Ray Casting

Some Slides/Images adapted from Marschner and Shirley and David Levin

Announcements

Assignment 1 is due tomorrow at midnight (12 May)

Reminders:

- Tutorials are on Fridays and are used to ask questions about the concepts, assignments, and course in general
- Use the github issues page to ask questions about the assignments.
    - There will be a TA monitoring the page

Clarifications

Over operator from wikipedia (https://en.wikipedia.org/wiki/Alpha_compositing):

$$C_o = \frac{C_a \alpha_a + C_b \alpha_b (1 - \alpha_a)}{\alpha_a + \alpha_b (1 - \alpha_a)}$$

or

$$c_o = c_a + c_b(1 - \alpha_a), \quad \alpha_o = \frac{c_o}{C_o} = \alpha_a + \alpha_b(1 - \alpha_a)$$

For further reading:

https://keithp.com/~keithp/porterduff/p253-porter.pdf

https://tomforsyth1000.github.io/blog.wiki.html#%5B%5BPremultiplied+alpha%5D%5D

Clarifications

"Normal" alpha-blending munges together two physically separate effects - the amount of light this layer of rendering lets through from behind, and the amount of light this layer adds to the image. Instead, it keeps the two related - you can't have a surface that adds a bunch of light to a scene without it also masking off what is behind it. Physically, this makes no sense - just because you add a bunch of photons into a scene, doesn't mean all the other photons are blocked. Premultiplied alpha fixes this by keeping the two concepts separate - the blocking is done by the alpha channel, the addition of light is done by the colour channel. This is not just a neat concept, it's really useful in practice.

$$C_o = \frac{C_a\alpha_a + C_b\alpha_b(1-\alpha_a)}{\alpha_a + \alpha_b(1-\alpha_a)}$$

or

$$c_o = c_a + c_b(1-\alpha_a),$$

$$\alpha_o = \frac{c_o}{C_o} = \alpha_a + \alpha_b(1-\alpha_a)$$

https://tomforsyth1000.github.io/blog.wiki.html#%5B%5BPremultiplied+alpha%5D%5D

Any Questions?

Today: Ray Casting

The Ray Casting Algorithm

Introduction to Rays

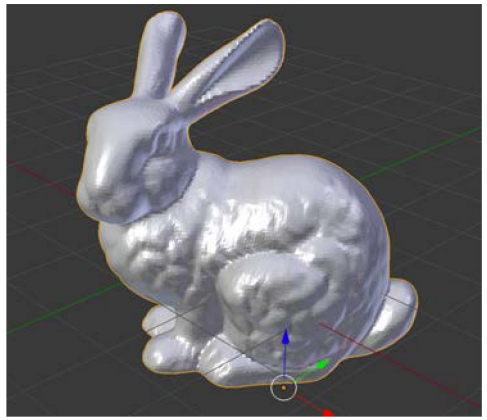
The Camera

Ray-Object Intersection

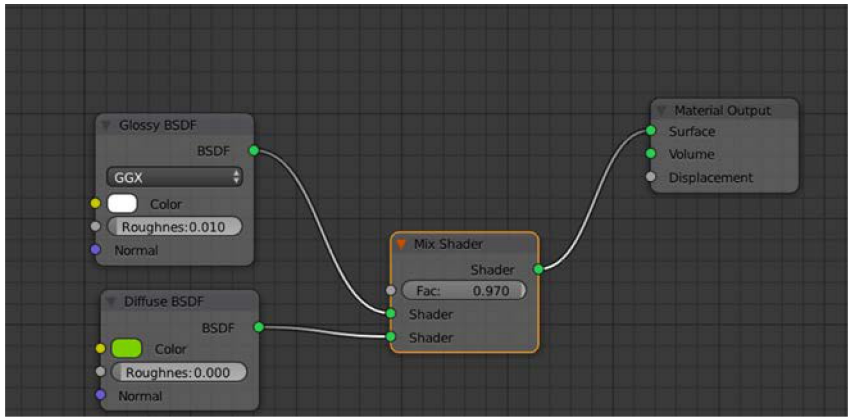
- Ray-Plane Intersection
- Ray-Sphere Intersection
- Ray-Triangle Intersection

Rendering

Input:

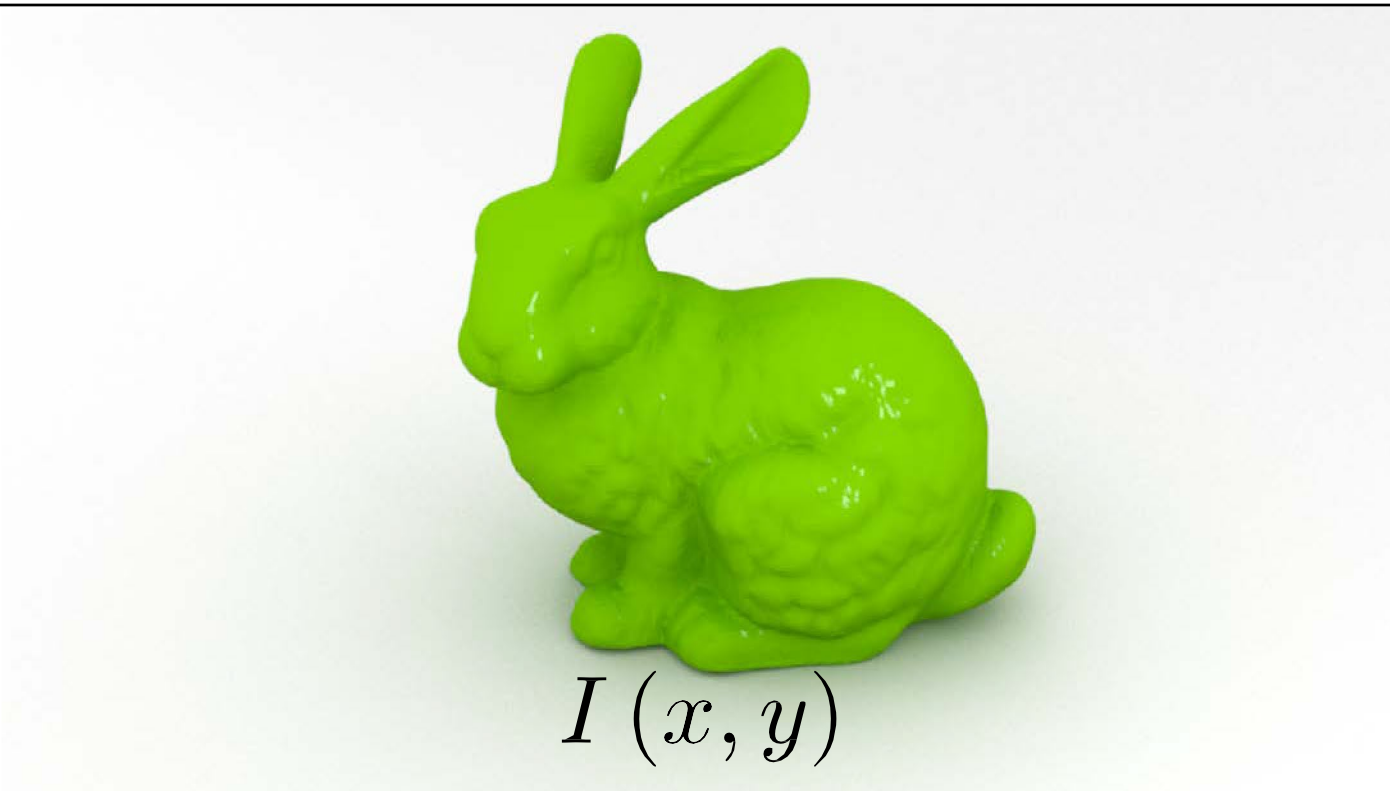


Objects



Materials

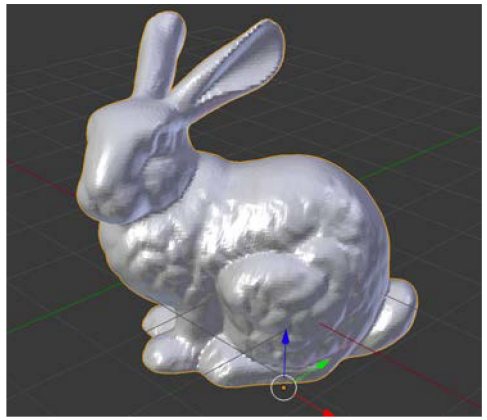
Output:



$I(x, y)$

Cameras

Input:



Objects

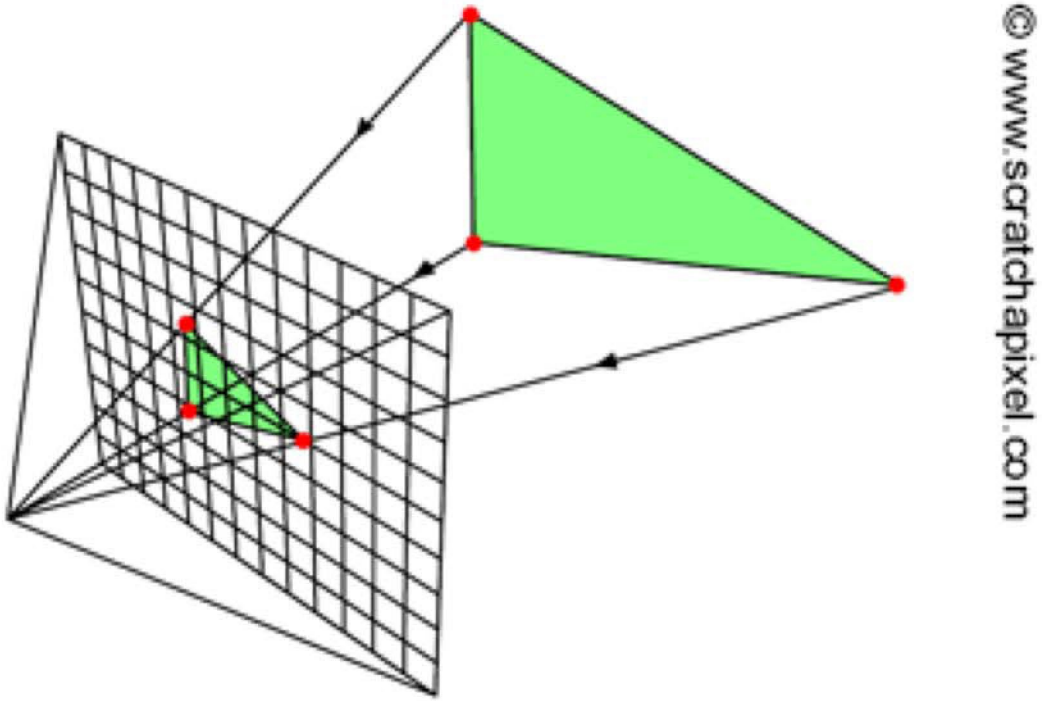
Lights

Output:

