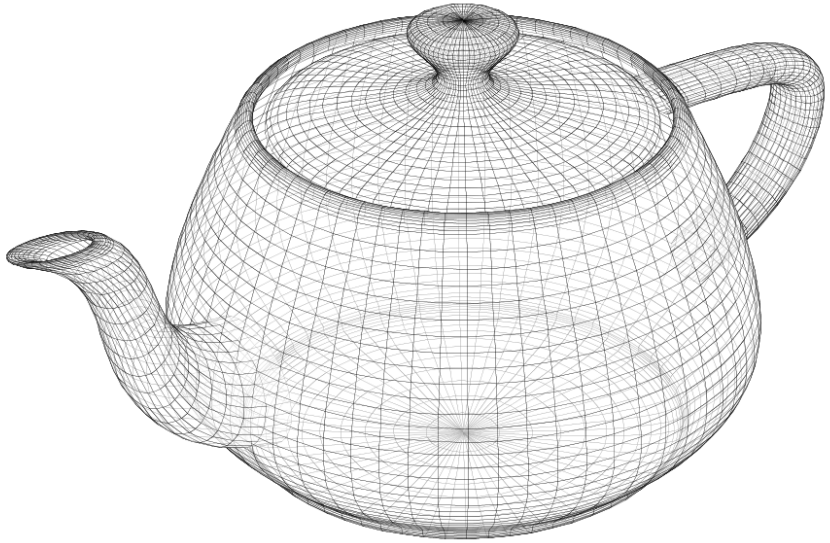


Basic Ray Tracing

Production Computer Graphics

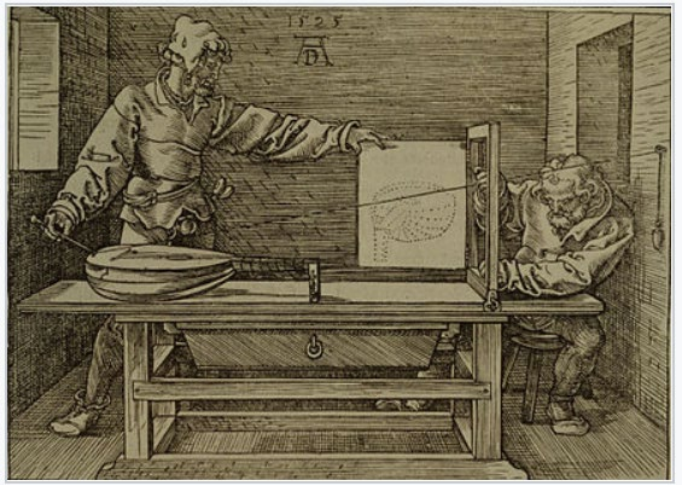
Professor Eric Shaffer

ILLINOIS

Our Model of Light Rays

Three key ideas about light rays

- Light travels in straight lines
- Light rays do not interfere with each other if they cross
- Light rays travel from light sources to the eye
  - ***but the physics is invariant under path reversal (reciprocity)***

