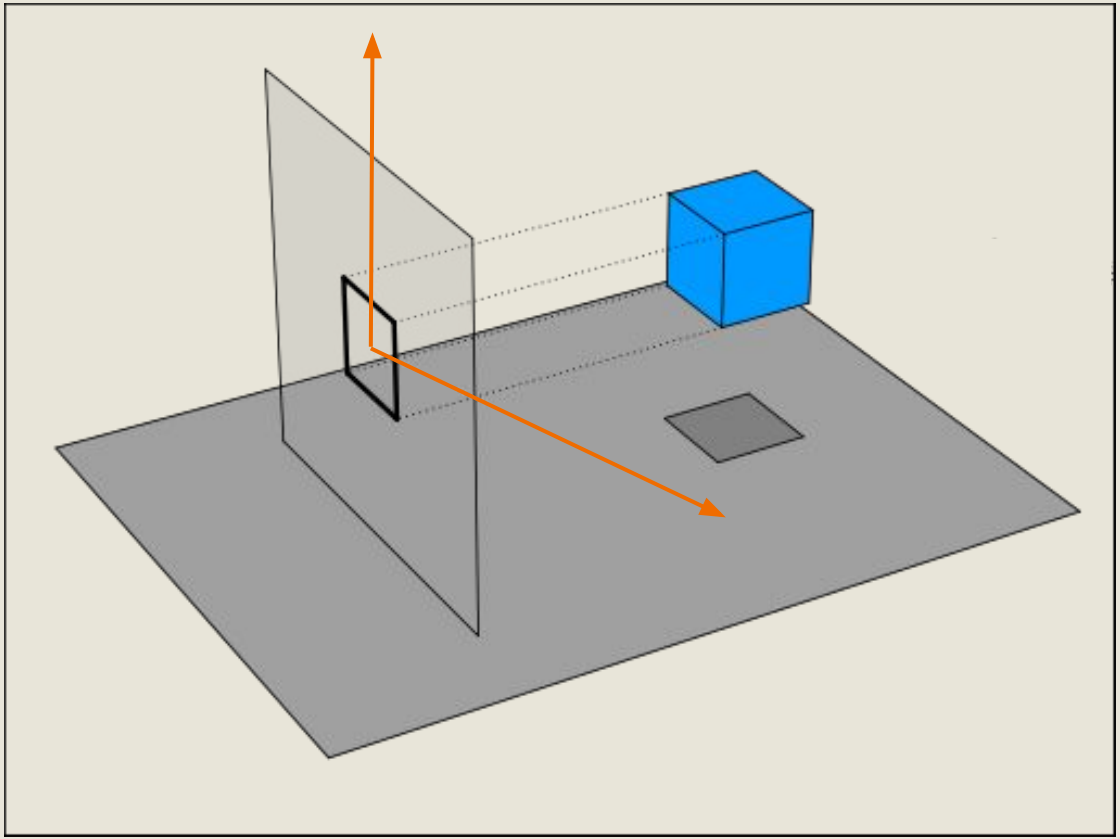
- A solution: Multiple samples per pixel (Random)