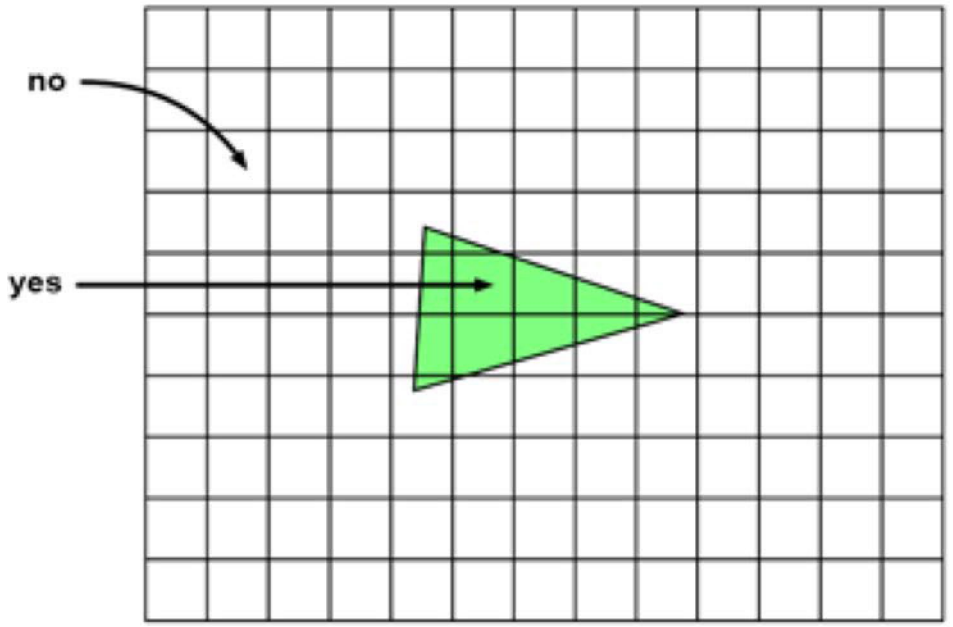
$$I\left(x, y\right)$$


WWW.GRY-ONLINE.PL
zvarownik
13878049a9f142c2b036e491198e2149
WARIOR_GAMING_57
YZx-_Vulka
danielek185
zvarownik
danielek185
285 300 NW 330 345 N 15 30 NE 60 75 E
WARIOR_GAMING_57
0:52
94
0
0 5
0 0 0
0 100
100 100
Przytrzymaj
Fortnite | Epic Games

Rasterization



1. Project Vertices to Image Plane



2. Turn on pixels inside triangle

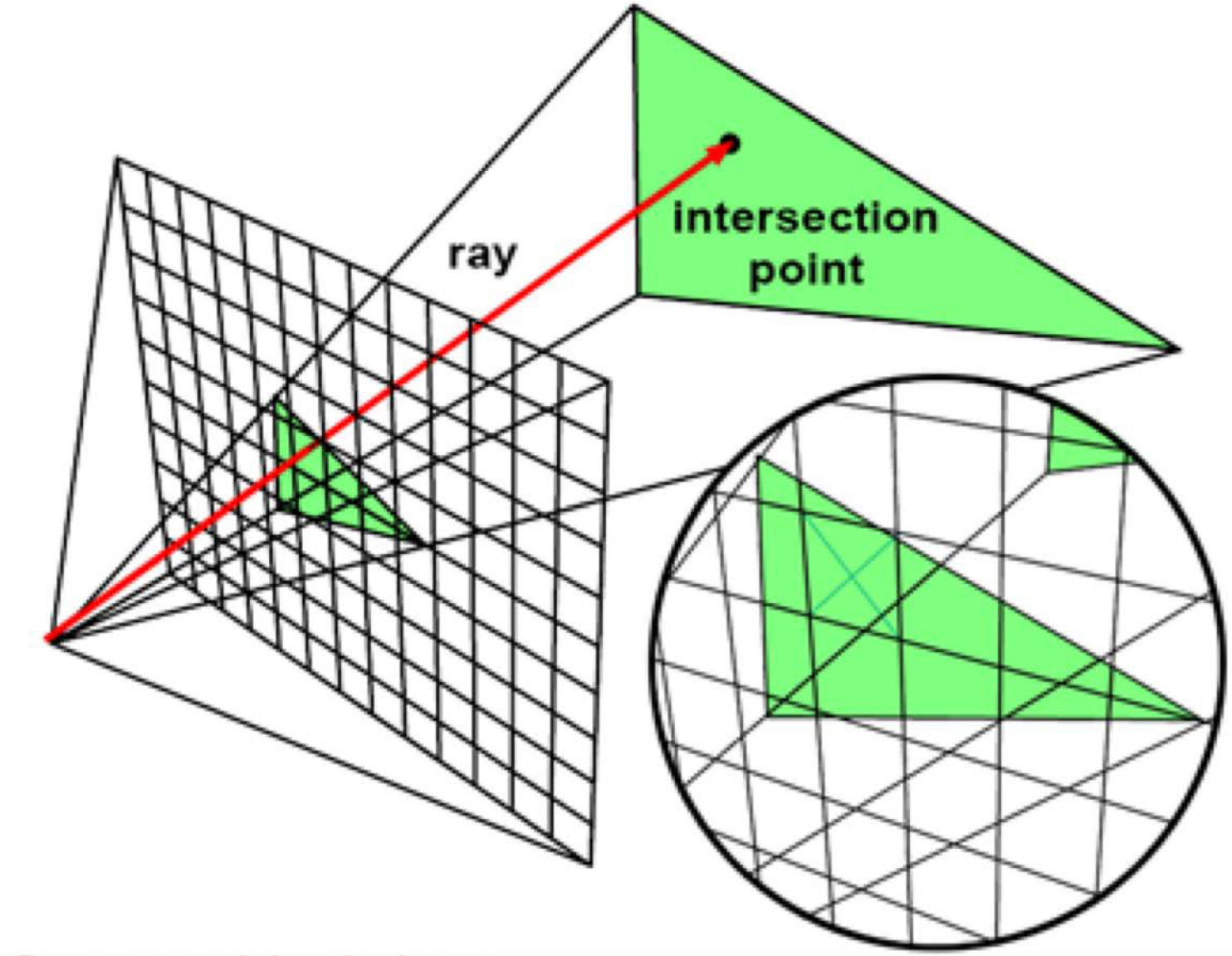
https://www.scratchapixel.com/lessons/3d-basic-rendering/rasterization-practical-implementation

Rasterization

```
for each object in the scene {
    for each pixel in the image
    {
        if (object affects pixel)
            {
            do something
        }
    }
}
```

operations can be done quickly on the GPU!

Ray Casting



https://www.scratchapixel.com/lessons/3d-basic-rendering/rasterization-practical-implementation

Ray Casting

```
for each pixel in the image {
    Generate a ray
    for each object in the scene {
        if (Intersect ray with
            object) {  Set pixel
            colour
        }
    }
}
```

