Rendering algorithms

Raghavendra G S

Rasterization vs Ray tracing

For each primitive

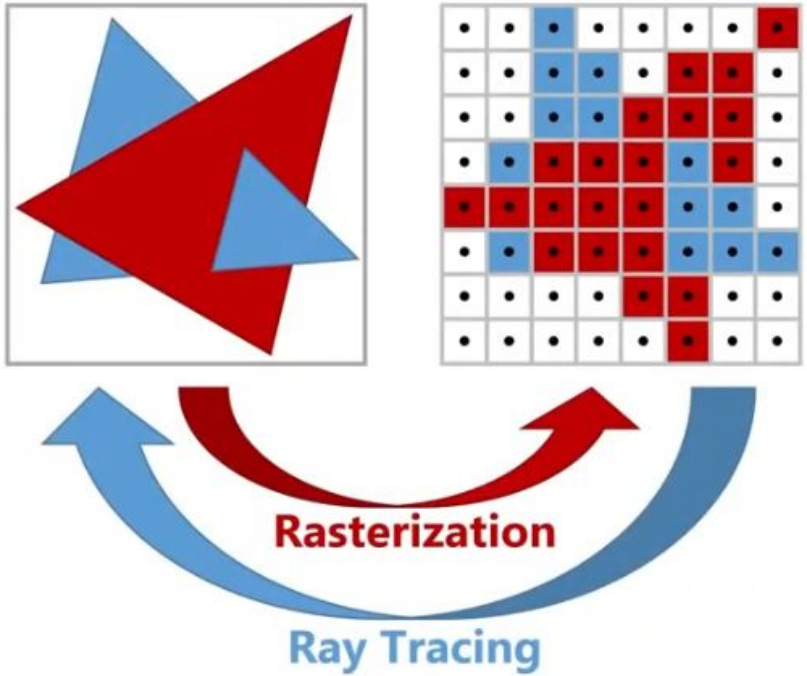
Find the pixel which it maps to

For each pixel

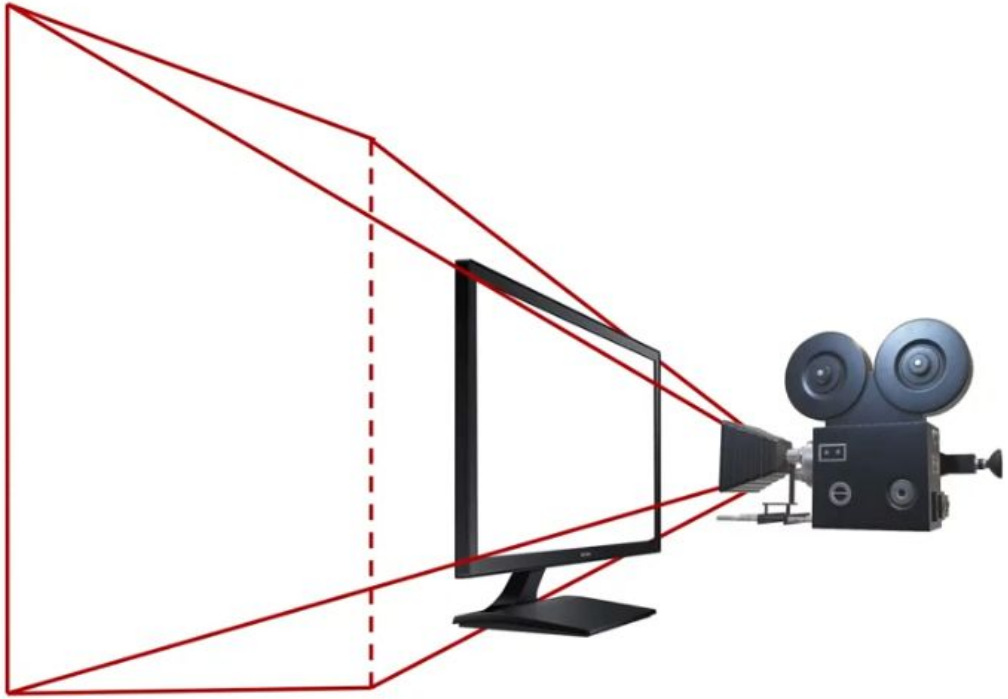
Find all the primitive which contributes to that pixel