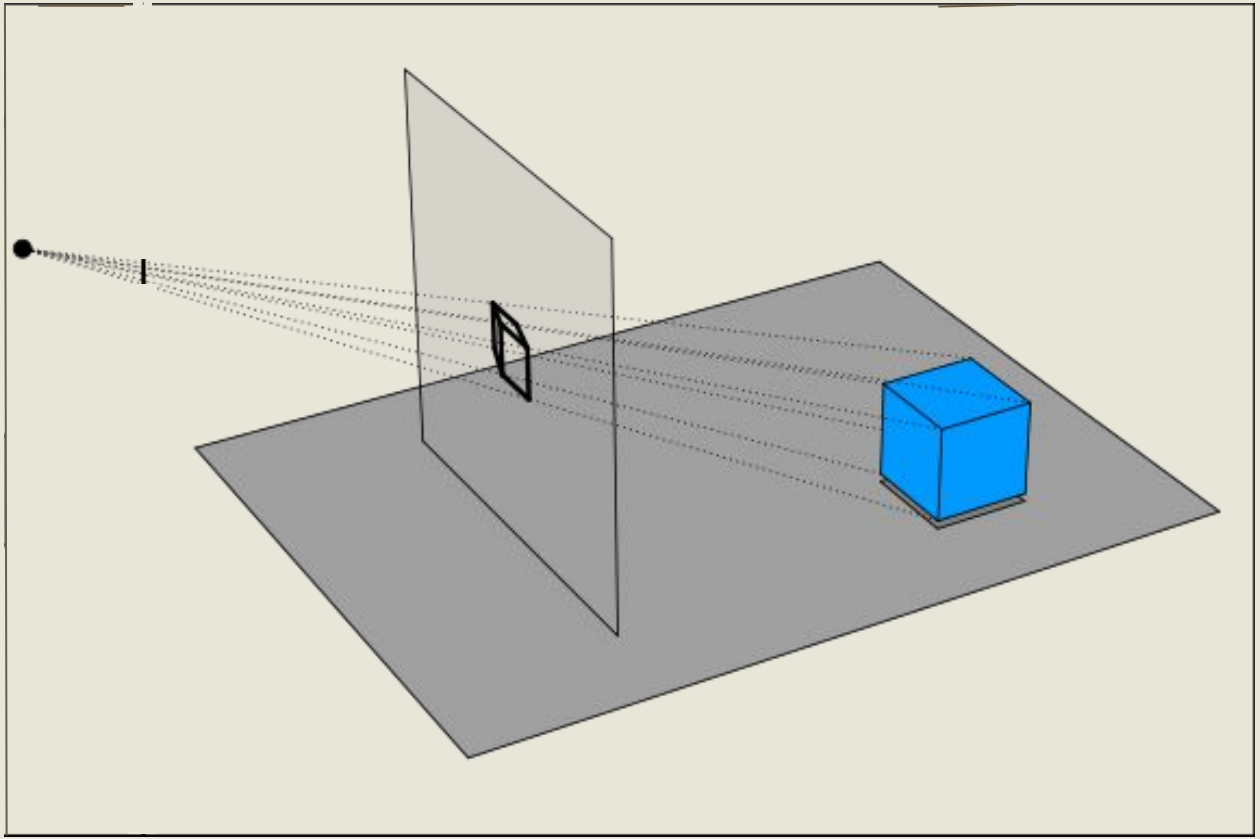




Last time: parallel rays, object right on screen