Basic Components of Ray Casting

Ray

Camera

Intersection Tests

Basic Components of Ray Casting

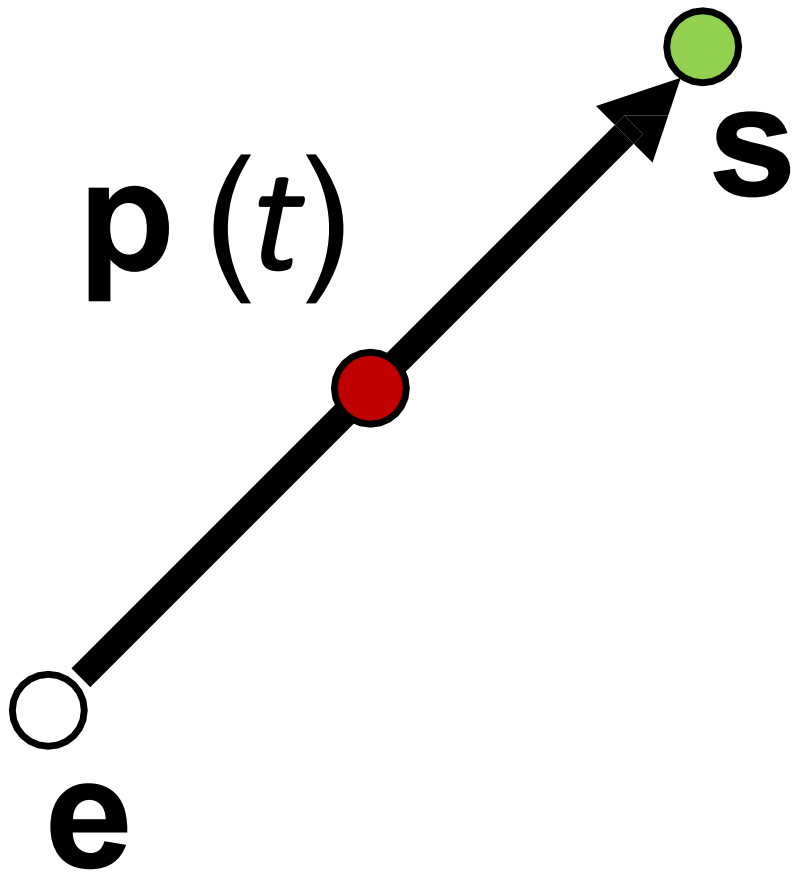
Ray

Camera

Intersection Tests

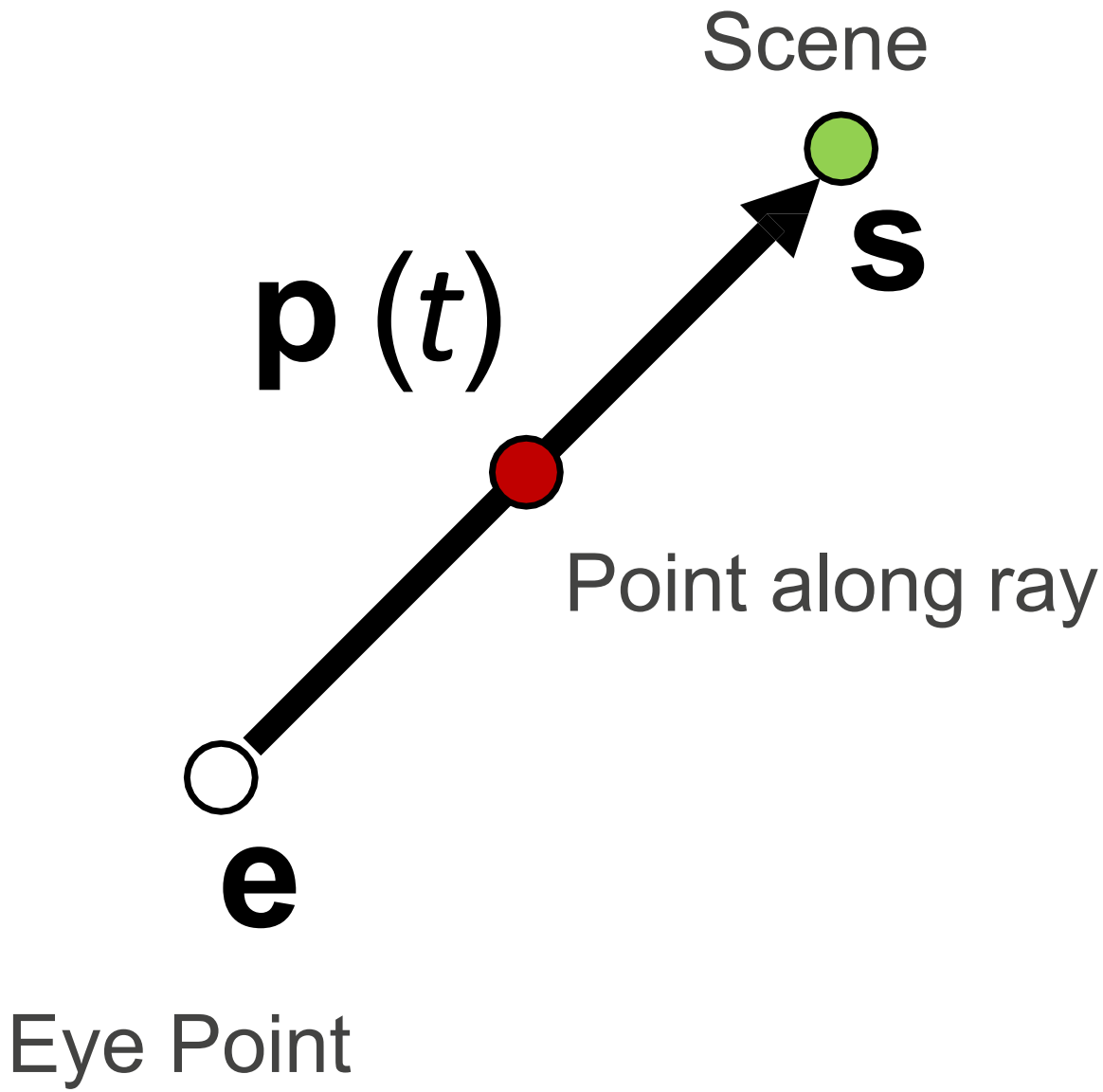
The Ray

$$\mathbf{p}(t) = \mathbf{e} + t(\mathbf{s} - \mathbf{e})$$



The Ray

$$\mathbf{p}(t) = \mathbf{e} + t(\mathbf{s} - \mathbf{e})$$

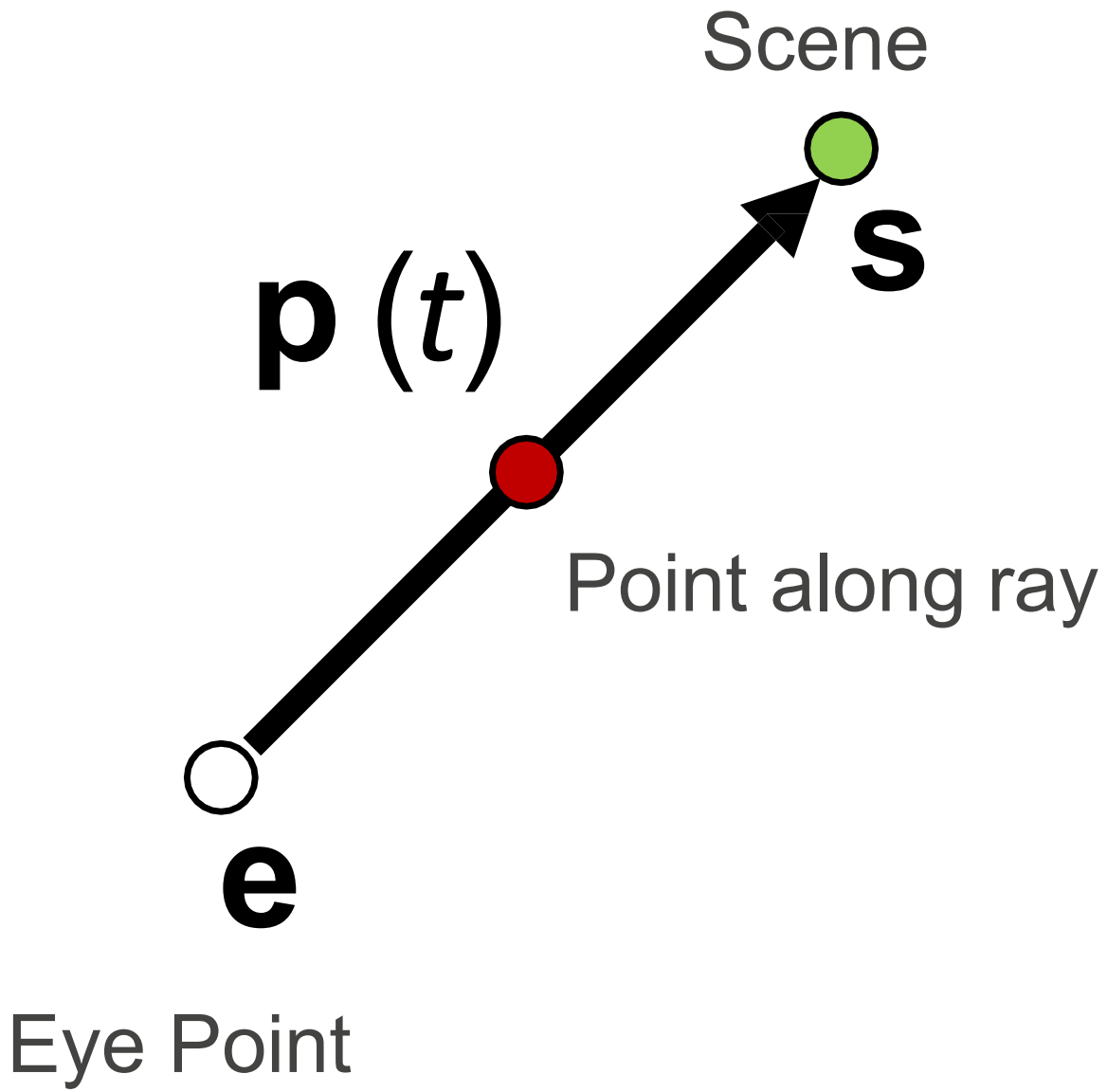


The Ray

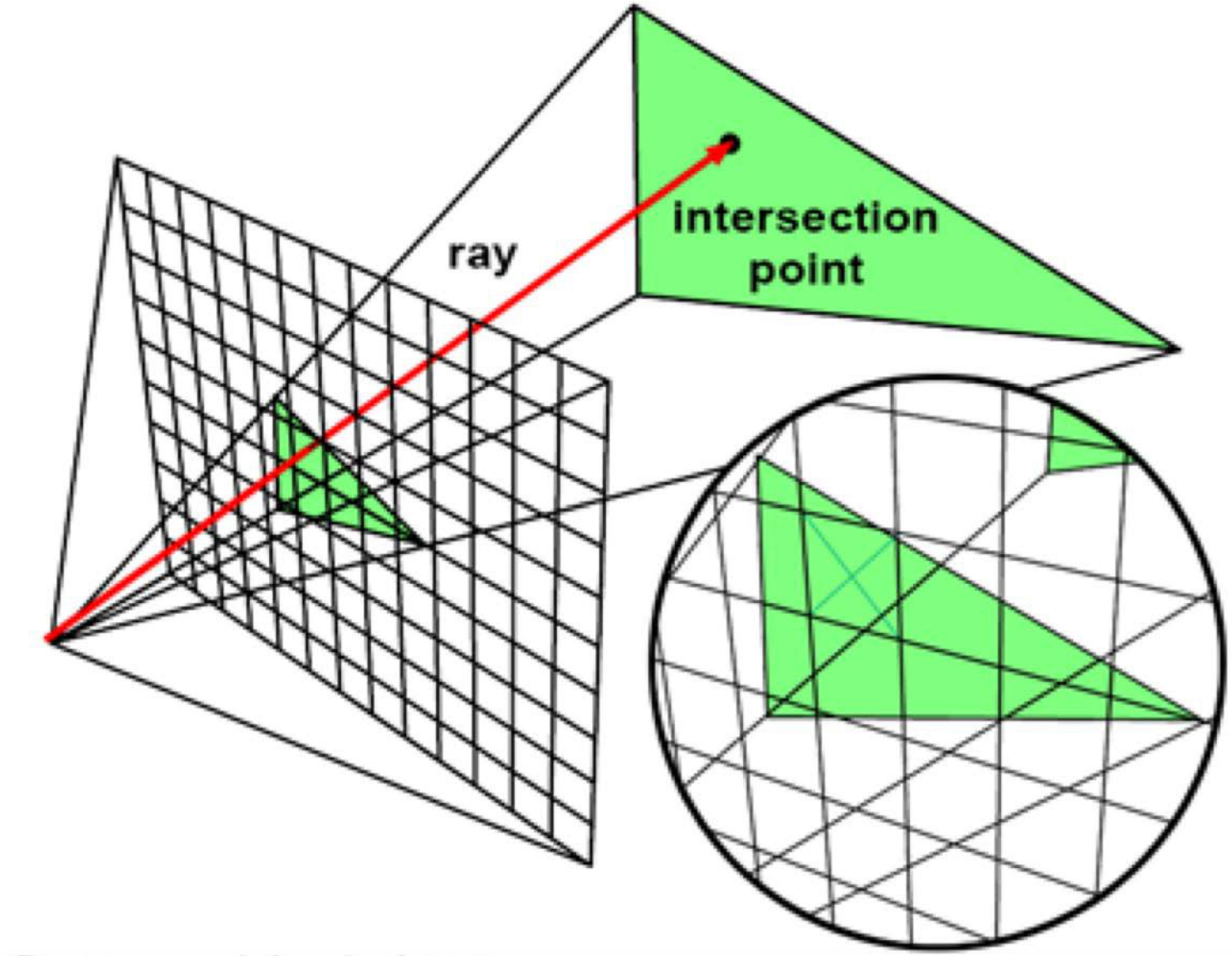
$$\mathbf{p}(t) = \mathbf{e} + t(\mathbf{s} - \mathbf{e})$$