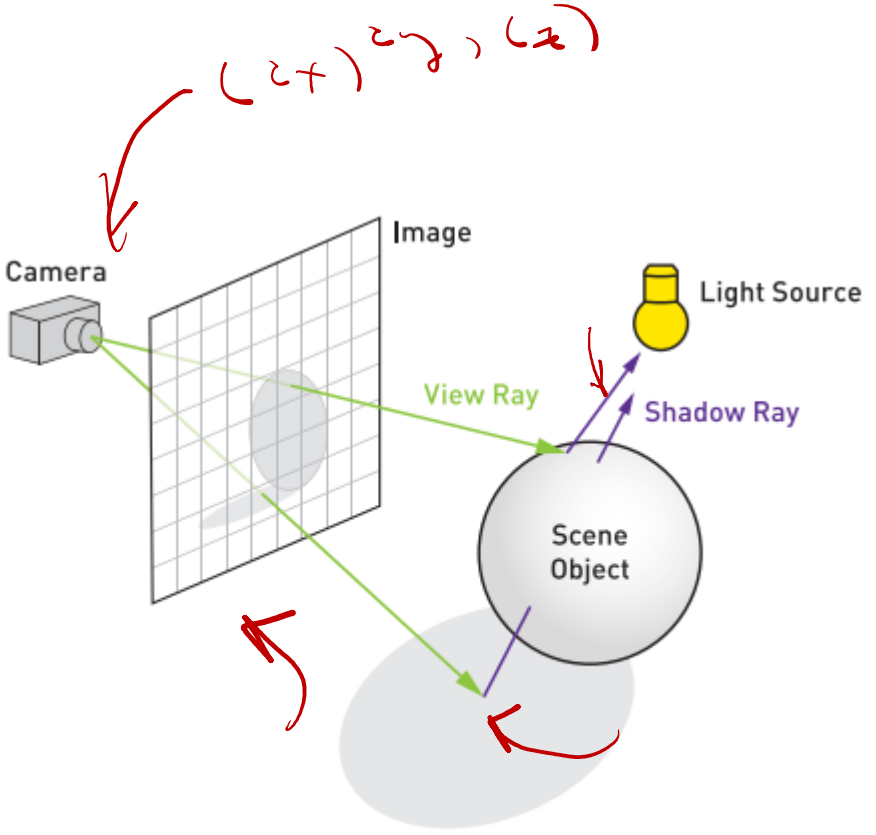


This woodcut by Albrecht Dürer from 1525 shows the use of a Dürer's door.

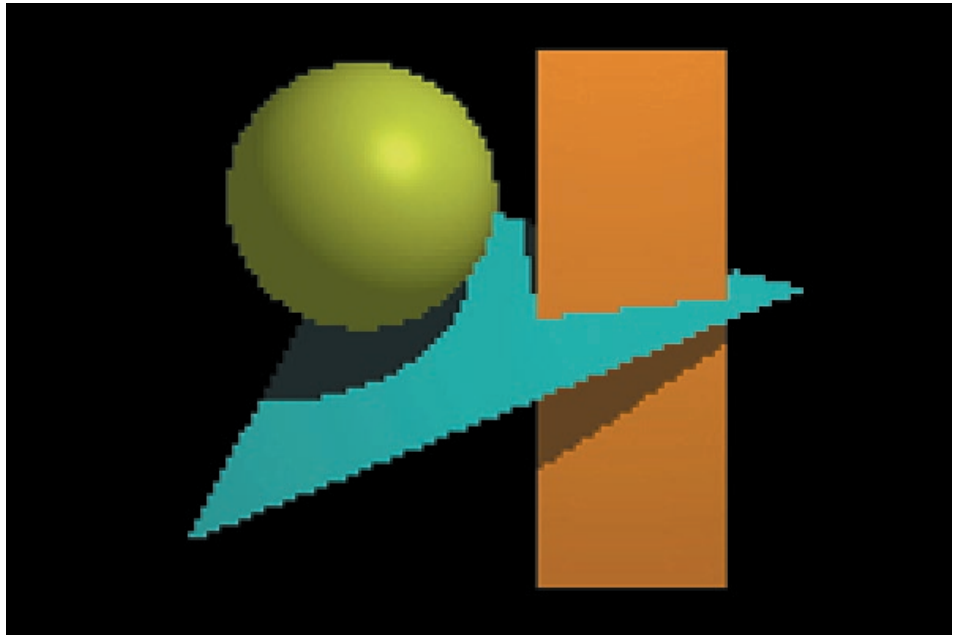
Why is reciprocity important to us computationally?