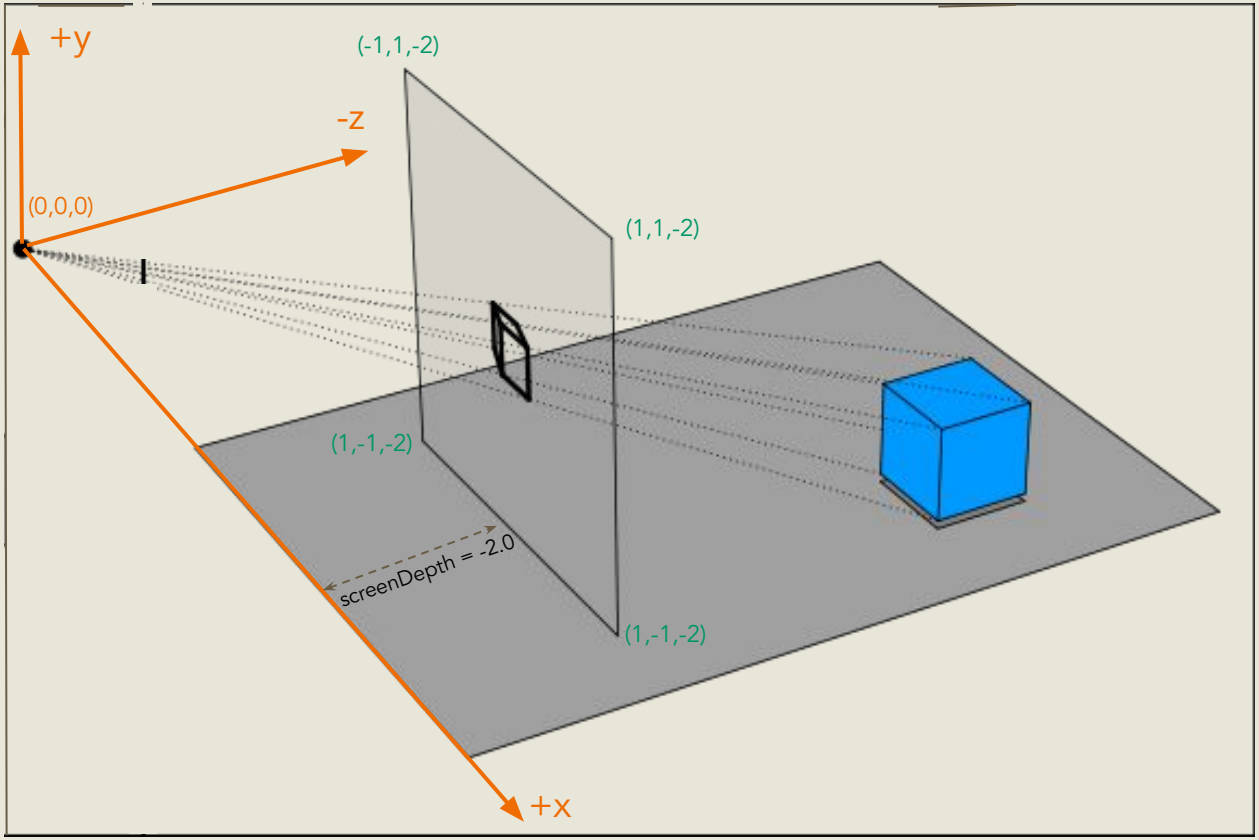
Extending to the third dimension



World Setup

Eye/Camera is at: (0, 0, 0)