$$\mathbf{p}(0) = \mathbf{e}$$

$$\mathbf{p}(1) = \mathbf{s}$$

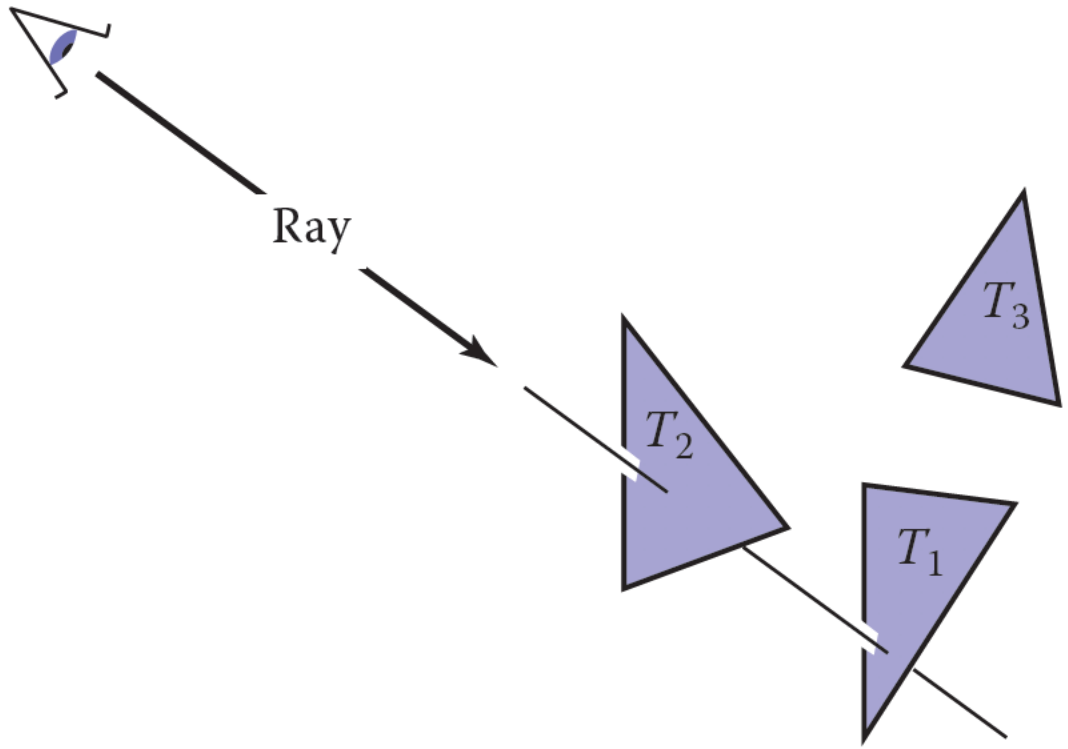


Ray Casting



https://www.scratchapixel.com/lessons/3d-basic-rendering/rasterization-practical-implementation

Ray Casting



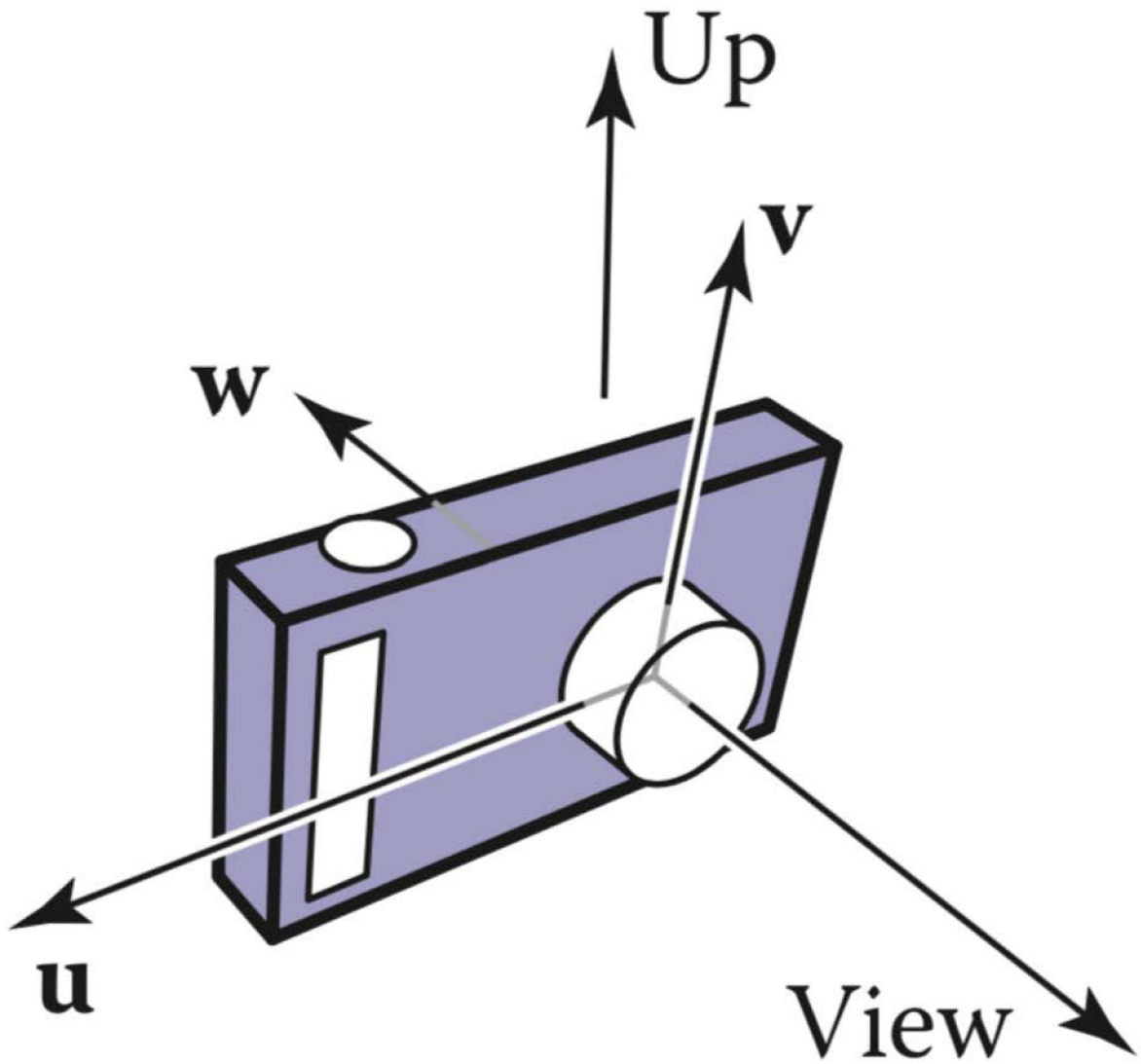
Basic Components of Ray Casting

Ray

Camera

Intersection Tests

The Camera

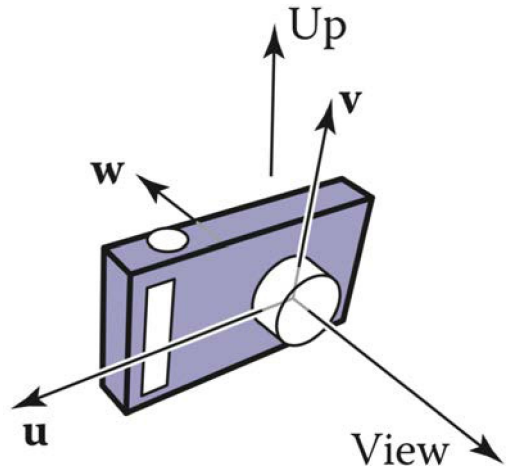


The Camera

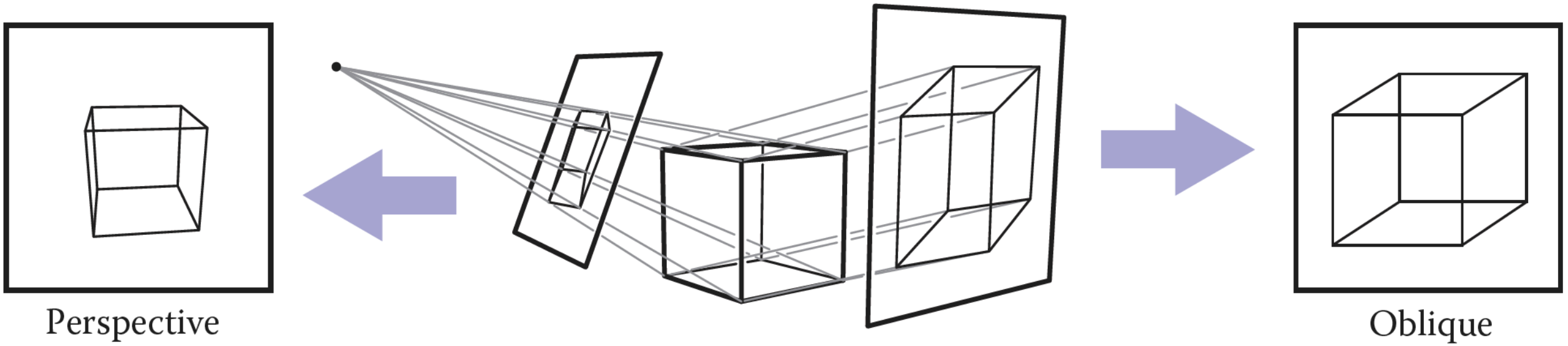
$$\mathbf{w} = -\frac{\text{View}}{\|\text{View}\|}$$