ILLINOIS

Ray Tracing



Resolution

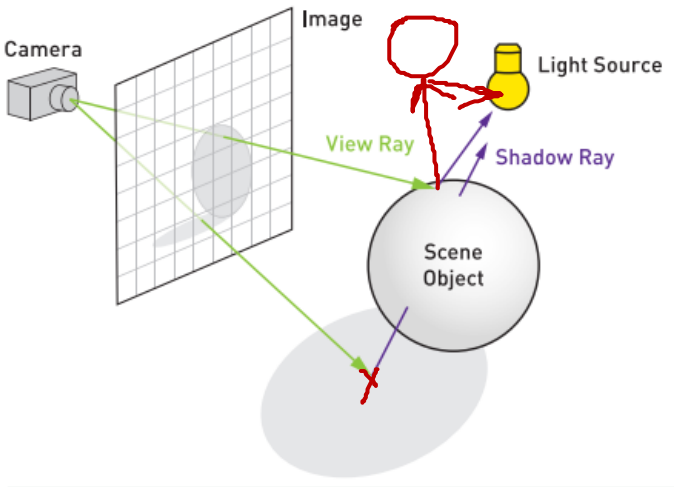


Ray Tracing – basic algorithm

1. define some objects
2. specify a material for each object
3. define some light sources
4. define window that consists of a grid of pixels (the view plane)
5. for each pixel
6. construct a ray through the pixel
7. compute the intersection of the ray with each object
8. find the intersection (if any) closest to the view plane
9. if there was an intersection
10. use lights and material to compute the pixel color
11. else
12. pixel is set to background color

Well…actually we're ray-casting

- We can also cast some other rays to achieve other effects
  - That's when we are able to say we ray-tracing
- Types of rays:
  - Primary rays – rays shot from pixel (or eyepoint) into the world
  - Secondary rays
  - Shadow rays
  - Light rays



Orthographic ray-tracing

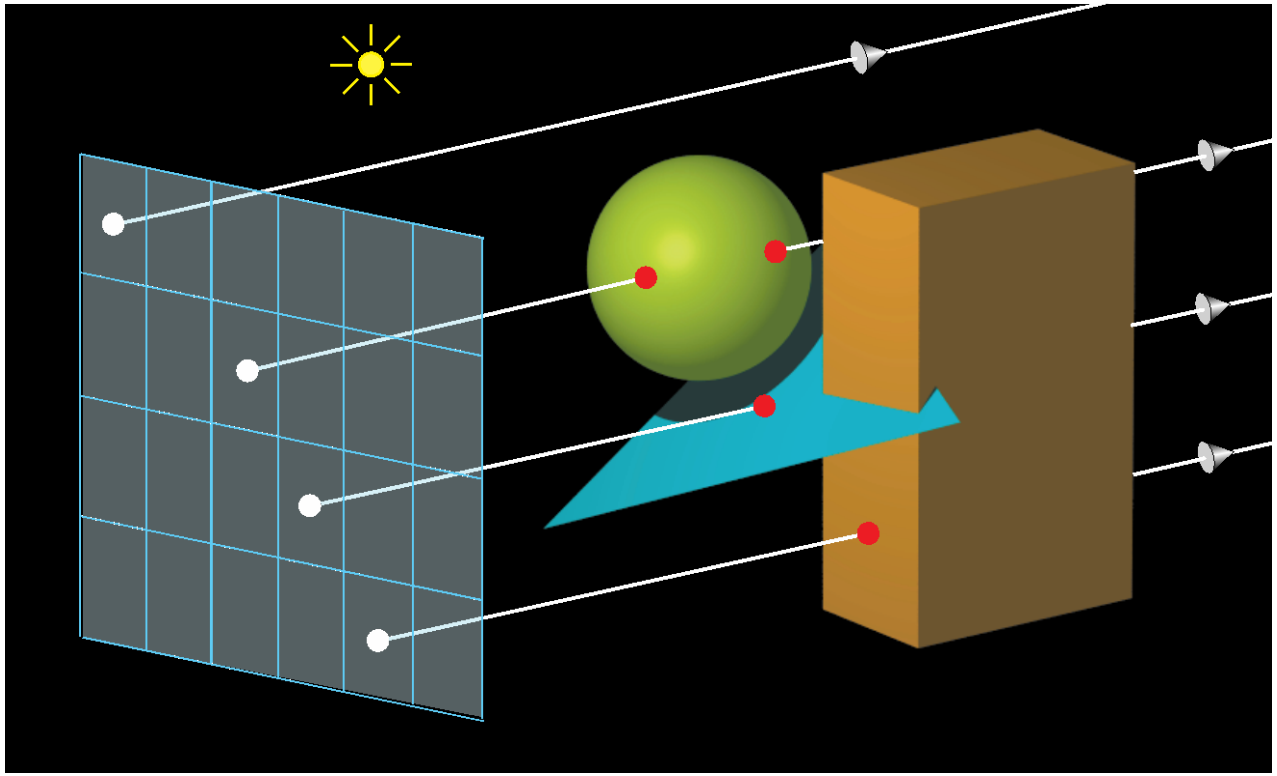
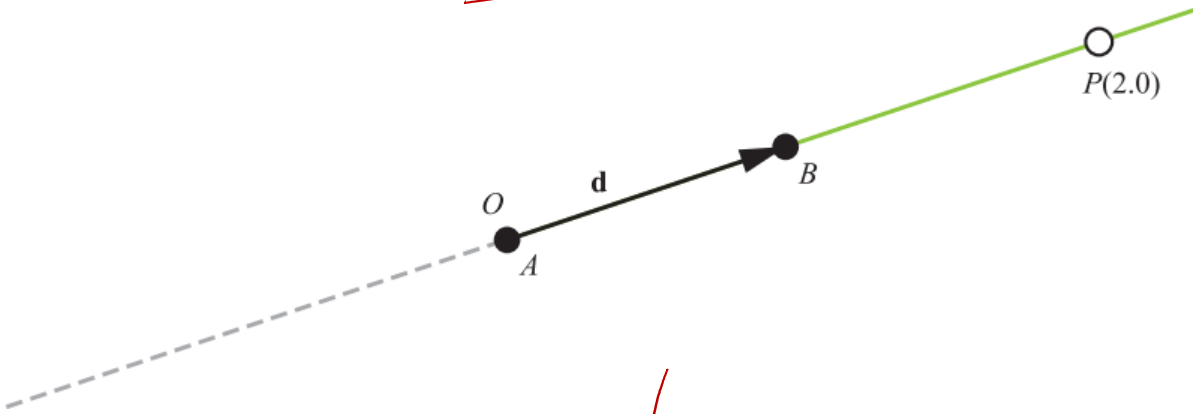