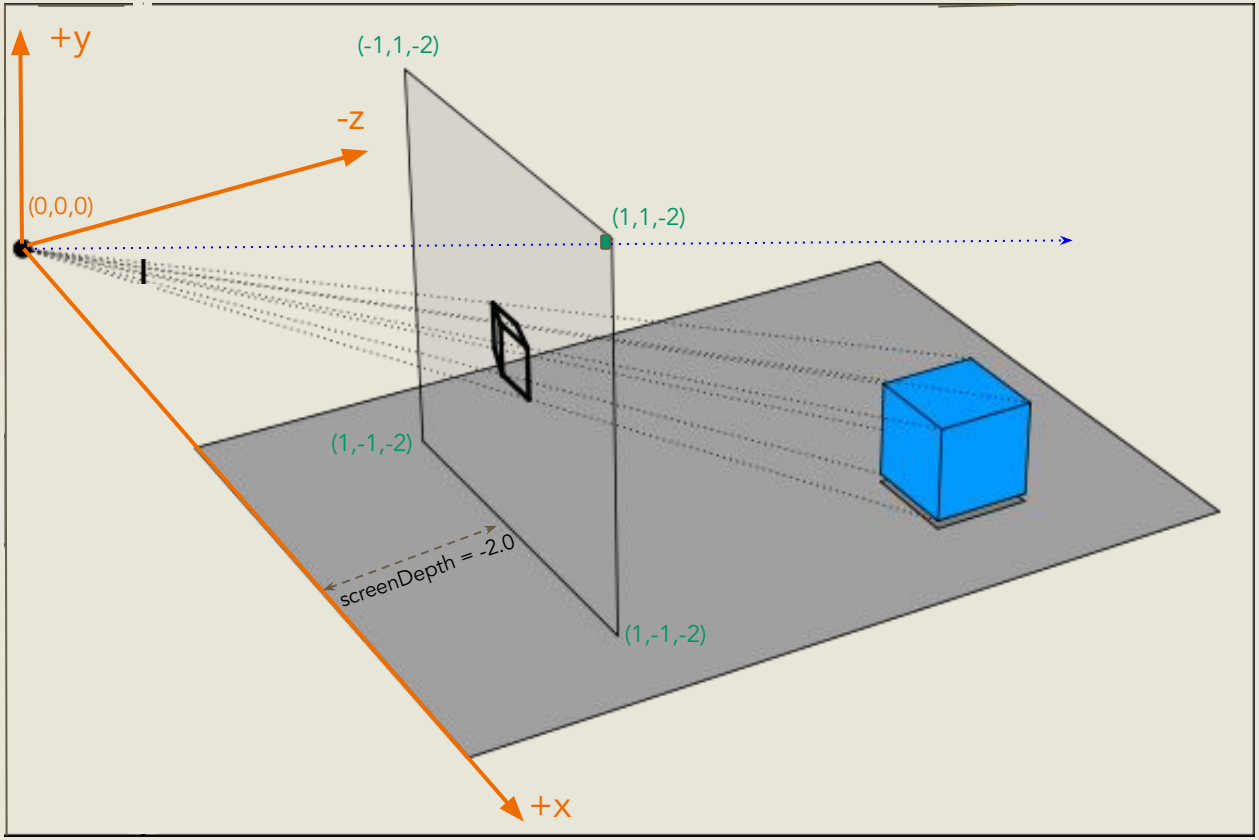
Screen is 2 units in negative Z



Rays: from eye through the screen pixels

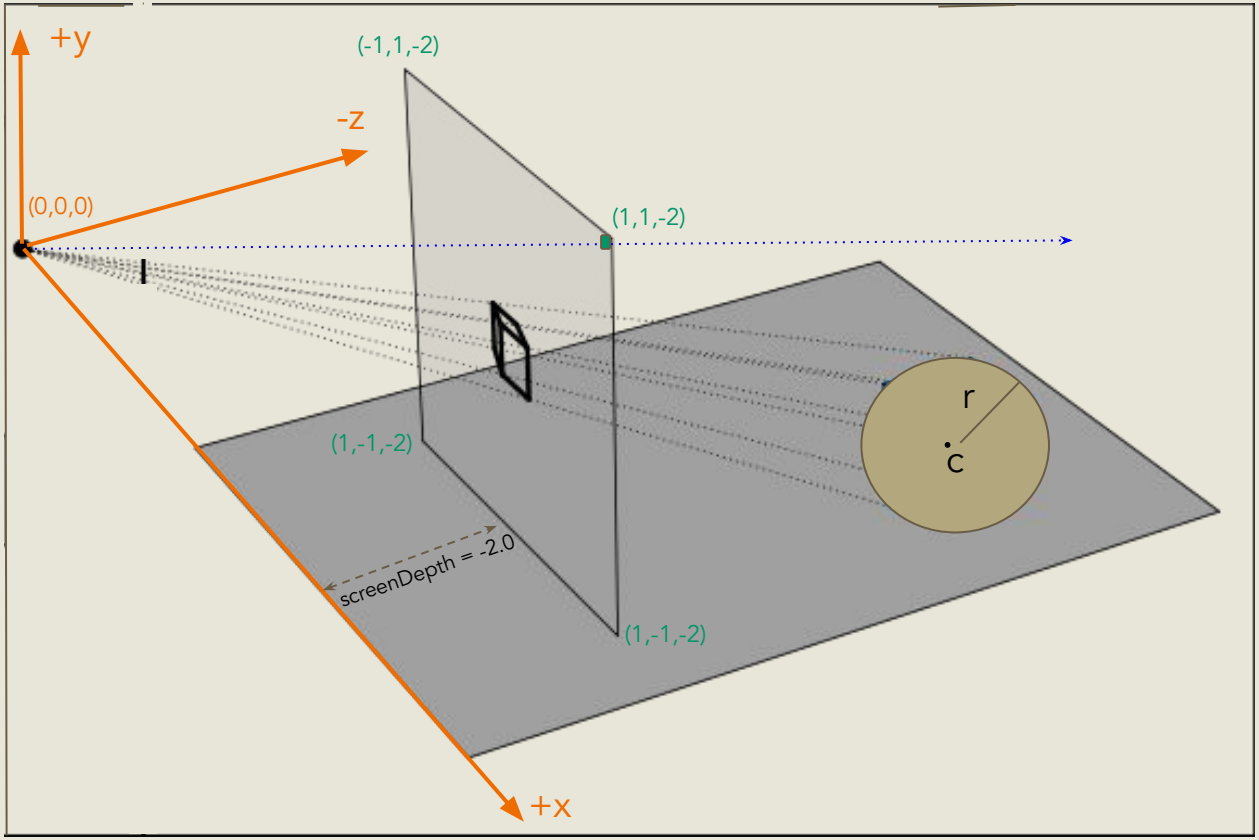
Ray(origin, direction)