$$\mathbf{u} = \text{View} \times \text{Up}$$

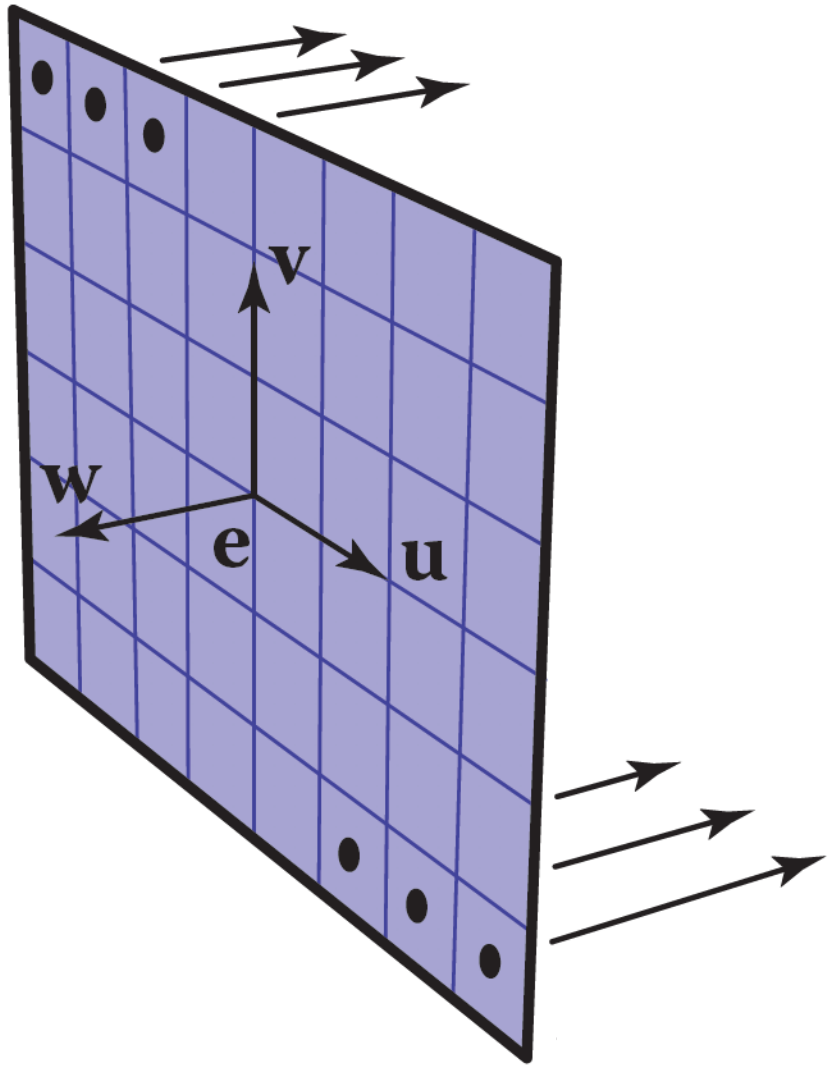
$$\mathbf{v} = \mathbf{w} \times \mathbf{u}$$



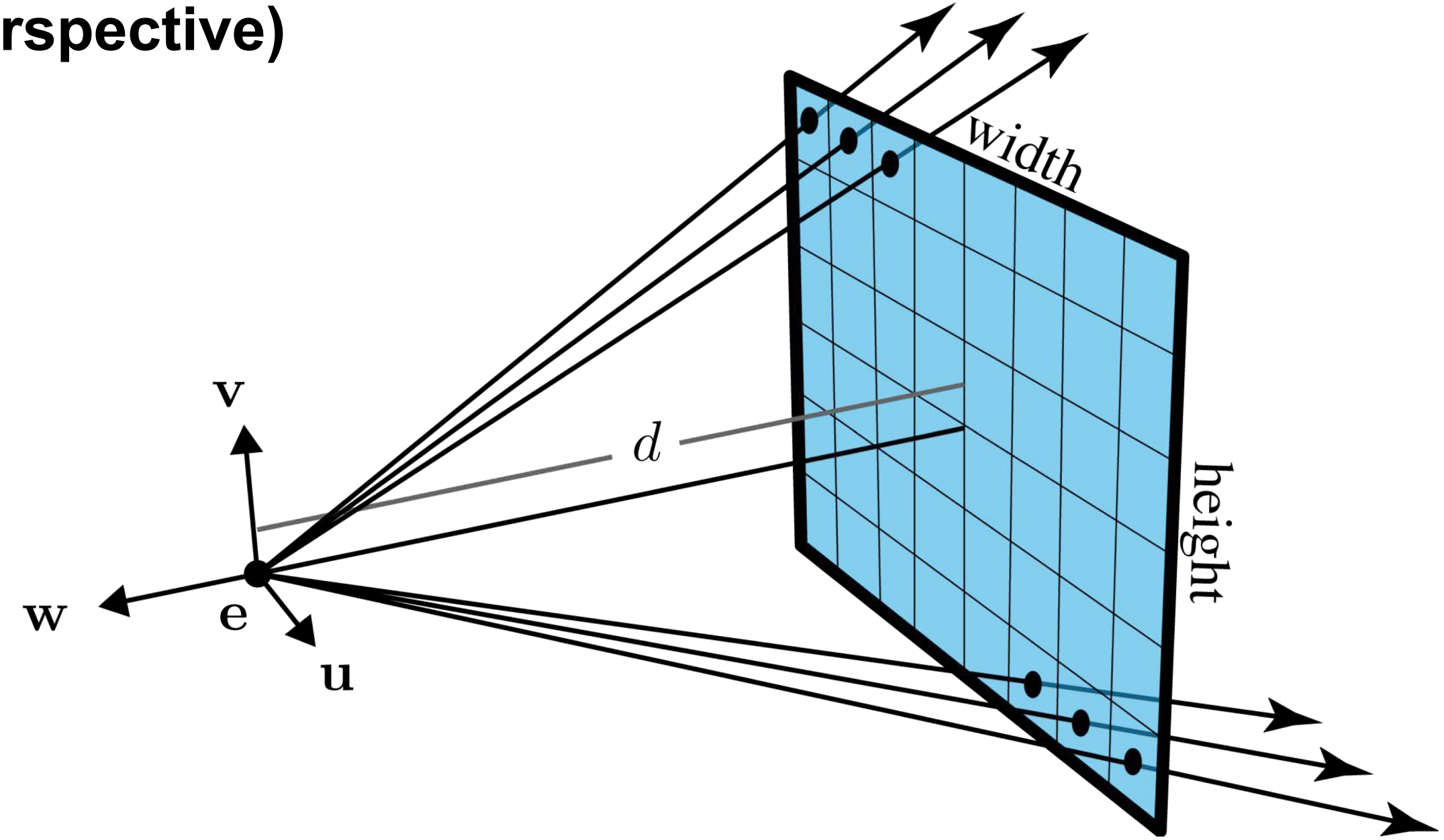
Orthographic v Perspective Projection



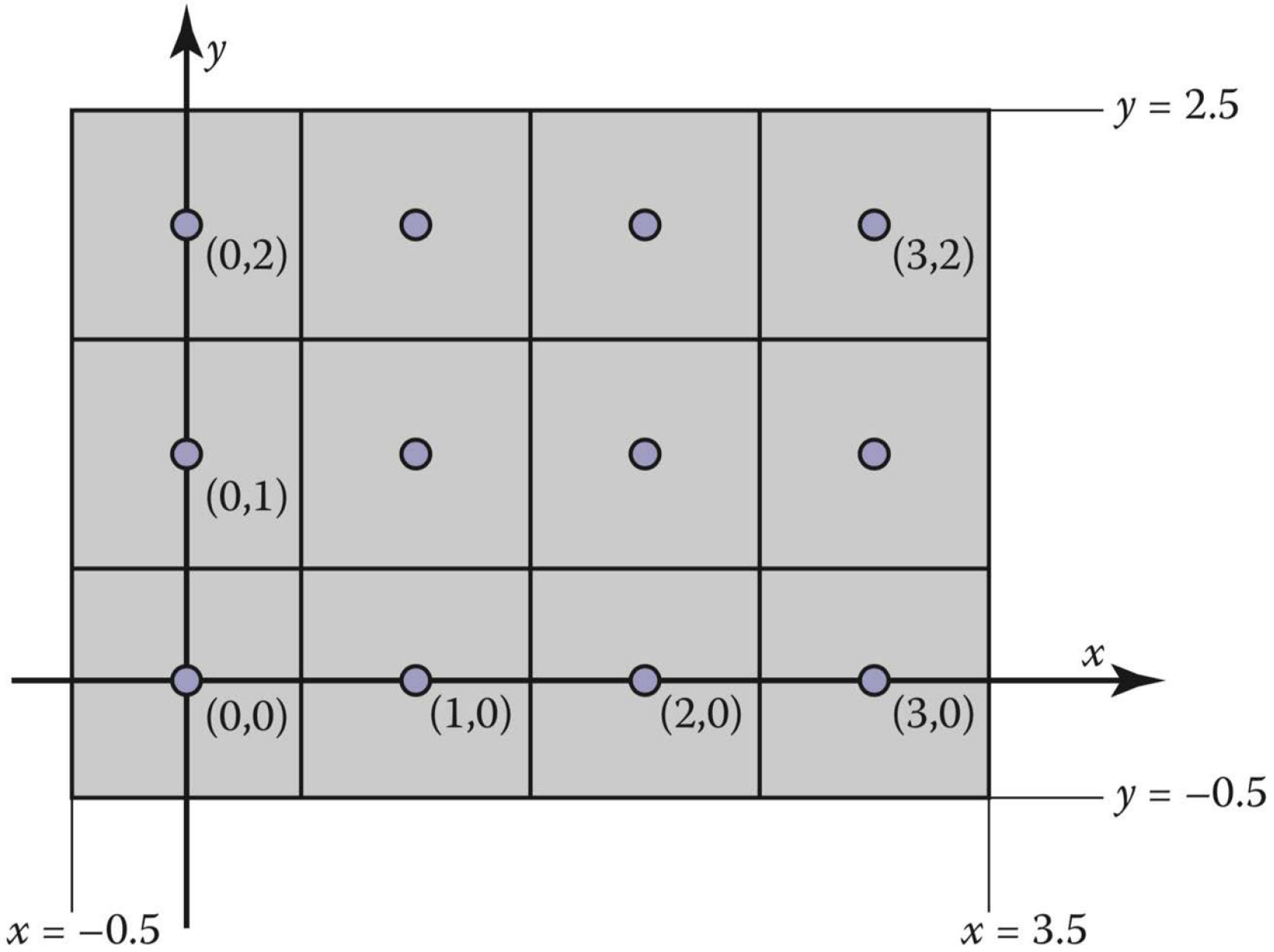
Generating Rays (Orthographic)