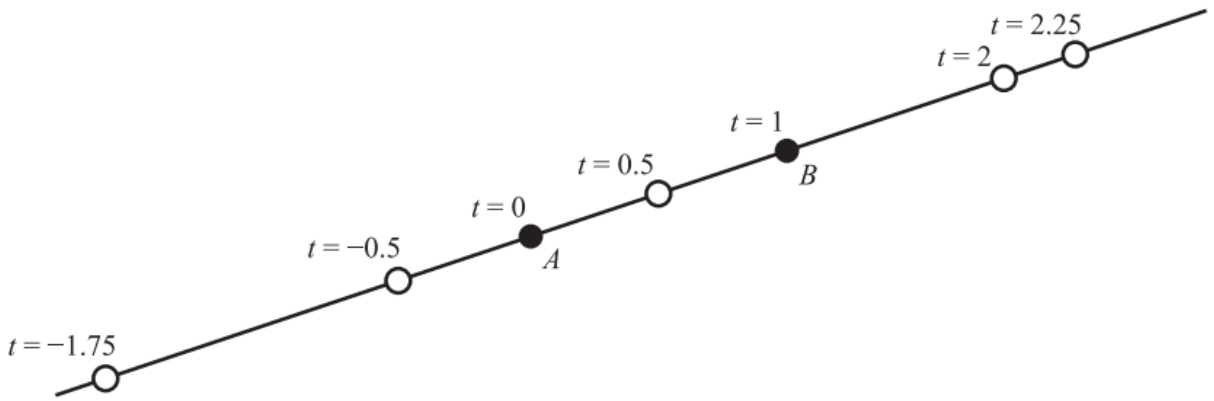
Figure from *Ray Tracing from the Ground Up* by Kevin Suffern

ILLINOIS

Rays

$$P(t) = O + t\mathbf{d}.$$





P(t) is a point on the ray
O is a point that is the origin of the ray
t is a scalar parameter…representing "time"
d is unit vector giving the direction of the ray