If objects are opaque, find the closest primitive

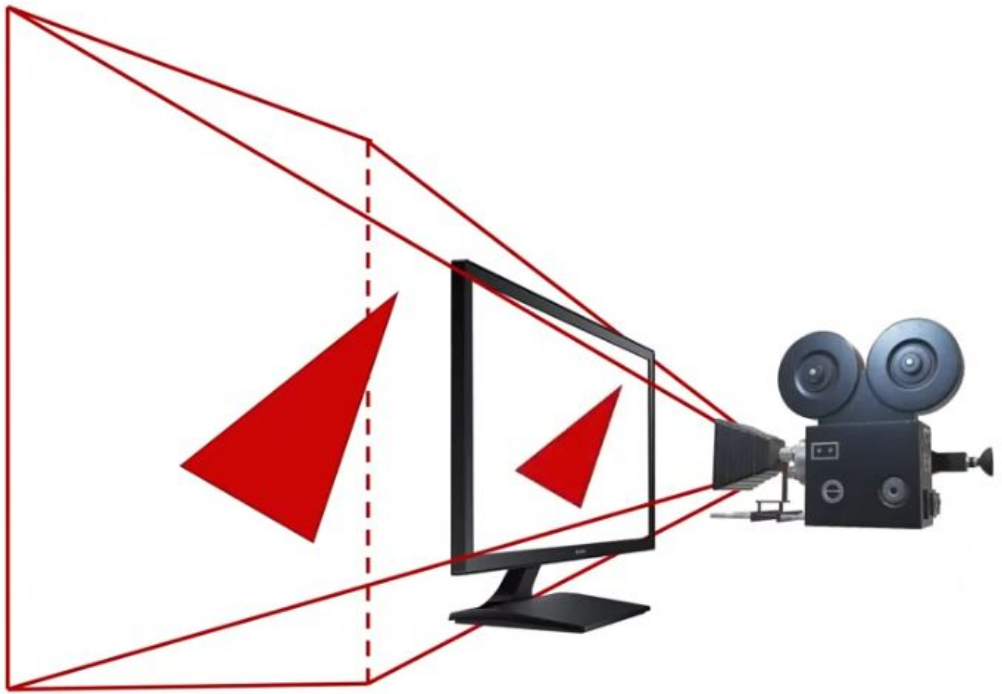
Rasterization vs Ray tracing



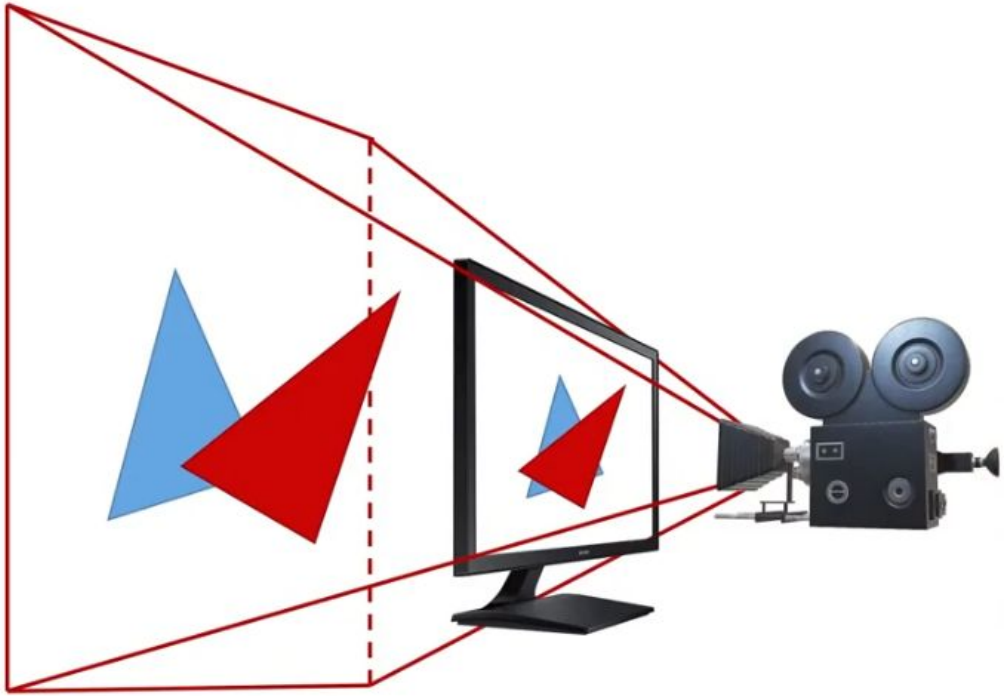
Ray tracing



Ray tracing



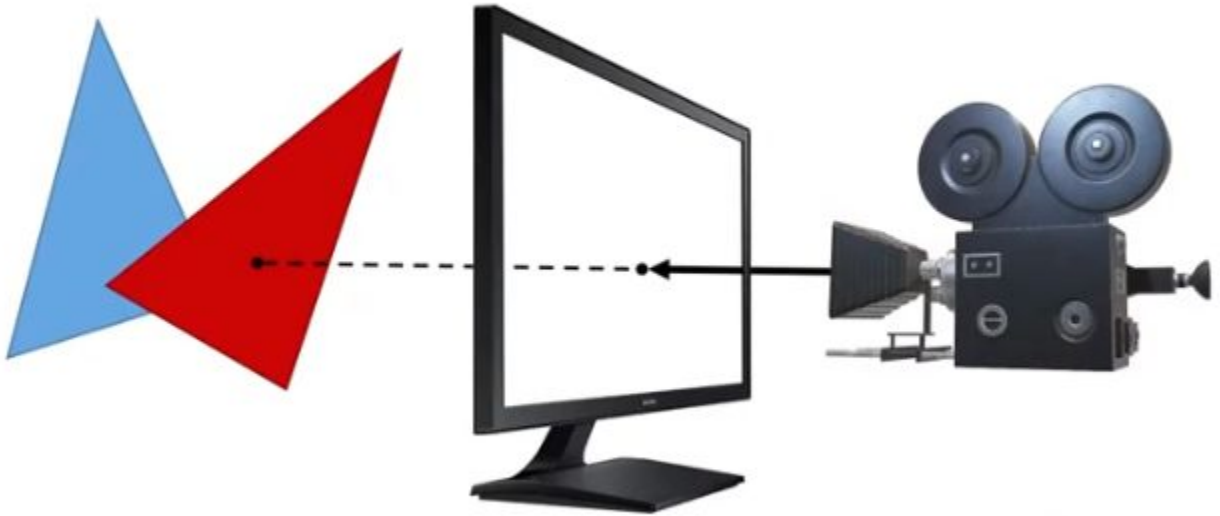
Ray tracing



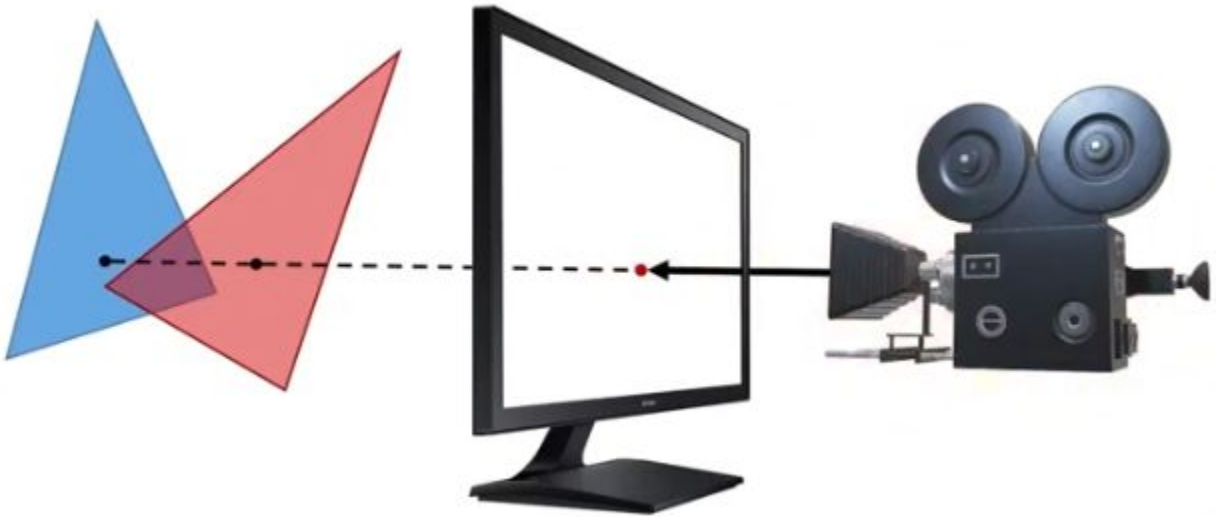
Ray tracing

Ray tracing

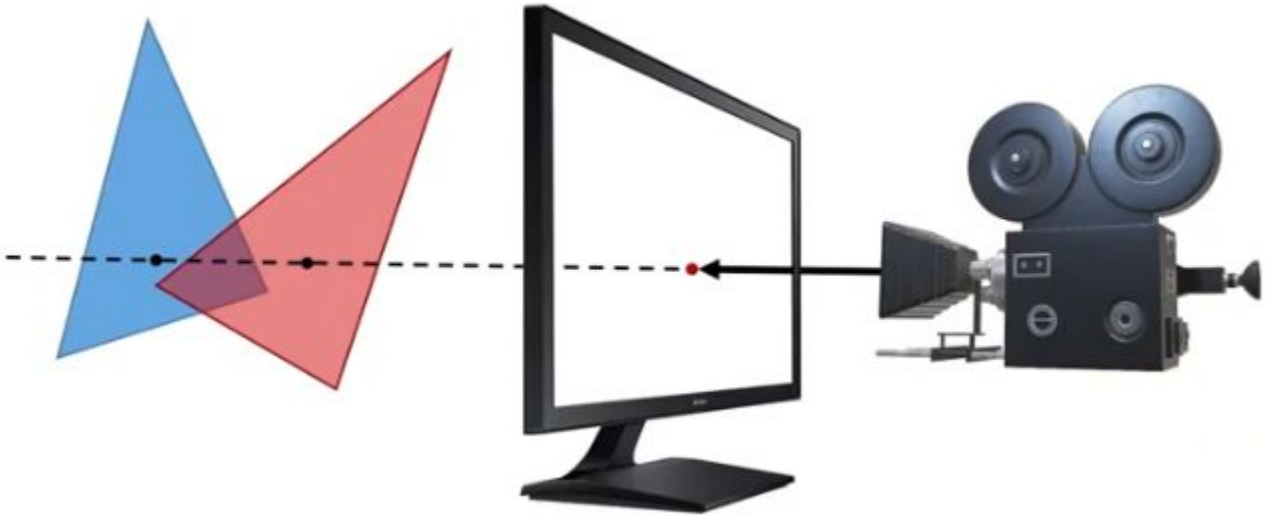
Ray tracing



Ray tracing

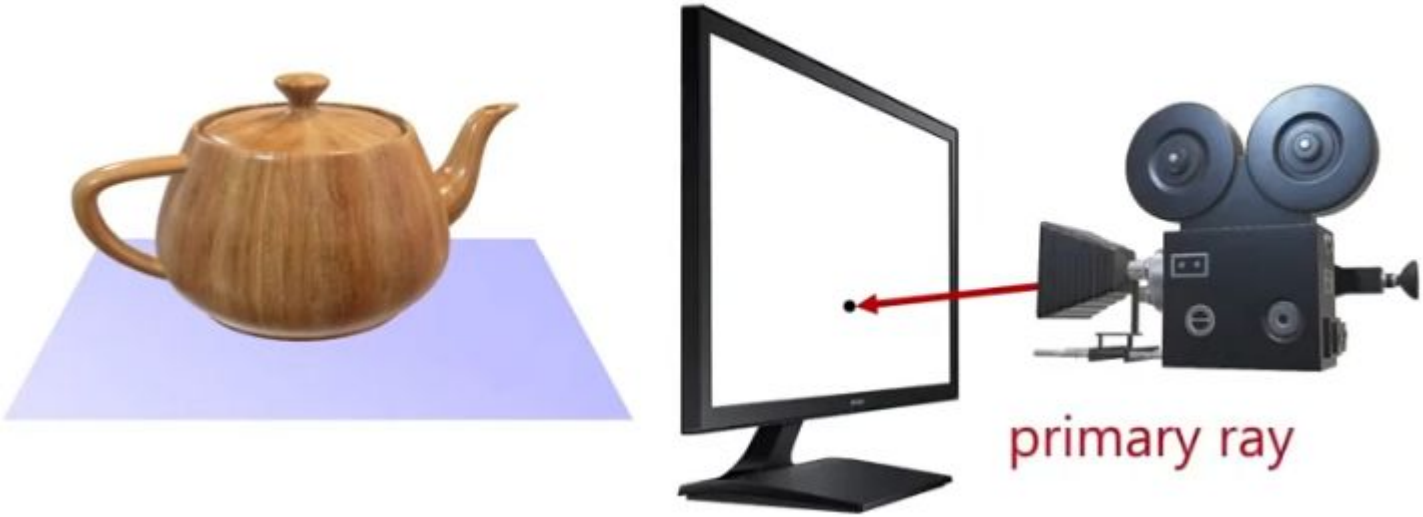


Ray tracing

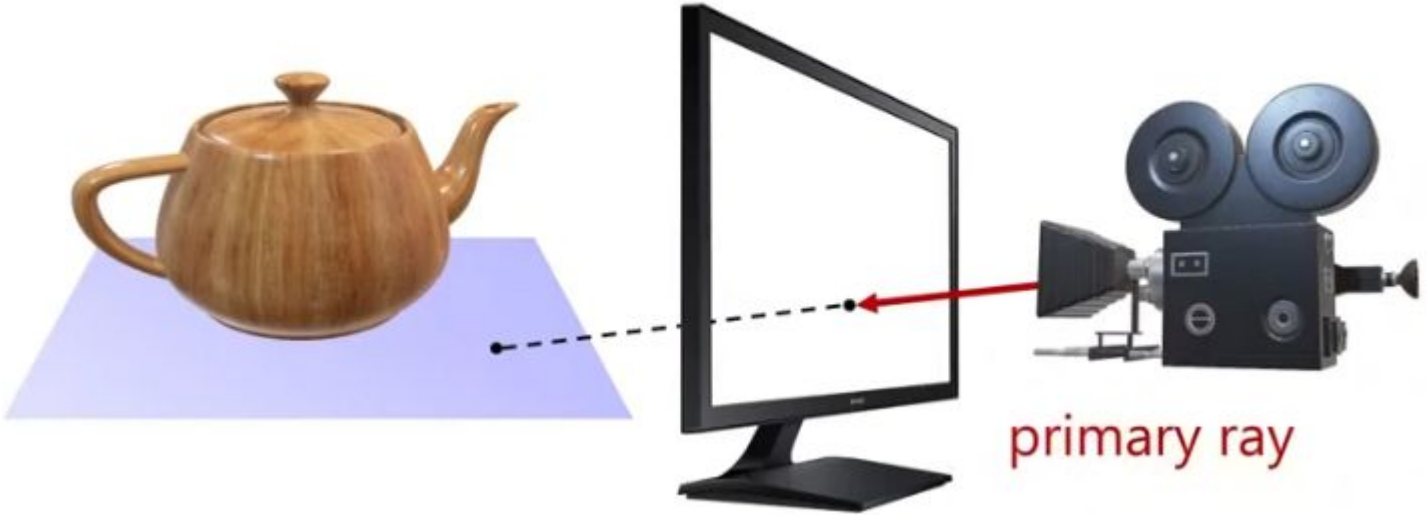


Ray tracing

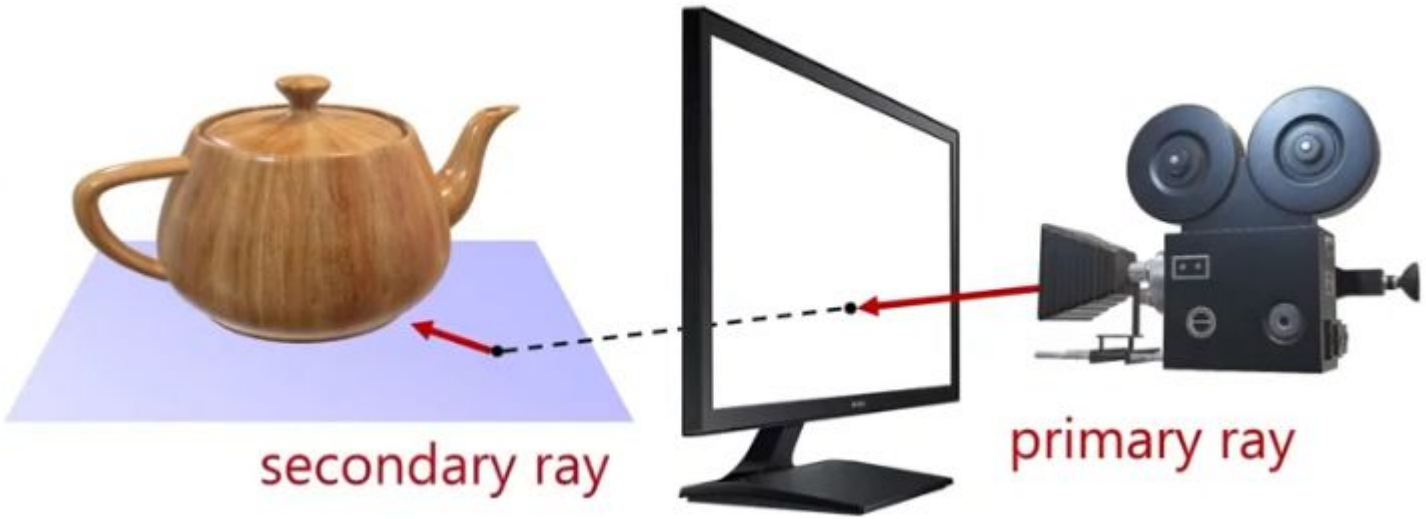
Ray tracing



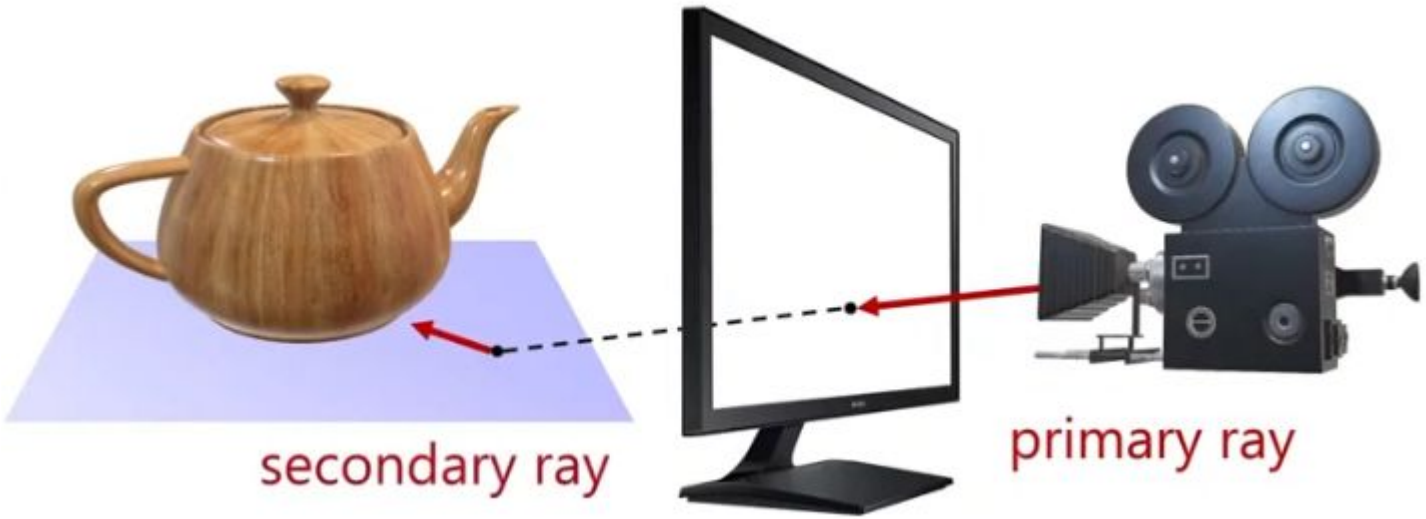
Ray tracing



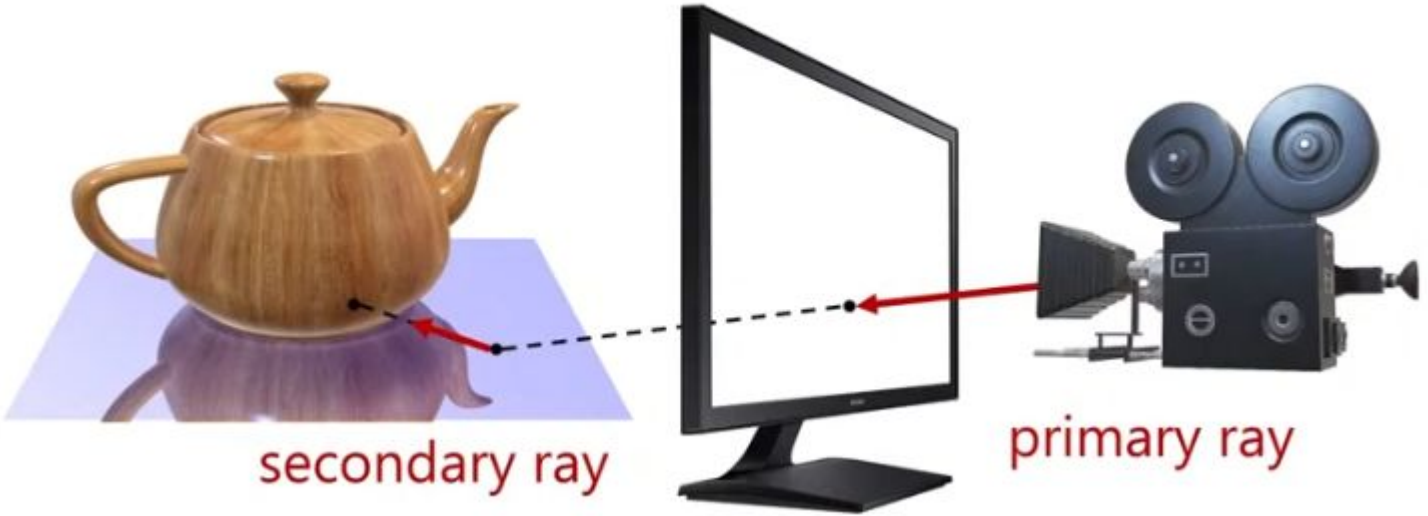
Ray tracing



Ray tracing



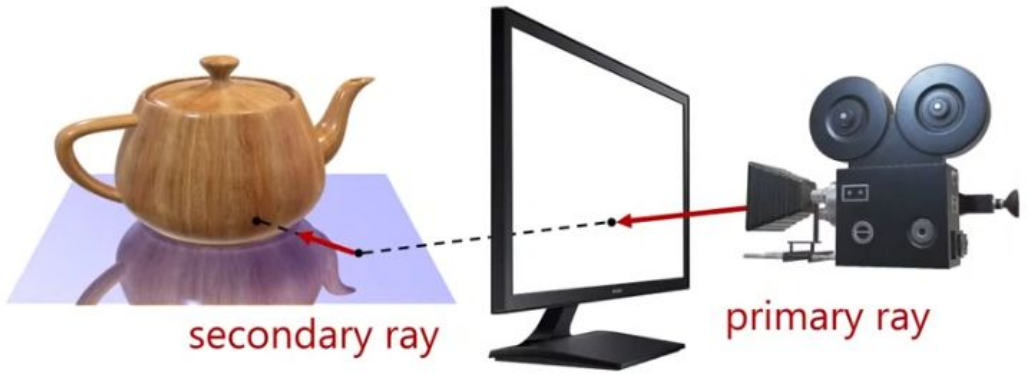
Ray tracing



Ray tracing

Secondary rays handle

1. Shadows
2. Reflection
3. Refraction
4. Realistic illumination
5. …