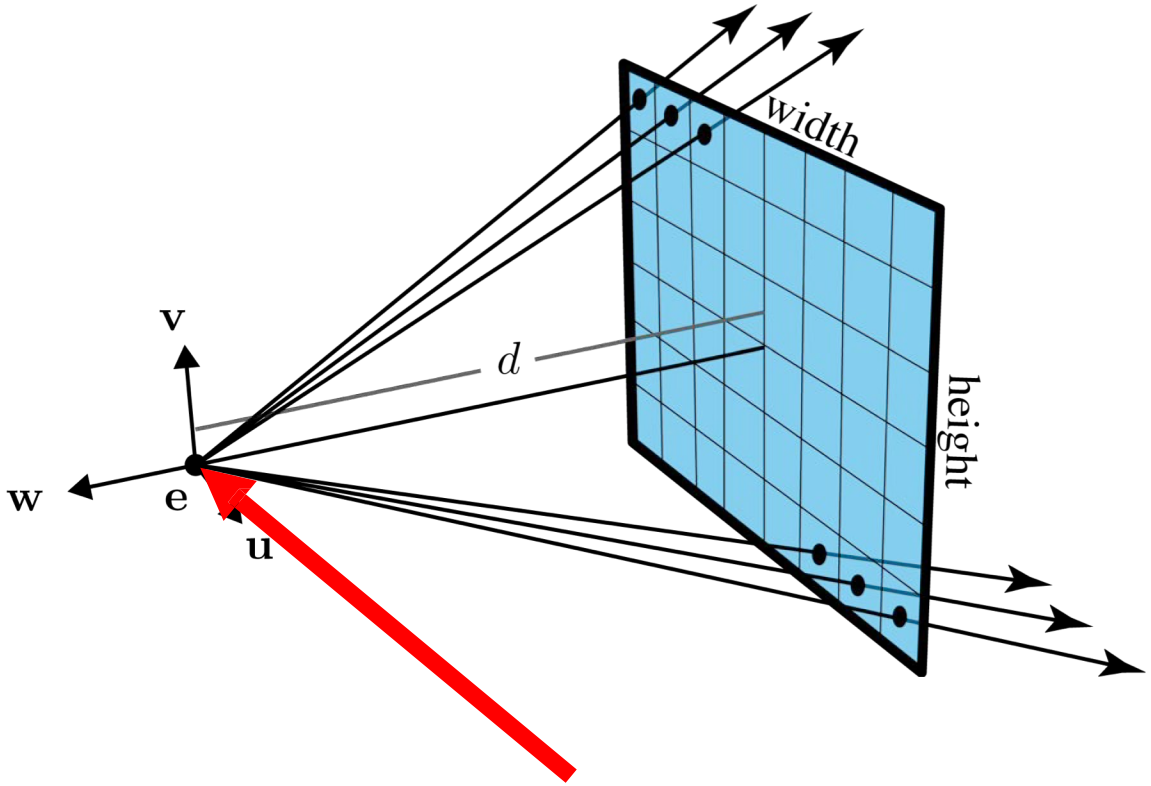


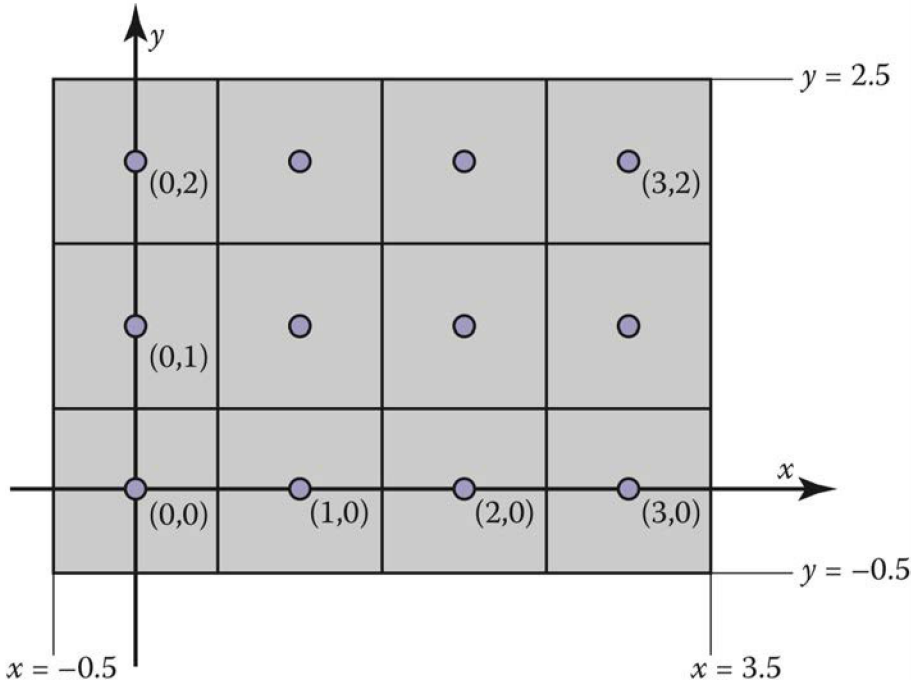
Generating Rays (Perspective)



Recall: Standard Pixel Coordinate System

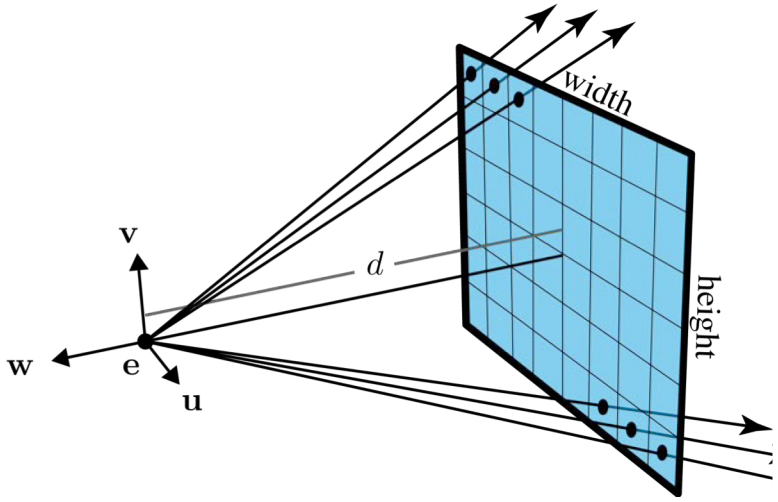


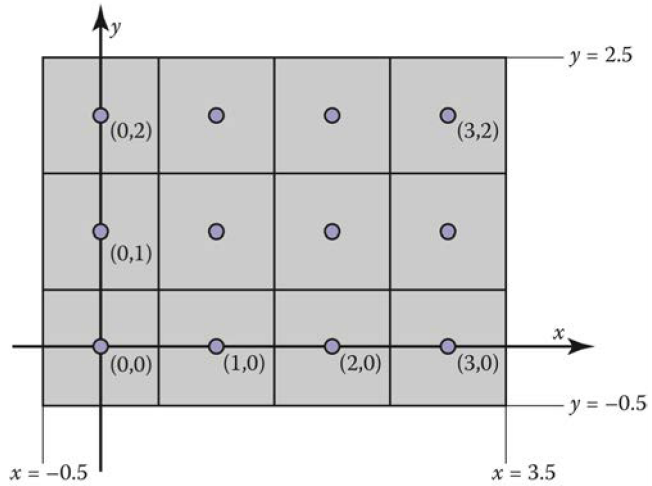




Origin of camera frame (the eye)

What are the coordinates for pixel (i, j) in the camera frame?





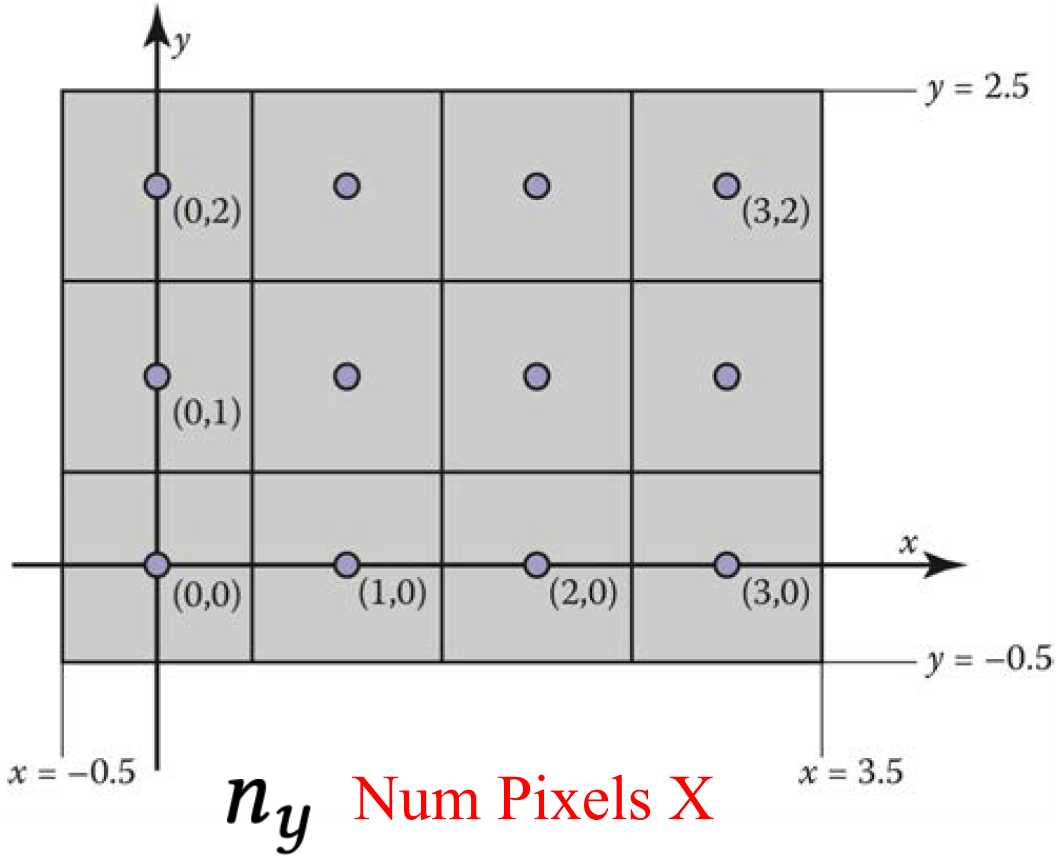
Bottom Left Corner (i, j) : ?