$d = B - A$

Orthographic ray-tracing

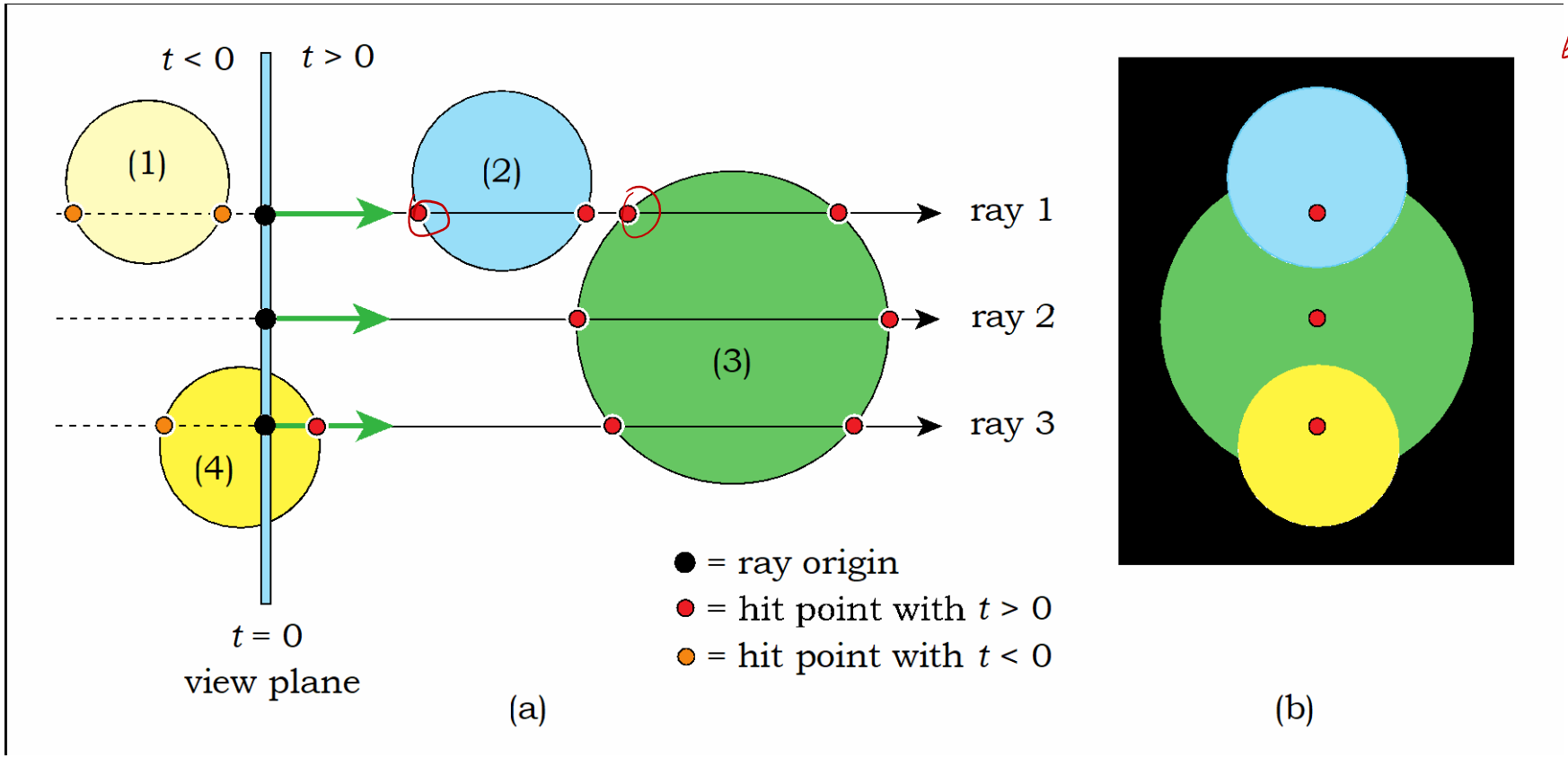


Figure from *Ray Tracing from the Ground Up* by Kevin Suffern