Rasterization vs Ray tracing

For each primitive

Find the pixel which it maps to

Fast

Linear memory access

Linear complexity

For each pixel

Find all the primitive which contributes to that pixel

If objects are opaque, find the closest primitive

Slow

Random memory access

Logarithmic complexity

Rasterization vs Ray tracing

Combining the two

Rasterization

Visibility (Primary function of a rendering algorithm)

Ray tracing

Secondary functions like

Shadows etc

Ray tracing

Software

On CPU

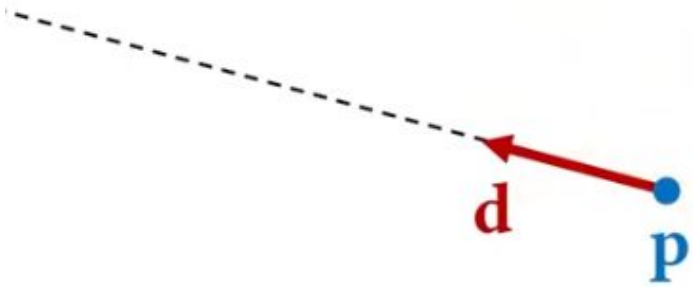
On GPU

On hardware

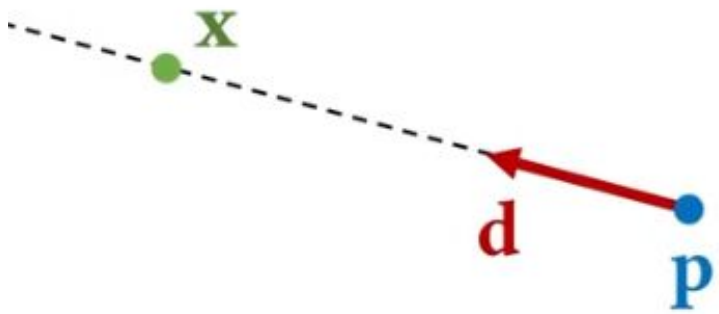
On GPU

On special hardware

How

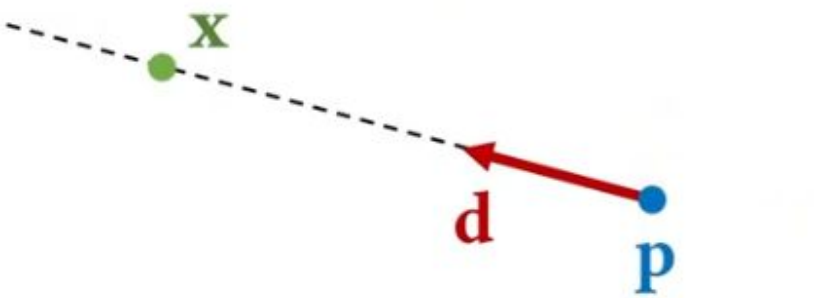


How



How

$$\mathbf{x} = \mathbf{p} + t\,\mathbf{d}$$



How

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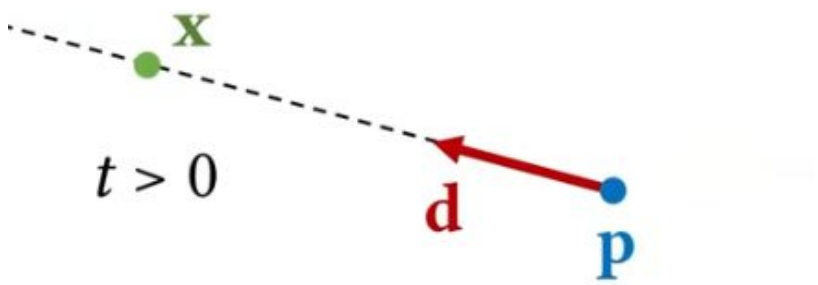