Top Right Corner (i, j) : ?

Bottom Left Corner (u, v) : ?

Top Right Corner (u, v) : ?

n_x Num Pixels Y



Bottom Left Corner (i, j) : $(-\frac{1}{2}, -\frac{1}{2})$

Top Right Corner (i, j) : $(n_x - \frac{1}{2}, n_y - \frac{1}{2})$

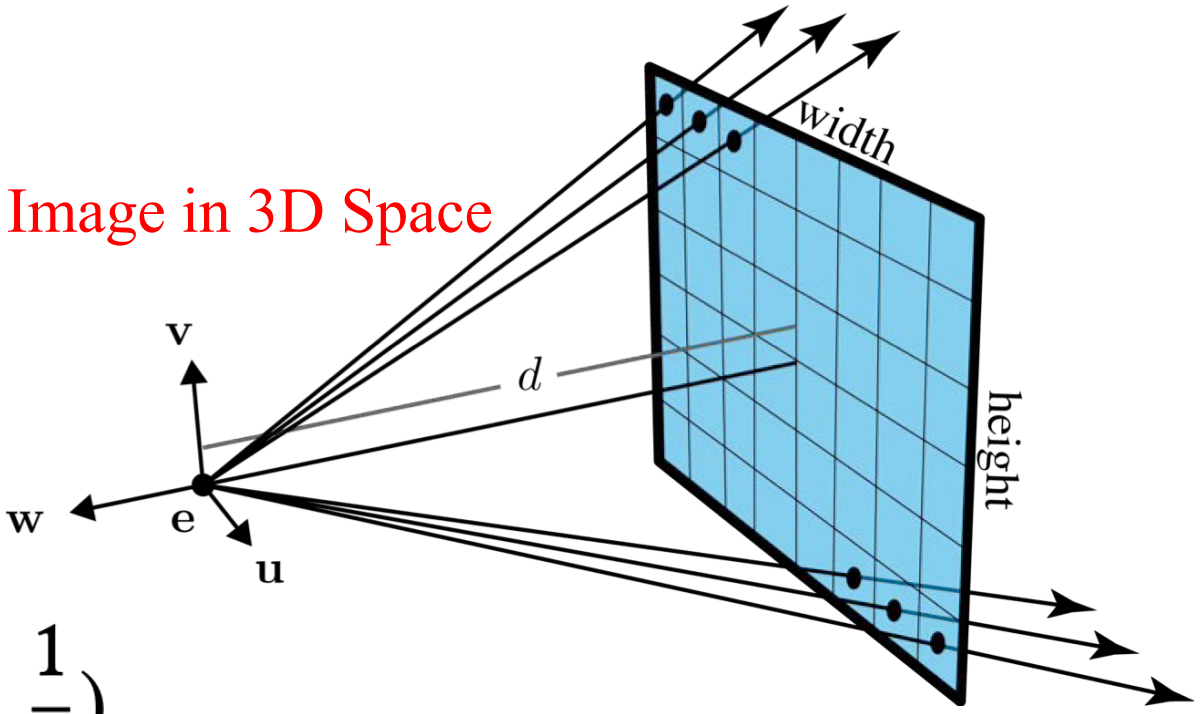
n_y Num Pixels X

Bottom Left Corner (u, v) :

Top Right Corner (u, v) :

Physical Width of Image in 3D Space

Physical Height of Image in 3D Space



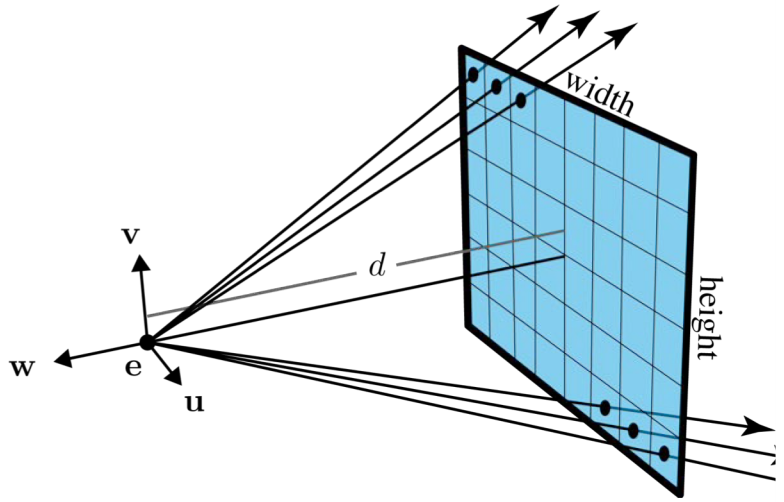
Bottom Left Corner (i, j) : $(-\frac{1}{2}, -\frac{1}{2})$

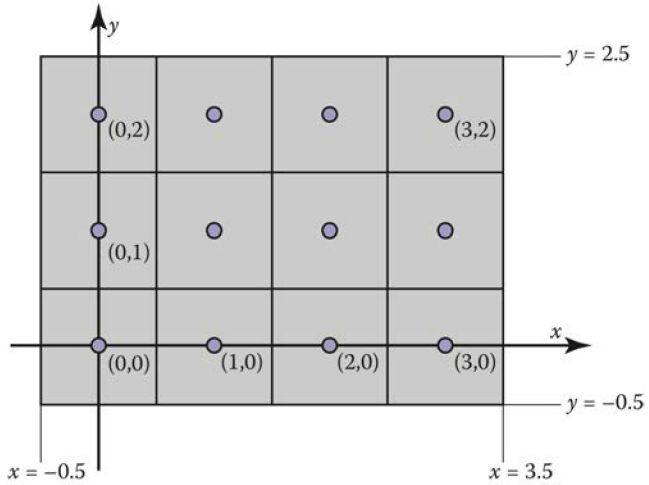
Top Right Corner (i, j) : $(n_x - \frac{1}{2}, n_y - \frac{1}{2})$

Bottom Left Corner (u, v) : $(-\frac{\text{width}}{2}, -\frac{\text{height}}{2})$

Top Right Corner (u, v) : $(\frac{\text{width}}{2}, \frac{\text{height}}{2})$

pixel at position (i, j) in the raster image has the position:





Physical Width of Image in 3D Space

$$u = \frac{\text{width}}{n_x} \cdot \left(i + \frac{1}{2}\right) - \frac{\text{width}}{2}$$

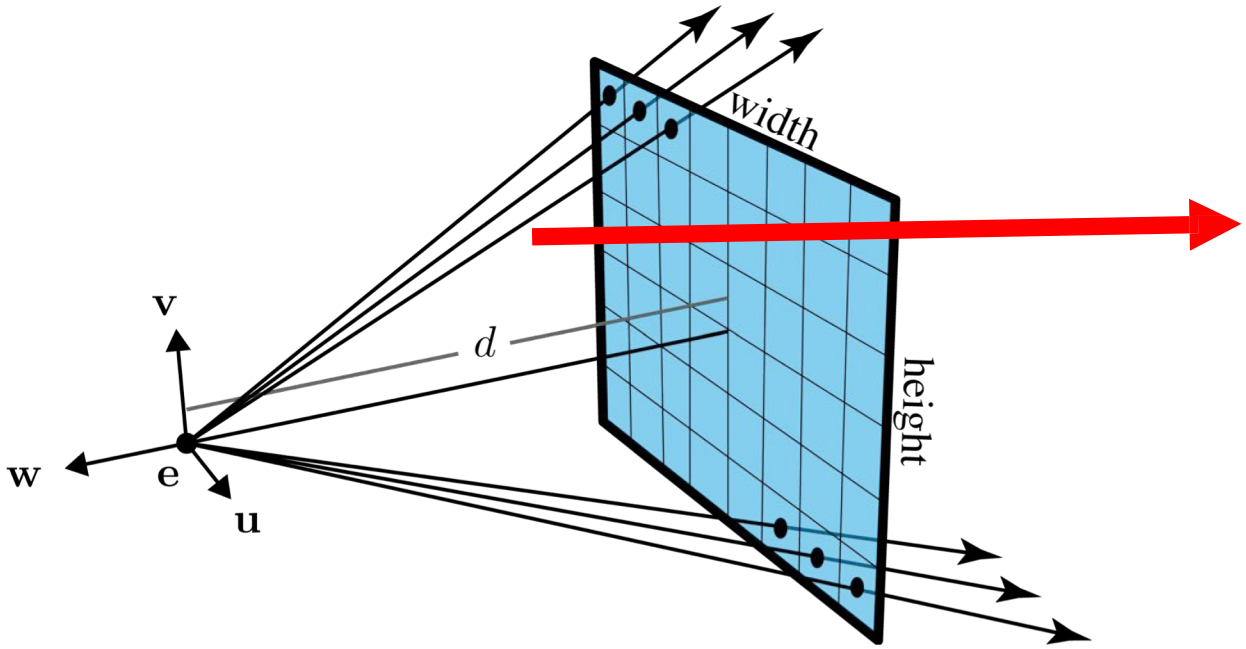
Num Pixels X

Physical Height of Image in 3D Space

$$v = \frac{\text{height}}{n_y} \cdot \left(j + \frac{1}{2}\right) - \frac{\text{height}}{2}$$