Computing Pixel Coordinates

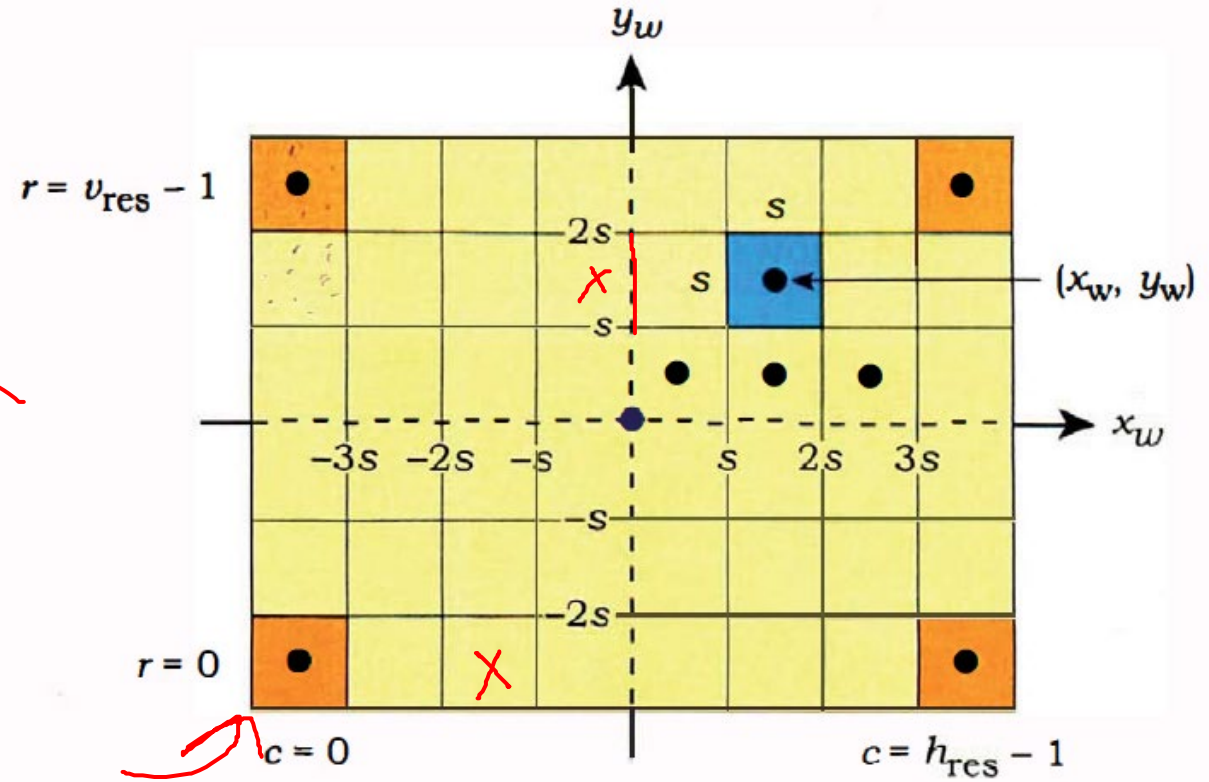
pixel extent

$$x_w = s(c - h_{res}/2 + 0.5)$$

$$y_w = s(r - v_{res}/2 + 0.5)$$

$Z_w = 0$

(c, r)