How

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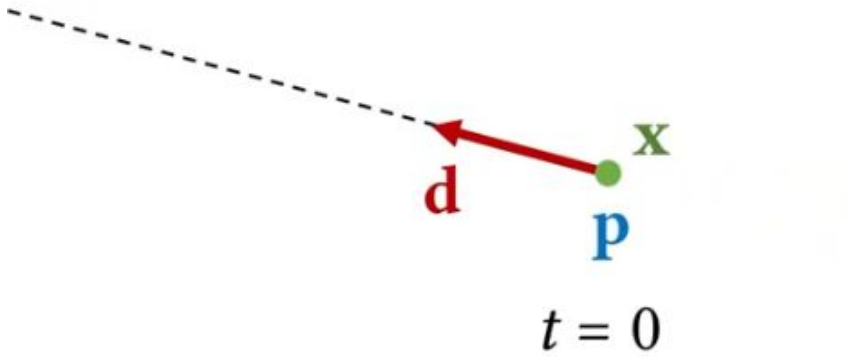
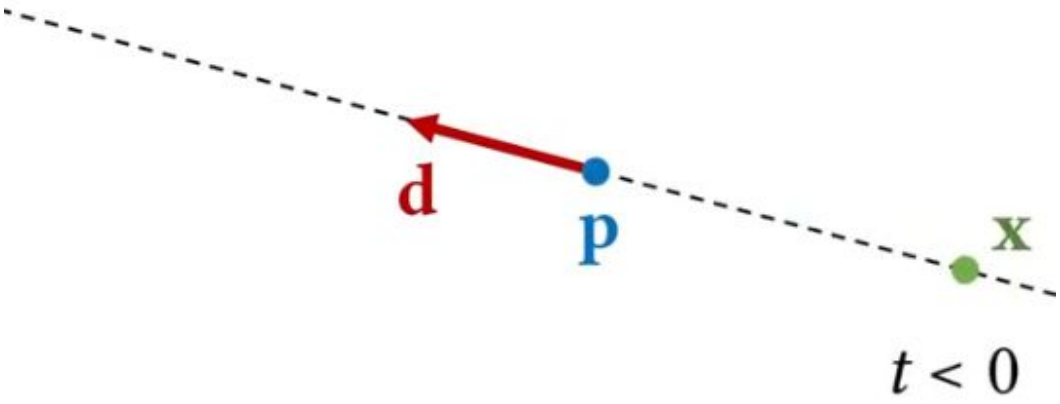


How

$$\mathbf{x} = \mathbf{p} + t\,\mathbf{d}$$



How

Implicit Surface:

$$f(\mathbf{x}) = 0$$

$$\mathbf{x} = \mathbf{p} + t\,\mathbf{d}$$

How

Implicit Surface:

$$f(\mathbf{p} + t\,\mathbf{d}) = 0$$

How

Implicit Surface:

$$f(\mathbf{p} + t\,\mathbf{d}) = 0$$

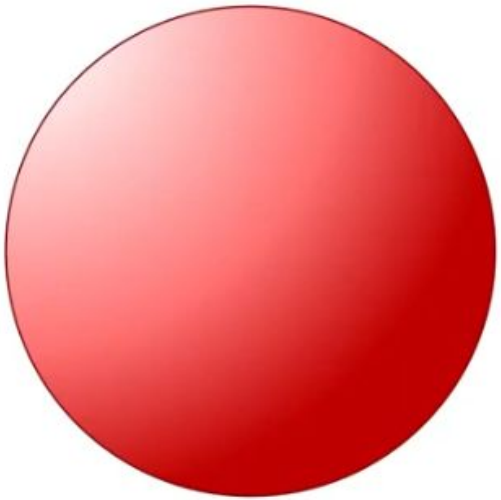
$\exists t$ ➡ **Hit!**

$$f(\mathbf{p} + t\,\mathbf{d}) \neq 0$$

$\forall t$ ➡ **No Hit!**

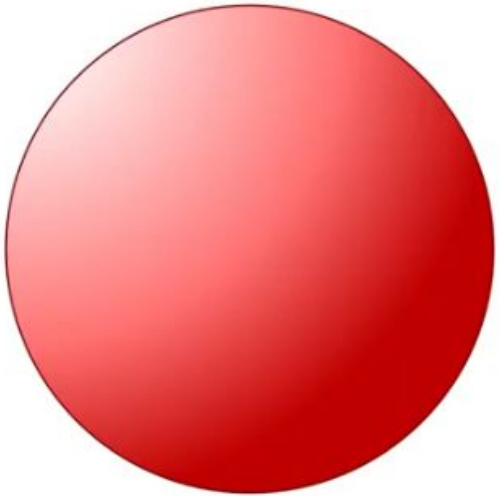
How

$$f(\mathbf{x}) = 0$$



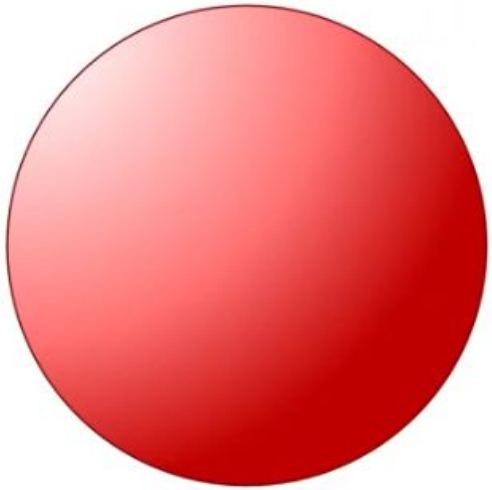
How

$$f(\mathbf{x}) = x^2 + y^2 + z^2 - r^2 = 0$$



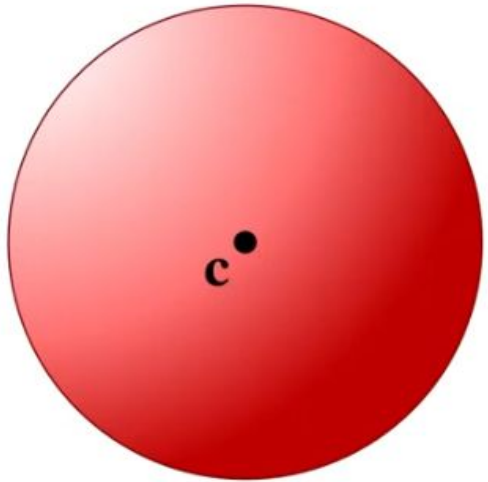
How

$$f(\mathbf{x}) = \mathbf{x} \cdot \mathbf{x} - r^2 = 0$$



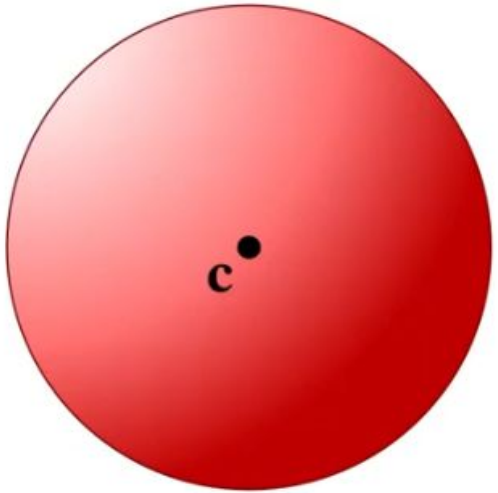
How

$$f(\mathbf{x}) = \mathbf{x} \cdot \mathbf{x} - r^2 = 0$$



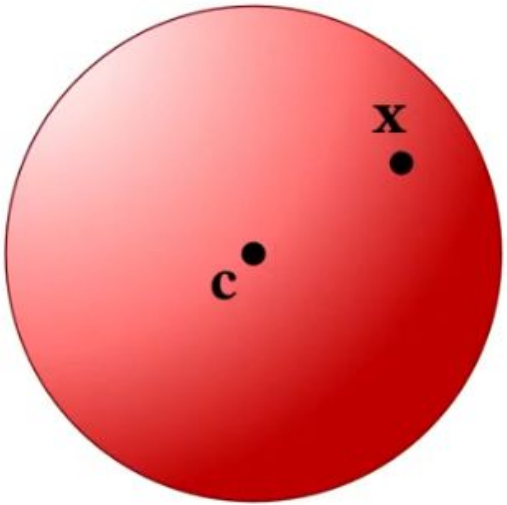
How

$$f(\mathbf{x}) = (\mathbf{x} - \mathbf{c}) \cdot (\mathbf{x} - \mathbf{c}) - r^2 = 0$$



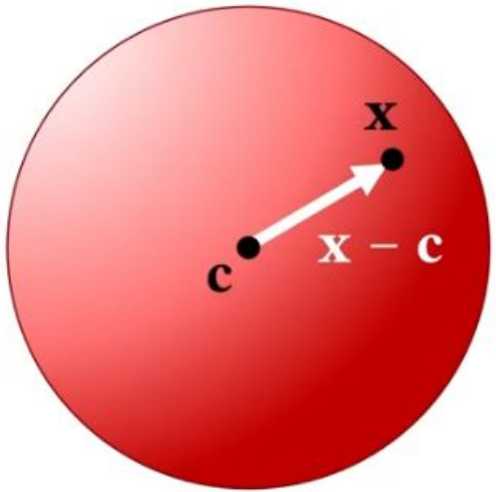
How

$$f(\mathbf{x}) = (\mathbf{x} - \mathbf{c}) \cdot (\mathbf{x} - \mathbf{c}) - r^2 = 0$$



How

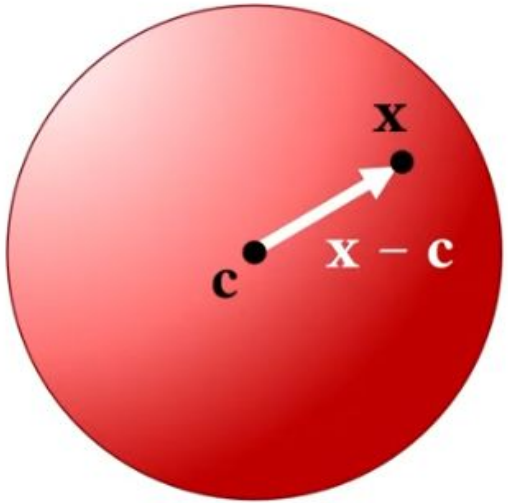
$$f(\mathbf{x}) = (\mathbf{x} - \mathbf{c}) \cdot (\mathbf{x} - \mathbf{c}) - r^2 = 0$$



$$|\mathbf{x} - \mathbf{c}| = r$$

How

$$f(\mathbf{x}) = (\mathbf{x} - \mathbf{c}) \cdot (\mathbf{x} - \mathbf{c}) - r^2 = 0$$