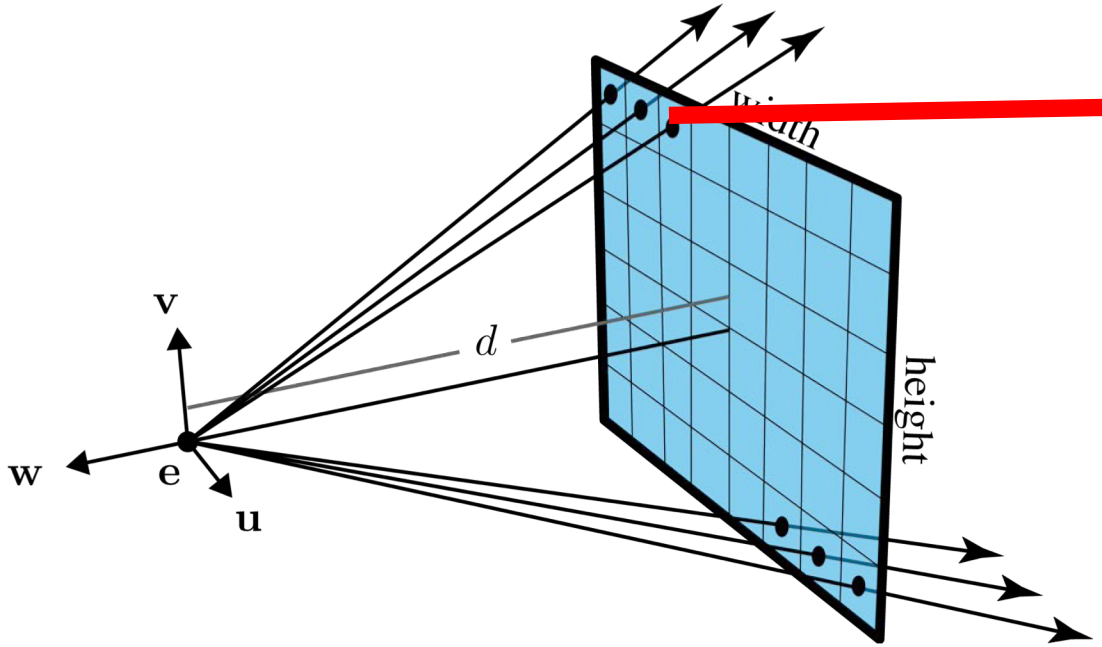
Num Pixels Y

Ray Equation in Camera Space



$$\mathbf{p}(t) = \mathbf{e} + t(\mathbf{s} - \mathbf{e})$$

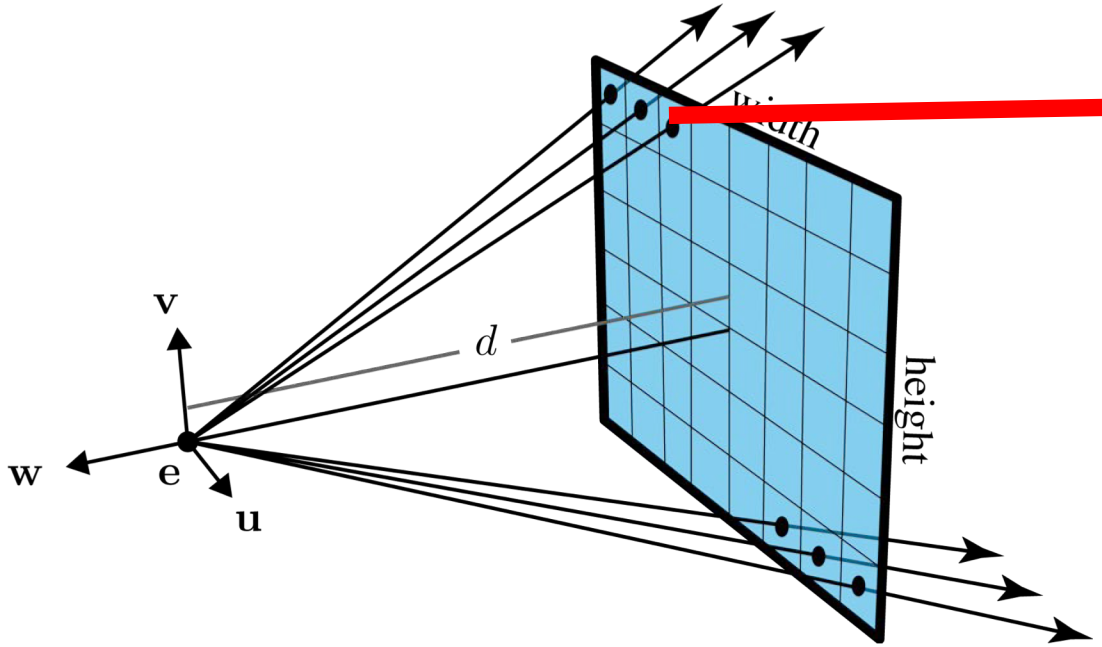
Ray Equation in Camera Space



$$\mathbf{p}(t) = \mathbf{e} + t(\mathbf{s} - \mathbf{e})$$

$$\mathbf{p}(t) = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} + t\left(\begin{bmatrix} u(i) \\ v(j) \\ -d \end{bmatrix} - \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}\right)$$

Ray Equation in Camera Space



$$\mathbf{p}(t) = \mathbf{e} + t(\mathbf{s} - \mathbf{e})$$

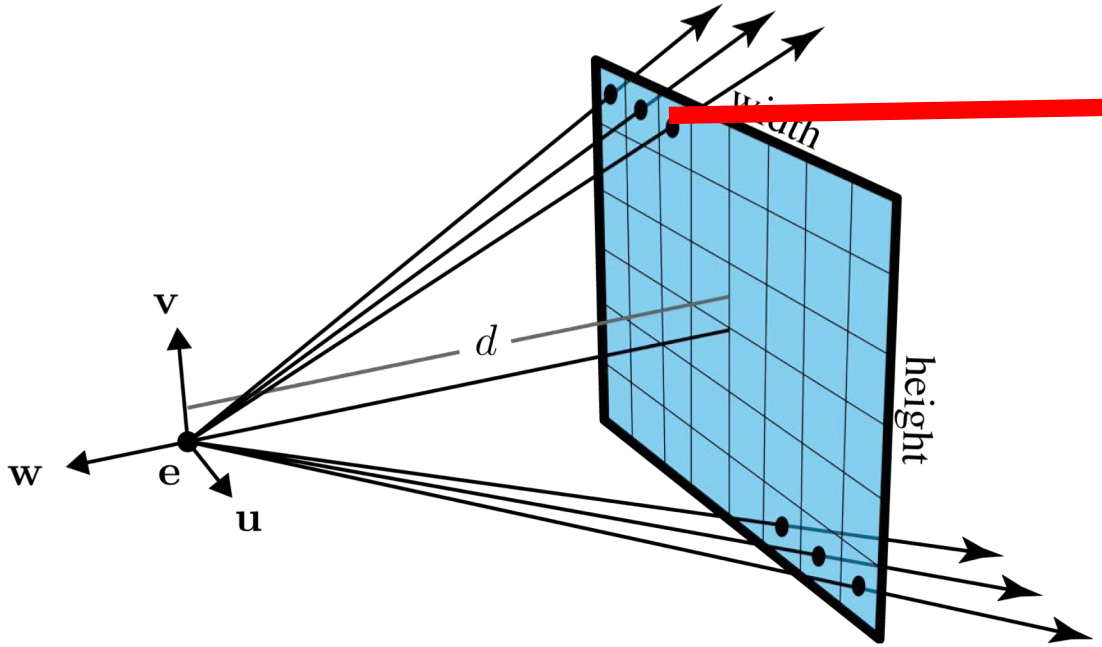
$$\mathbf{p}(t) = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} + t\left(\begin{bmatrix} u(i) \\ v(j) \\ -d \end{bmatrix} - \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}\right)$$

$$\mathbf{p}(t) = t \begin{bmatrix} u(i) \\ v(j) \\ -d \end{bmatrix}$$

$$u = \frac{\text{width}}{n_x} \cdot \left(i + \frac{1}{2}\right) - \frac{\text{width}}{2}$$

$$v = \frac{\text{height}}{n_y} \cdot \left(j + \frac{1}{2}\right) - \frac{\text{height}}{2}$$

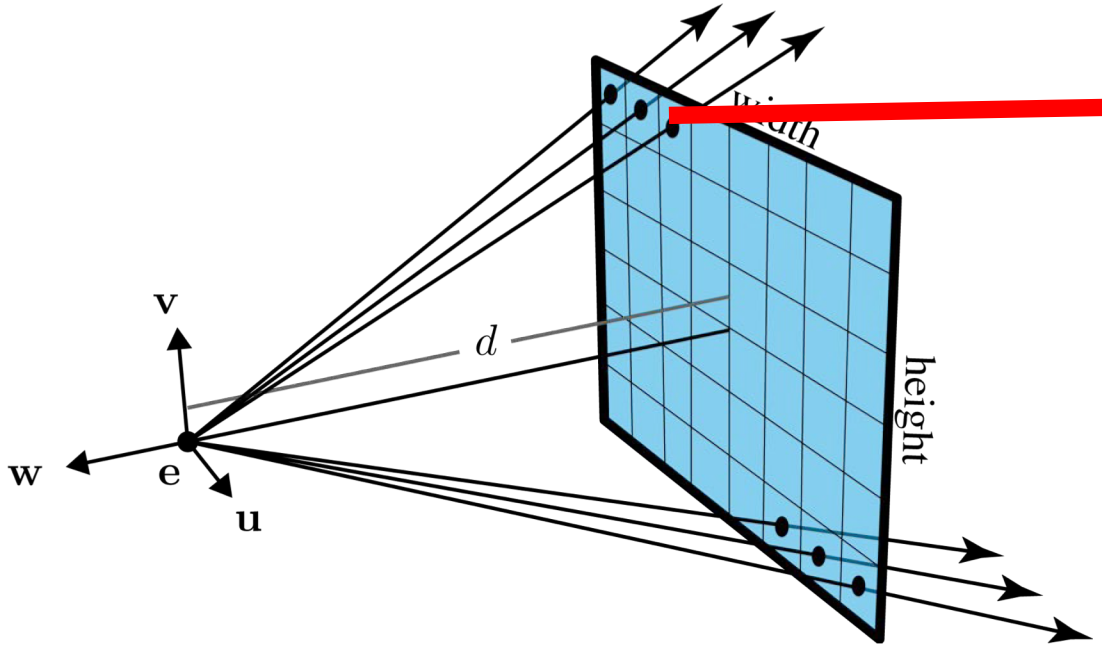
Ray Equation in World Space



$$\mathbf{p}(t) = \mathbf{e} + t(\mathbf{s} - \mathbf{e})$$

$$\mathbf{p}(t) = \mathbf{e} + t\left(u(i)\mathbf{u} + v(j)\mathbf{v} + -d\mathbf{w}\right)$$

Ray Equation in World Space



$$\mathbf{p}(t) = \mathbf{e} + t(\mathbf{s} - \mathbf{e})$$

$$\mathbf{p}(t) = \mathbf{e} + t \begin{bmatrix} \mathbf{u} & \mathbf{v} & \mathbf{w} \end{bmatrix} \begin{bmatrix} u(i) \\ v(j) \\ -d \end{bmatrix}$$

Camera Transformation Matrix

Ray Casting

```
for each pixel in the image {
    Generate a ray
    for each object in the scene {
        if (Intersect ray with
            object){  Set pixel
            colour
        }
    }
}
```

Next class

Ray Intersections