ILLINOIS

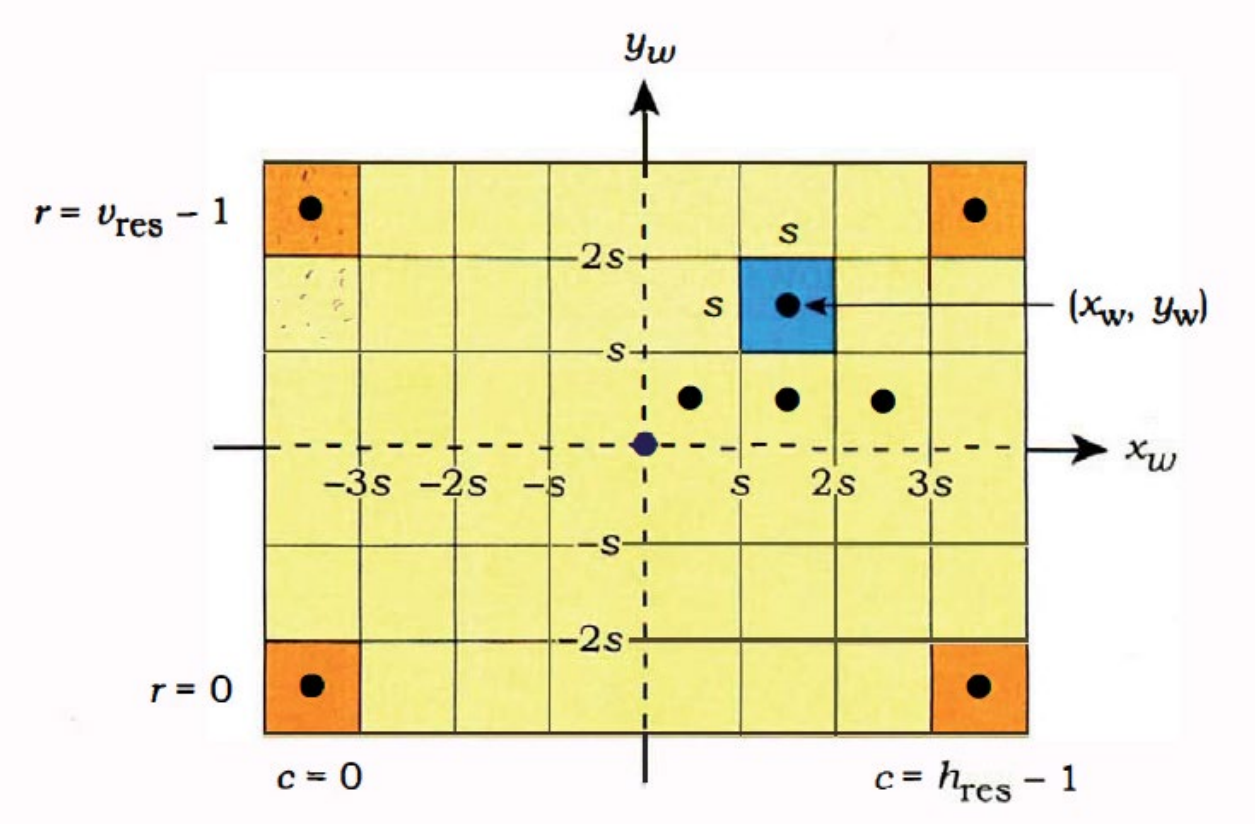
Constructing a Ray (Orthographic)

$$x_w = s(c - h_{res}/2 + 0.5)$$

$$y_w = s(r - v_{res}/2 + 0.5)$$

$O = (x_w, y_w, z_w)$

$d = (0, 0, -1)$



ILLINOIS

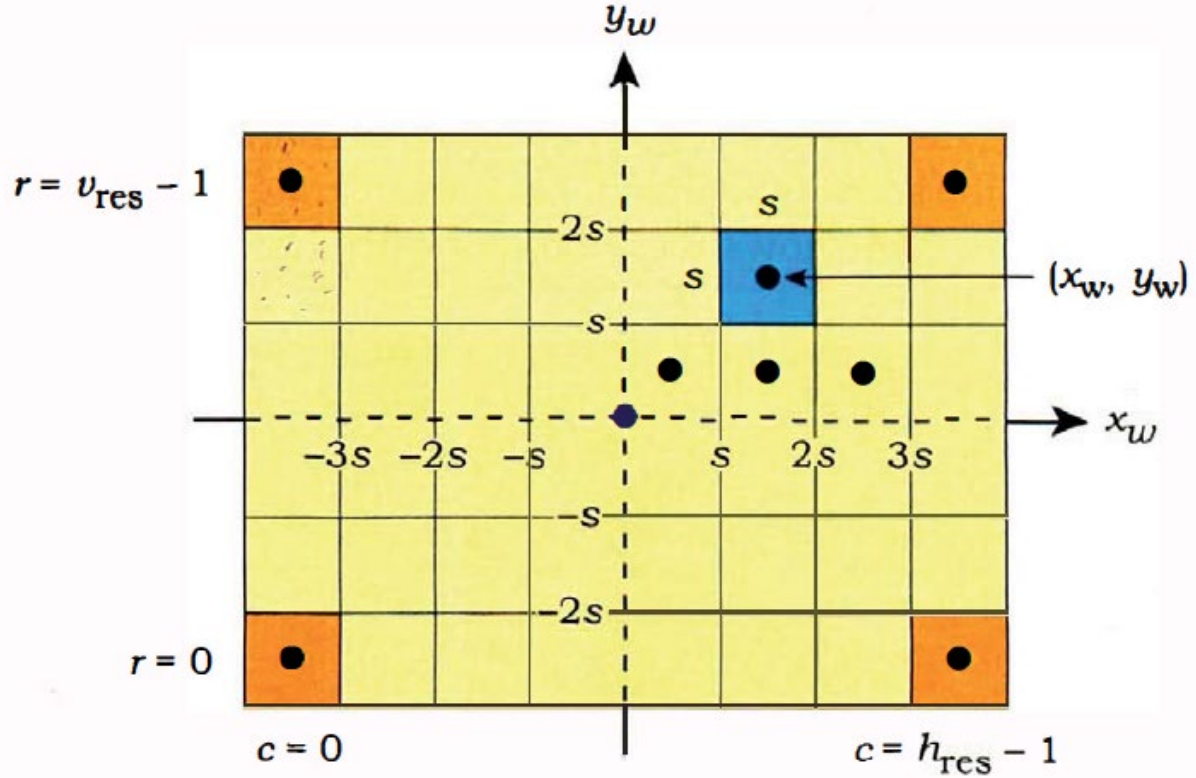
Constructing a Ray (Perspective)