origin = (0, 0, 0)
direction = screen coordinate



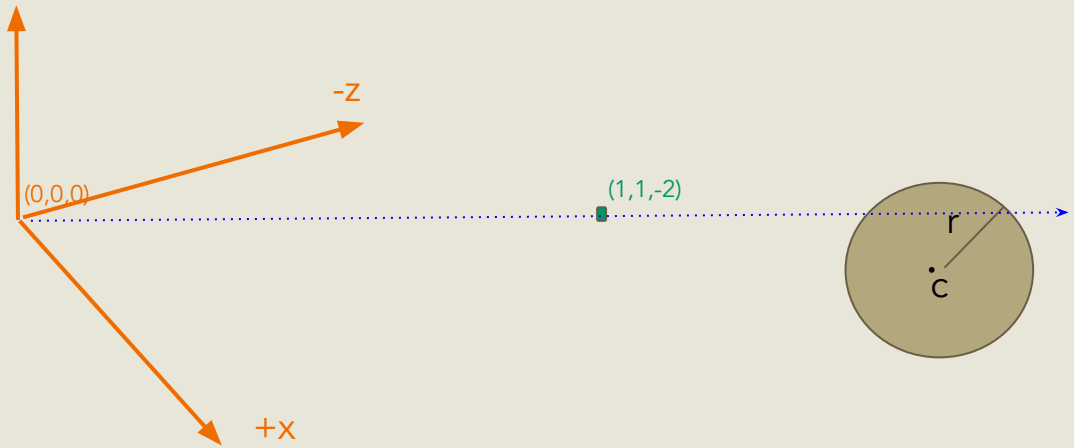
Objects: Sphere

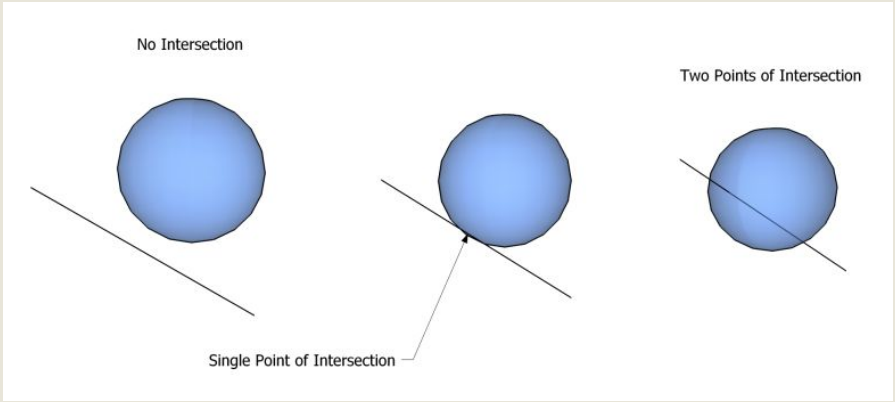
Sphere(center, radius)



Ray-Sphere Intersection

Ray(origin, direction)
Sphere(center, radius)





Ray-Sphere Intersection

Equation of Ray:

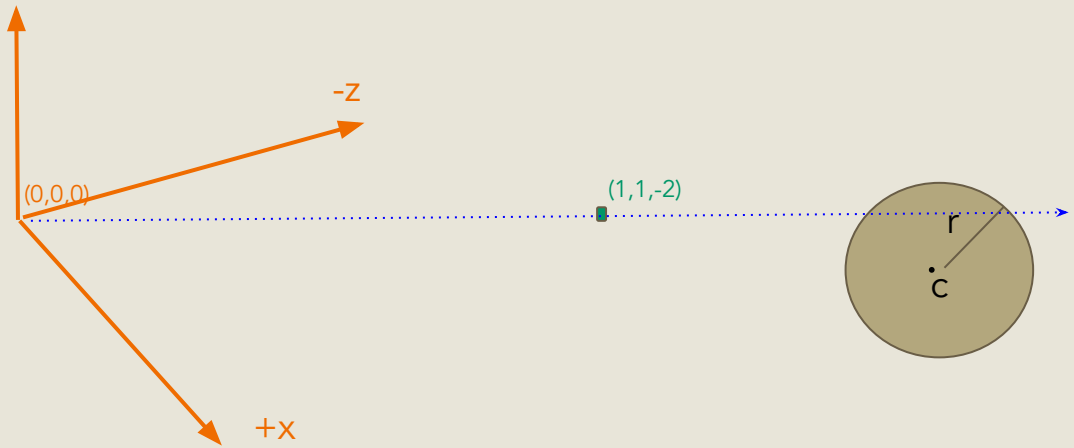
$$x = o + d\hat{u}$$

or r(t) = o + t*v, where d=dû

Equation of Sphere:

$$\|x-c\|^2 = r^2$$

or f(x) = (x-c).(x-c) - r^2 = 0
= dot(x-c, x-c) -r^2 = 0



Intersection when f(r(t)) == 0
Substitute, expand and solve for t:

```
dot(o+t*d-c, o+t*d-c) - r*r = 0
```

Using `dot(A,A) =` $\|A\|^2$

We get a quadratic equation of the form: `ax^2 + bx + c = 0`

Where `a = 1, b = 2*D*(o-c), c =` $\|o-c\|$ `* r^2`

Ray-Sphere Intersection

We get a quadratic equation of the form:

$ax^2 + bx + c = 0$

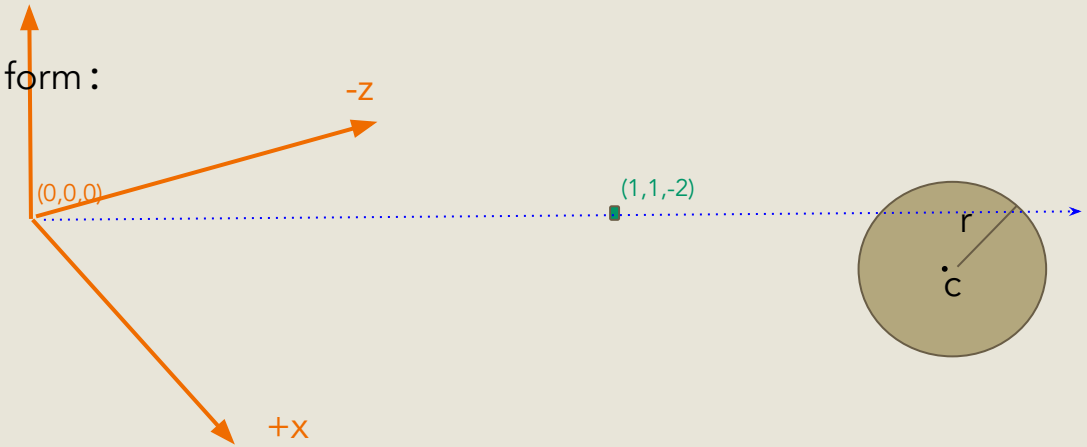
Where,

$a = 1,$

$b = 2*D*(o-c),$

$c = \|o-c\| * r^2$

Discriminant: disc = b^2 - 4a*c



When discriminant is greater than 0, we have two solutions (ray intersects the sphere at two points):
-b + sqrt(disc) and -b - sqrt(disc)

When discriminant is 0, there is only one solution (ray grazes the sphere)
When discriminant is negative, there is no solution (ray misses the sphere)

Solve for t, use the smaller t if it is positive. For negative t, the intersection is 'behind' the camera.

Hands-on

- ★ Log in to your google drive
- ★ Make a shortcut to: https://bit.ly/3viTHez
- ★ Create an account on shadertoy.com
- ★ Fork a copy of:
  - https://www.shadertoy.com/view/7ts3WN

Next Class

- Scene
- Recursion
- Homework:
  - Extend intersection to Quadrics
  - Create interesting scenes, animations
  - @xarmalarma, #siggraph2021

QUESTIONS?

- Chat
- #xarmalarma