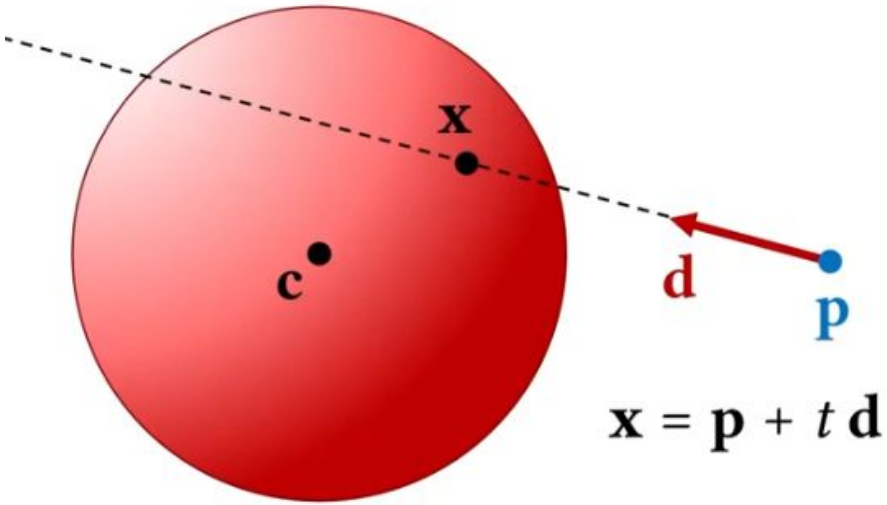
$$|\mathbf{x} - \mathbf{c}| = r$$

$$\sqrt{(\mathbf{x} - \mathbf{c}) \cdot (\mathbf{x} - \mathbf{c})} = r$$

$$(\mathbf{x} - \mathbf{c}) \cdot (\mathbf{x} - \mathbf{c}) = r^2$$

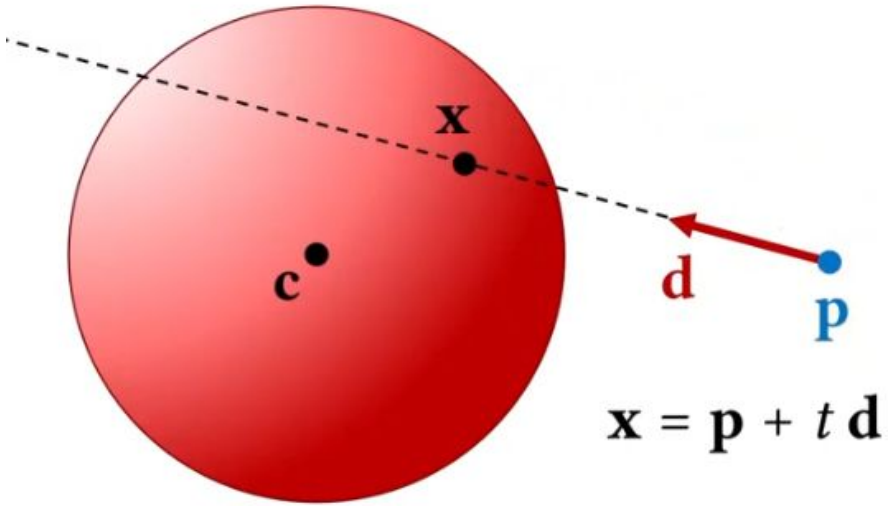
How

$$f(\mathbf{x}) = (\mathbf{x} - \mathbf{c}) \cdot (\mathbf{x} - \mathbf{c}) - r^2 = 0$$



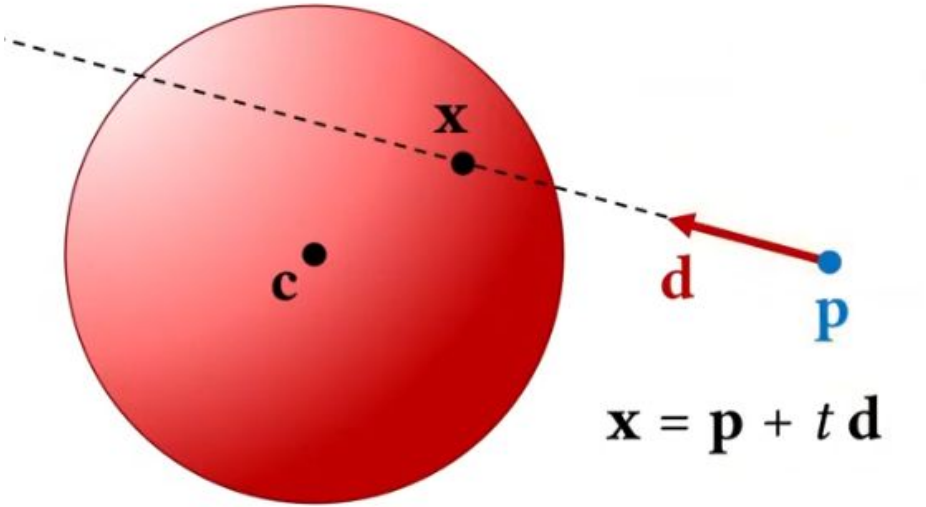
How

$$(\mathbf{p} + t\,\mathbf{d} - \mathbf{c}) \cdot (\mathbf{p} + t\,\mathbf{d} - \mathbf{c}) - r^2 = 0$$



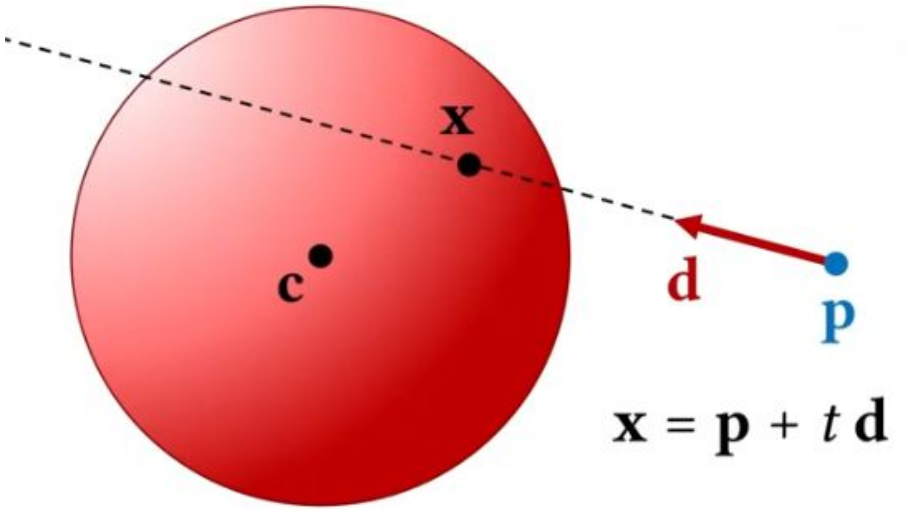
How

$$(\mathbf{p} - \mathbf{c} + t\,\mathbf{d}) \cdot (\mathbf{p} - \mathbf{c} + t\,\mathbf{d}) - r^2 = 0$$



How

$$(\mathbf{d}\cdot\mathbf{d})t^2 + 2\mathbf{d}\cdot(\mathbf{p}-\mathbf{c})t + (\mathbf{p}-\mathbf{c})\cdot(\mathbf{p}-\mathbf{c}) - r^2 = 0$$



$$\mathbf{x} = \mathbf{p} + t\,\mathbf{d}$$

How

$$\underbrace{(\mathbf{d}\cdot\mathbf{d})}_{a}t^2 + \underbrace{2\mathbf{d}\cdot(\mathbf{p}-\mathbf{c})}_{b}t + \underbrace{(\mathbf{p}-\mathbf{c})\cdot(\mathbf{p}-\mathbf{c}) - r^2}_{c} = 0$$

$$at^2 + bt + c = 0$$

$$t_{1,2} = \frac{-b \pm \sqrt{\Delta}}{2a}$$

$$\Delta = b^2 - 4ac$$

How

$$\underbrace{(\mathbf{d}\cdot\mathbf{d})}_{a}t^2 + \underbrace{2\mathbf{d}\cdot(\mathbf{p}-\mathbf{c})}_{b}t + \underbrace{(\mathbf{p}-\mathbf{c})\cdot(\mathbf{p}-\mathbf{c}) - r^2}_{c} = 0$$