$$x_w = s(c - h_{res}/2 + 0.5)$$

$$y_w = s(r - v_{res}/2 + 0.5)$$

$O = e = (e_x, e_y, e_z)$

$d = (x_w, y_w, z_w) - e$



Intersecting Rays and Implicit Surfaces

We can intersect an implicit surface with a ray

Just find the point p on the ray that satisfies the equation for the implicit surface

$$f(x,y,z)=0$$

$$f(p)=0$$

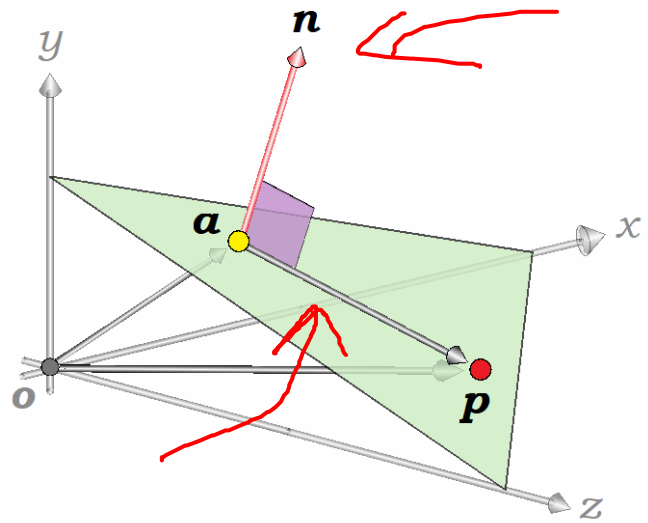
$$f(o+td)=0$$

For now, we'll just focus on planes ….

Plane Equation

$$Ax + By + Cz + D = 0$$

$$(p - a) \cdot n = 0$$



Here *a* is a point on the plane and *n* is the normal

All points *p* that satisfy the equation form the plane

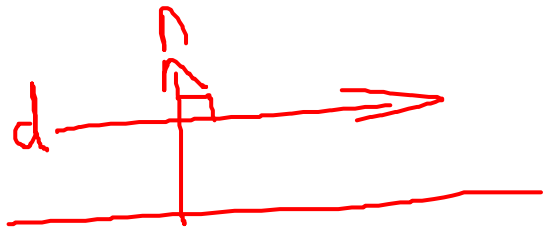
Ray-Plane Intersection

Use the plane equation with normal ***n*** and point on the plane ***a***
Solve for t…that value generates a point on both the plane and ray

$$(p - a) \cdot n = 0$$

$$(o + td - a) \cdot n = 0$$

$$t = ((a - o) \cdot n)/(d \cdot n)$$



What happens if d is parallel to the plane?

How do you know if the hit happens in front or behind the view plane?

ILLINOIS