$$at^2 + bt + c = 0$$

$$t_{1,2} = \frac{-b \pm \sqrt{\Delta}}{2a}$$

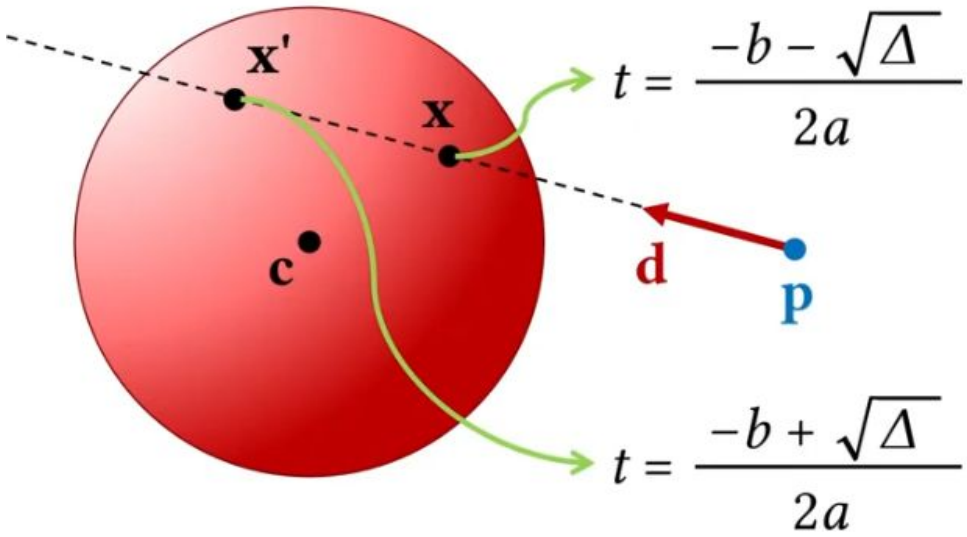
$$\Delta = b^2 - 4ac$$

$\Delta < 0$ ➡ **No Hit!**

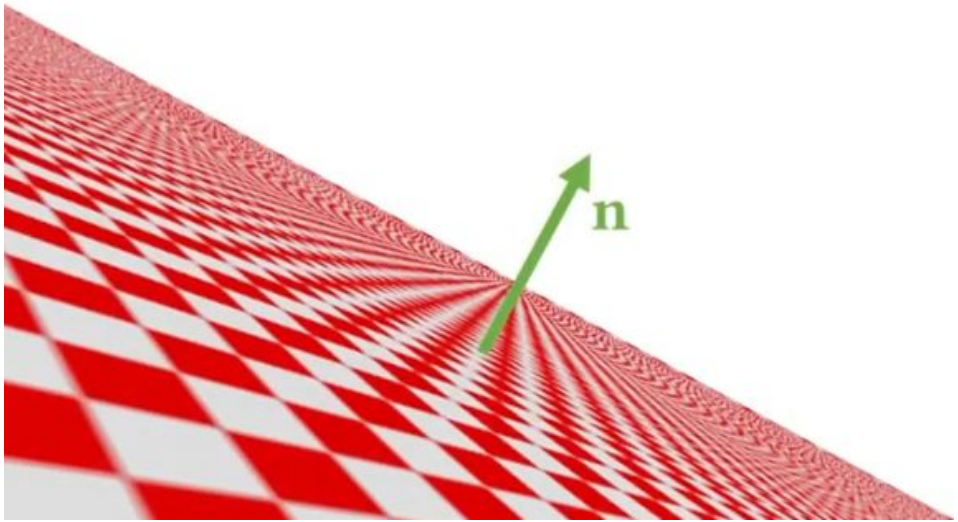
$\Delta \geq 0$ ➡ **Hit!**

How

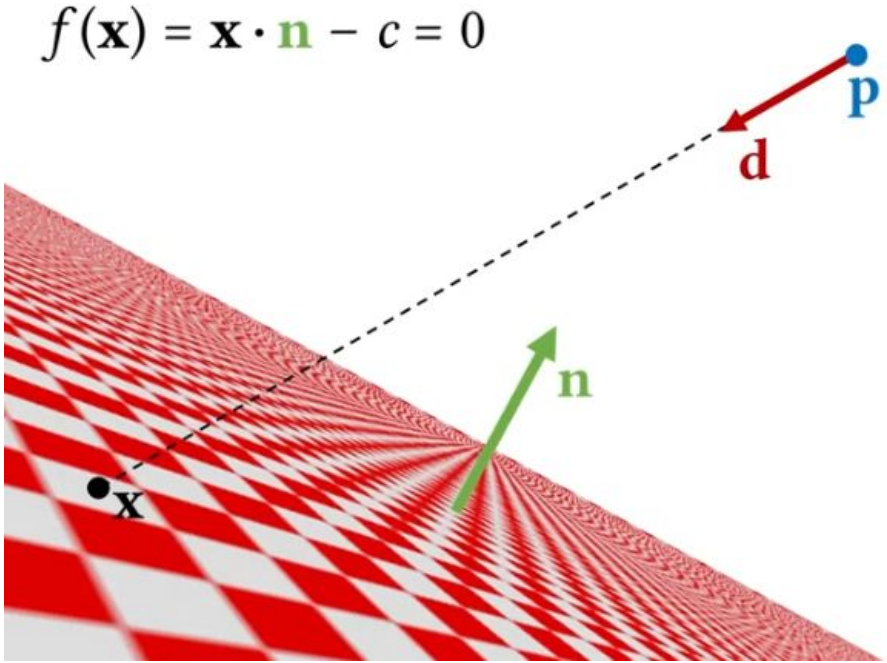
$$(\mathbf{d}\cdot\mathbf{d})t^2 + 2\mathbf{d}\cdot(\mathbf{p}-\mathbf{c})t + (\mathbf{p}-\mathbf{c})\cdot(\mathbf{p}-\mathbf{c}) - r^2 = 0$$



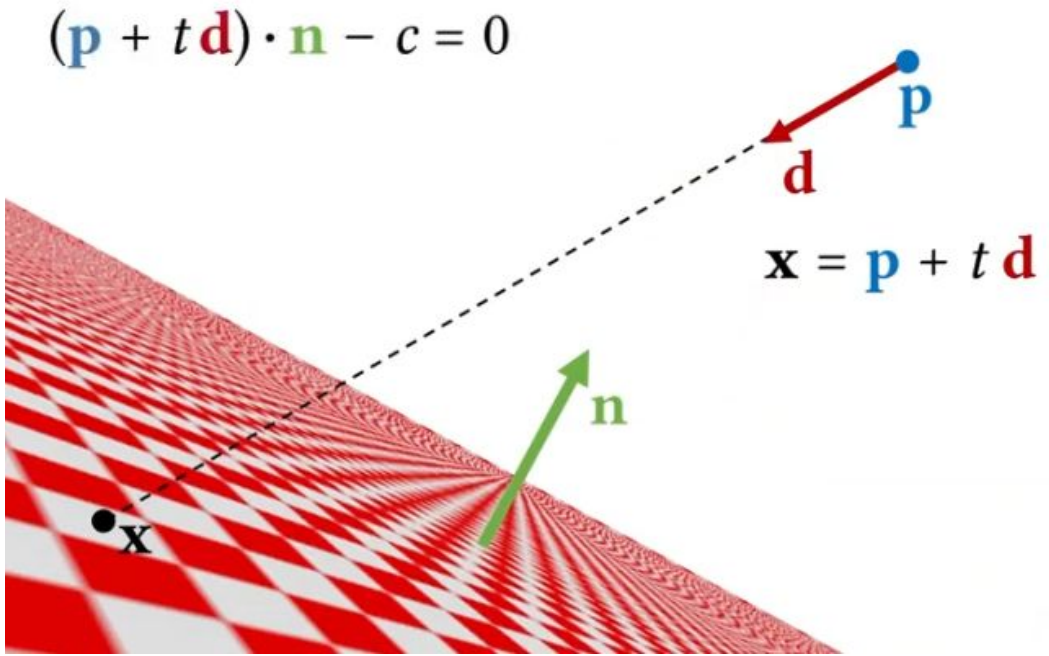
How



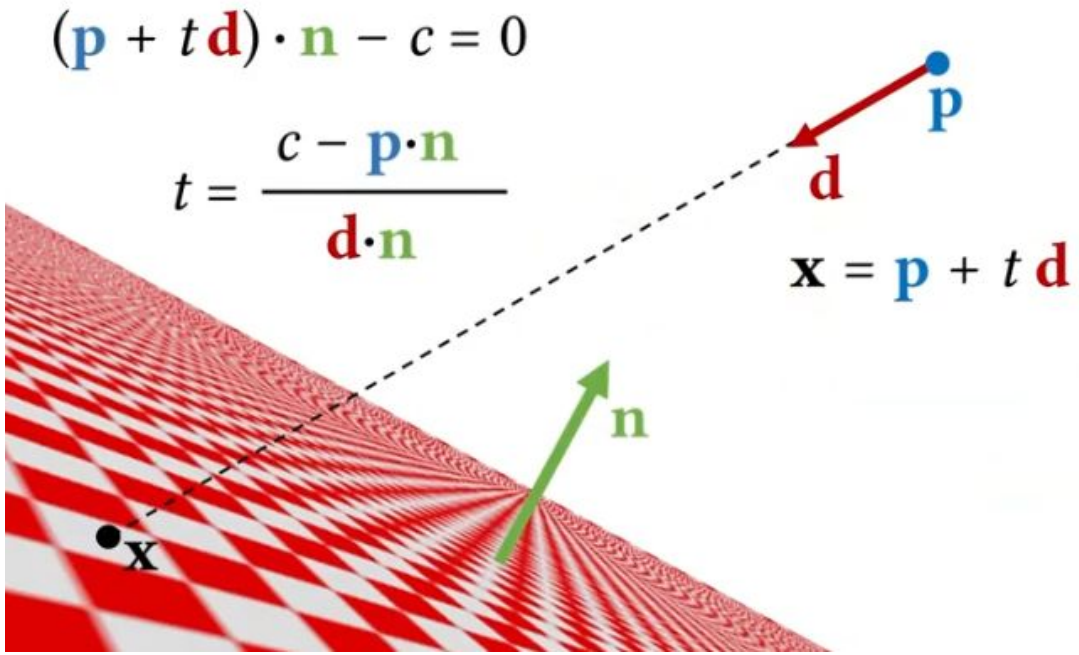
How



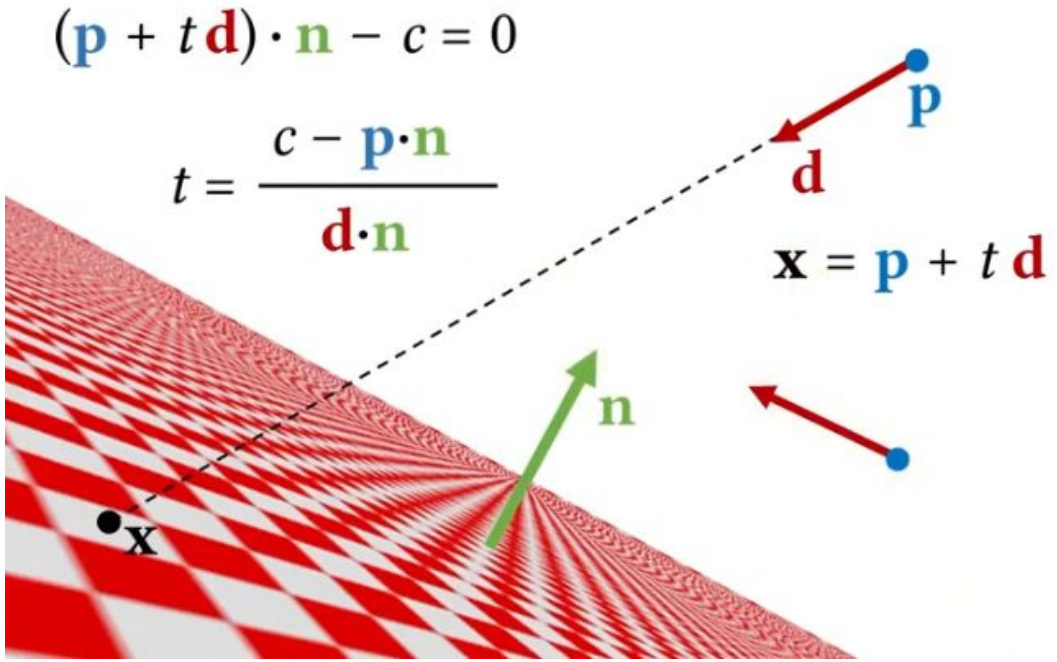
How



How



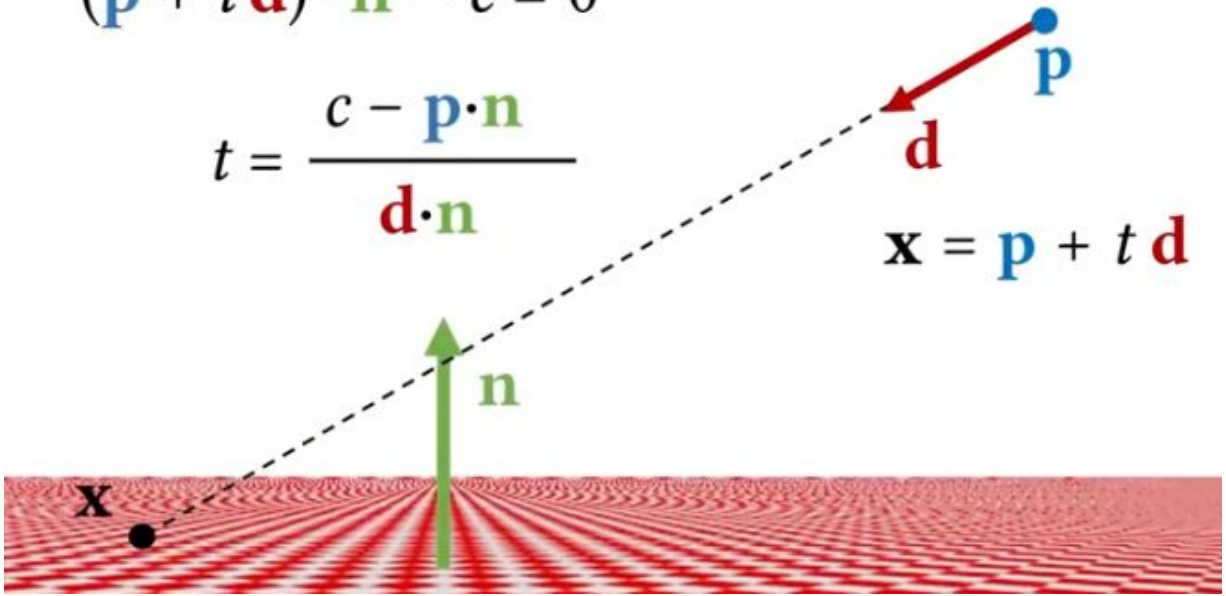
How


$(\mathbf{p} + t\,\mathbf{d}) \cdot \mathbf{n} - c = 0$
$t = \dfrac{c - \mathbf{p}\cdot\mathbf{n}}{\mathbf{d}\cdot\mathbf{n}}$
$\mathbf{x} = \mathbf{p} + t\,\mathbf{d}$
p
d
n
x

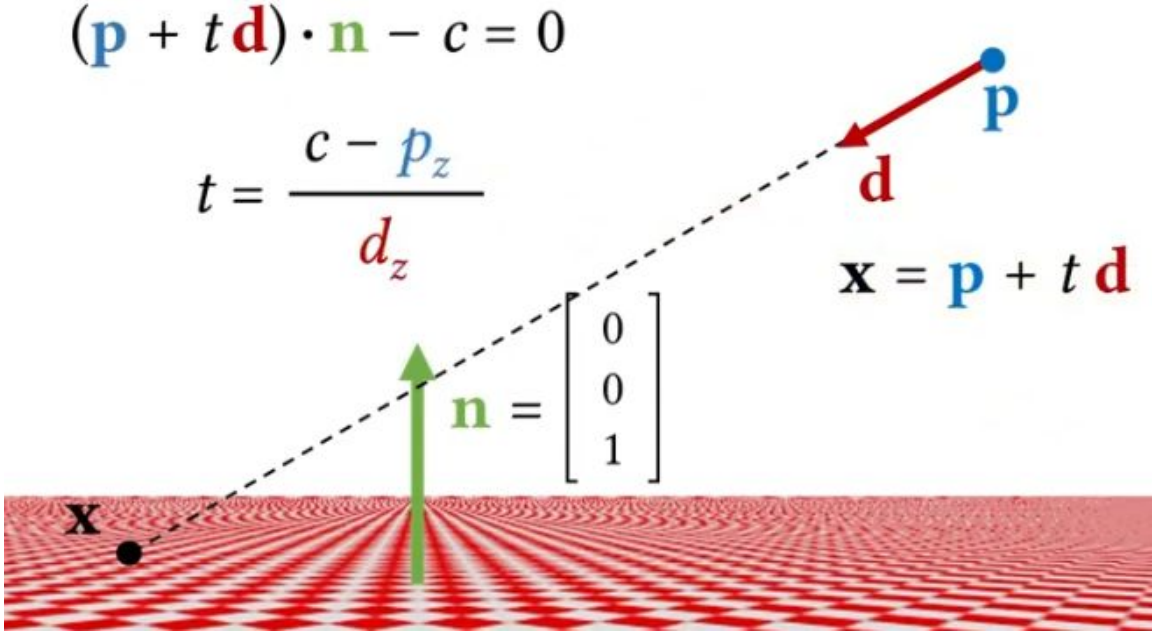
How

$$(\mathbf{p} + t\,\mathbf{d}) \cdot \mathbf{n} - c = 0$$

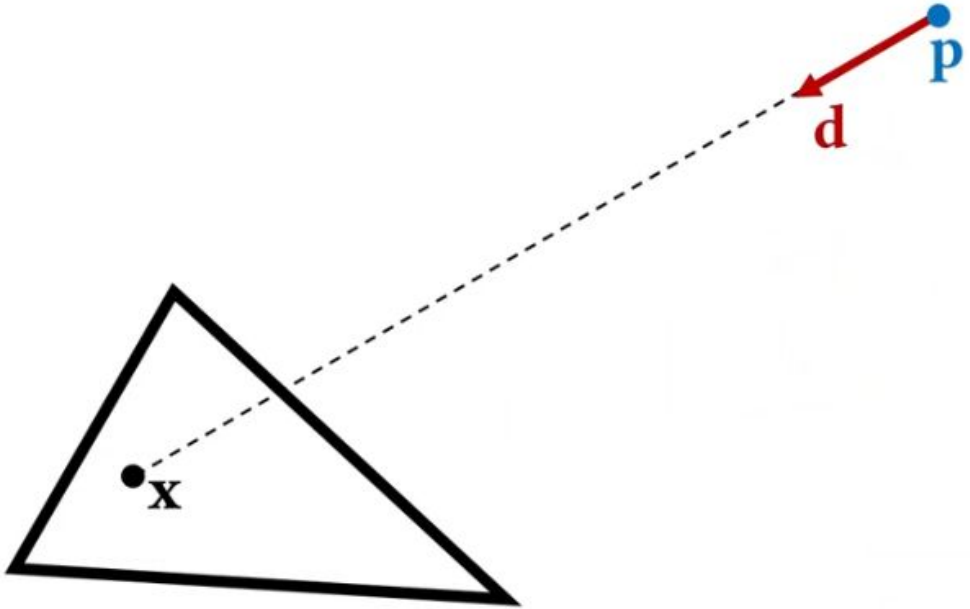
$$t = \frac{c - \mathbf{p}\cdot\mathbf{n}}{\mathbf{d}\cdot\mathbf{n}}$$



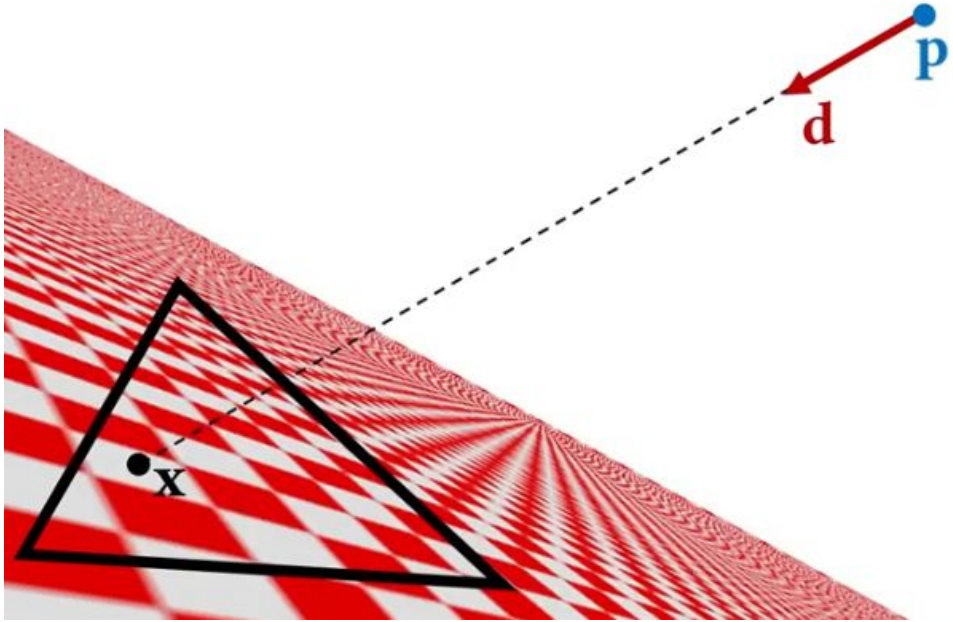
How


$(\mathbf{p} + t\,\mathbf{d}) \cdot \mathbf{n} - c = 0$
$t = \frac{c - p_z}{d_z}$
p
d
$\mathbf{x} = \mathbf{p} + t\,\mathbf{d}$
$\mathbf{n} = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$
x

How



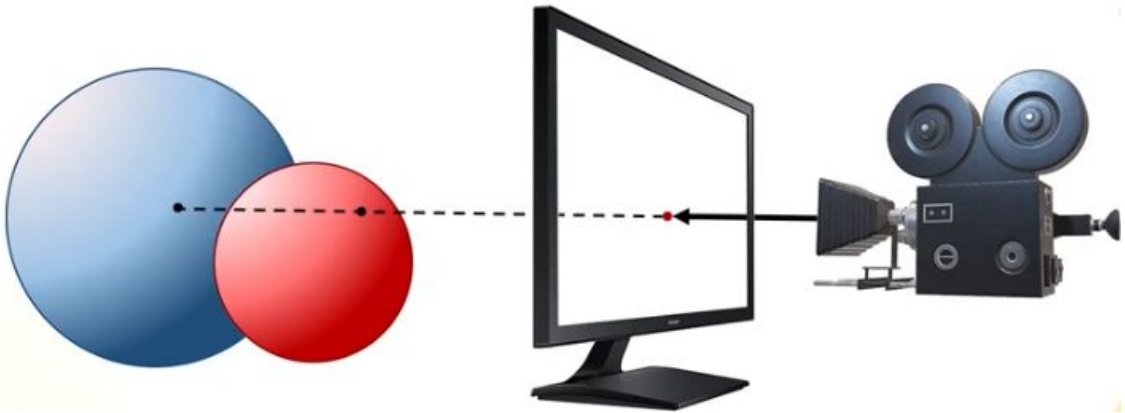
How



How

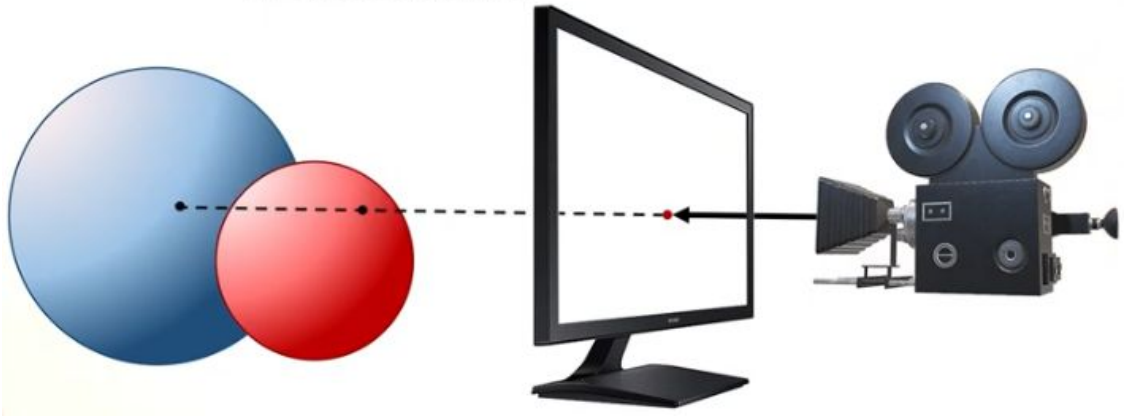
for each ray

find the *closest* primitive

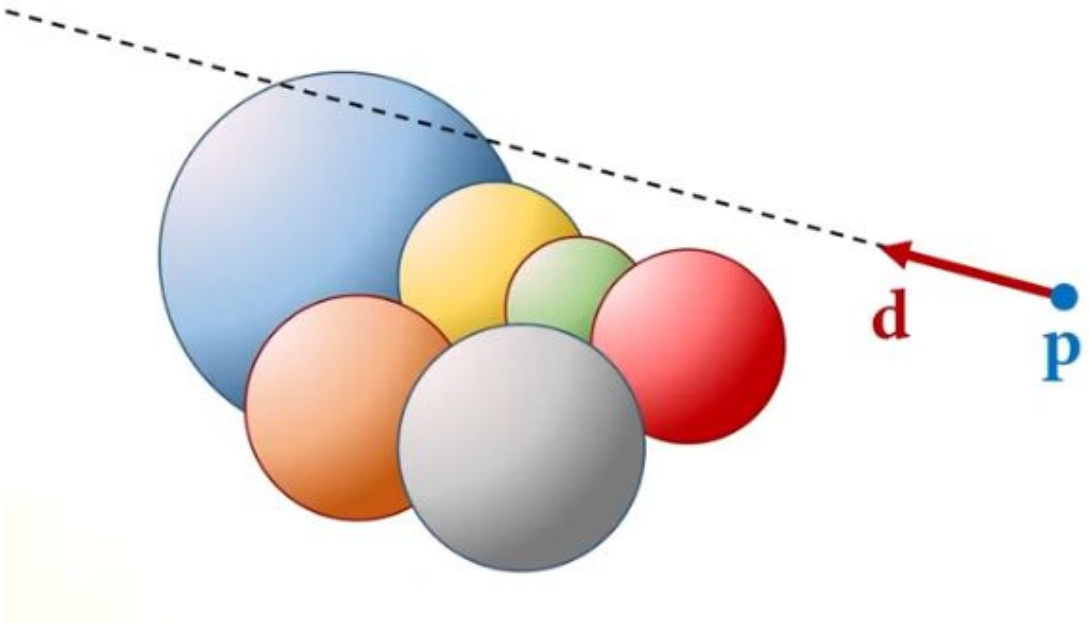


How

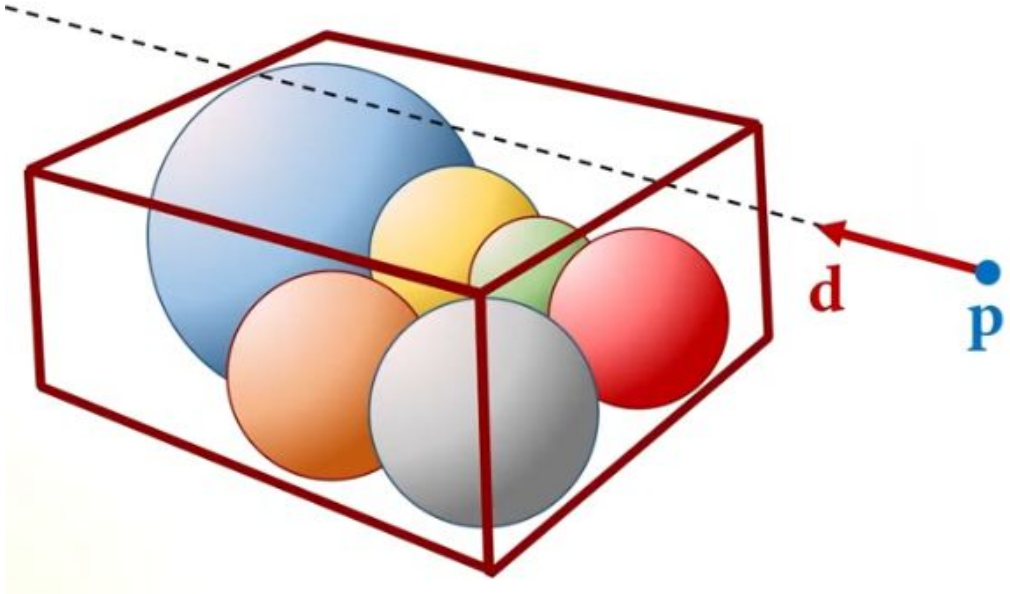
```
for each ray
    for each primitive
        if ray intersects primitive
            if closest hit
```



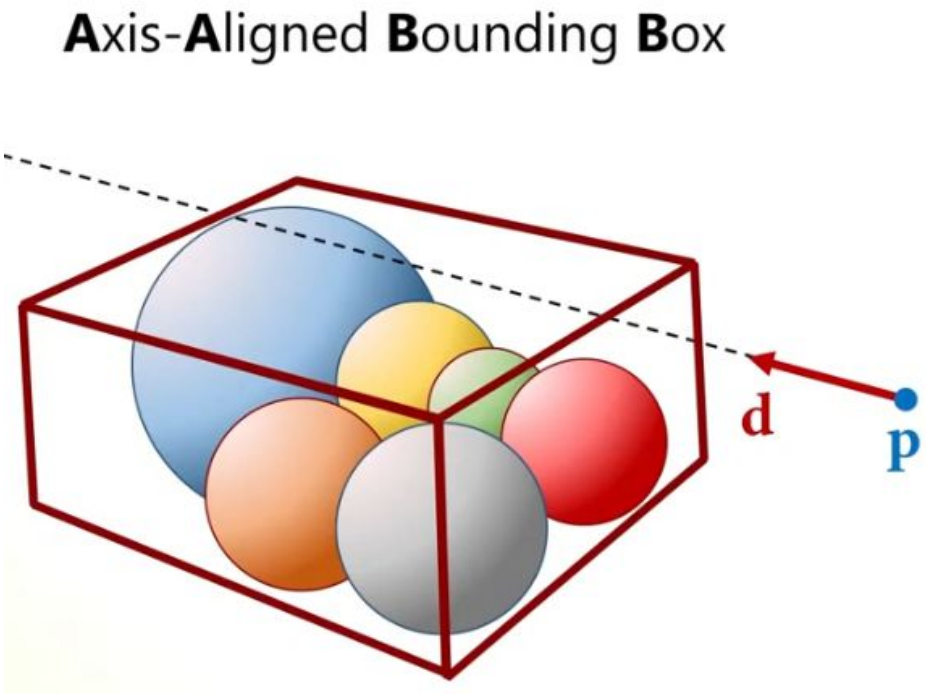
Accelerating ray tracing



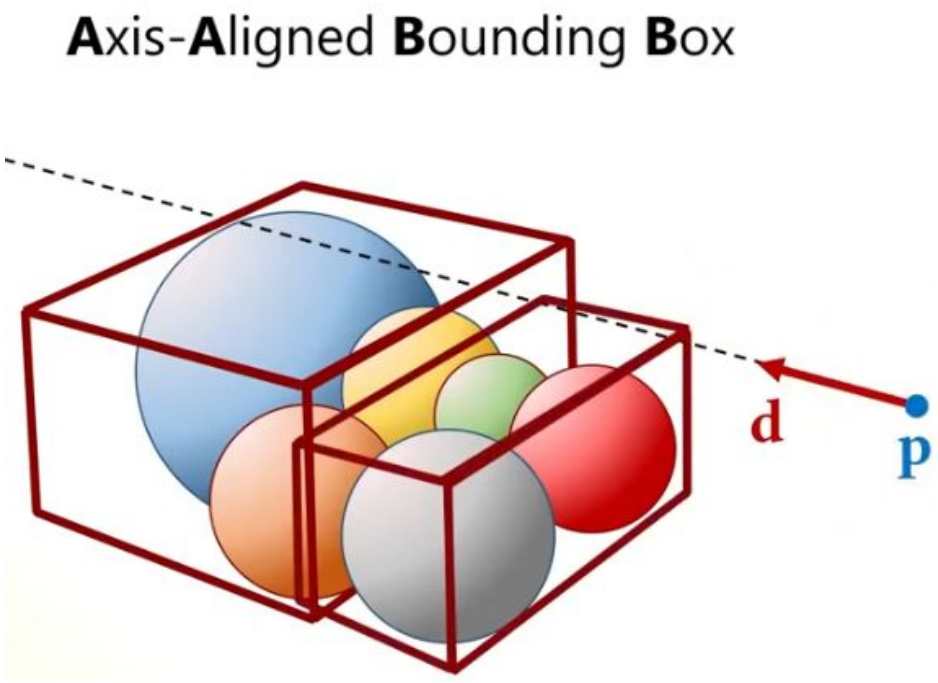
Accelerating ray tracing



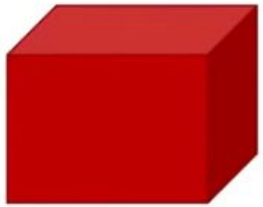
Accelerating ray tracing



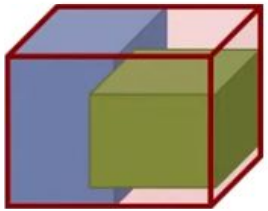
Accelerating ray tracing



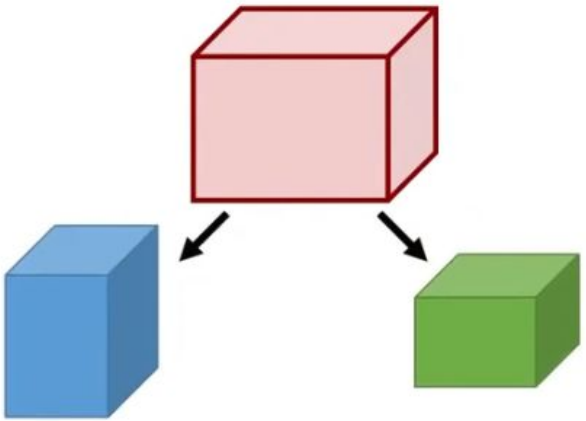
BVH



BVH



BVH



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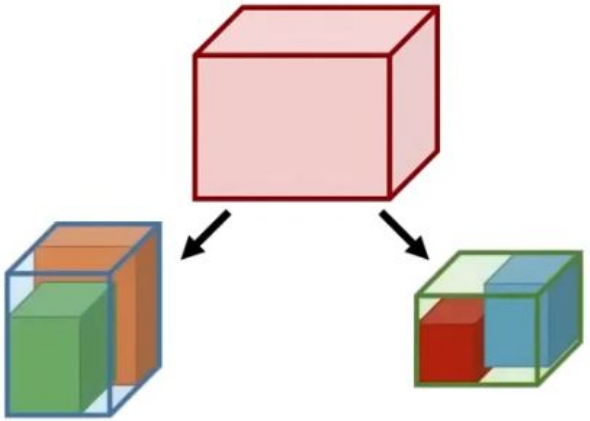

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