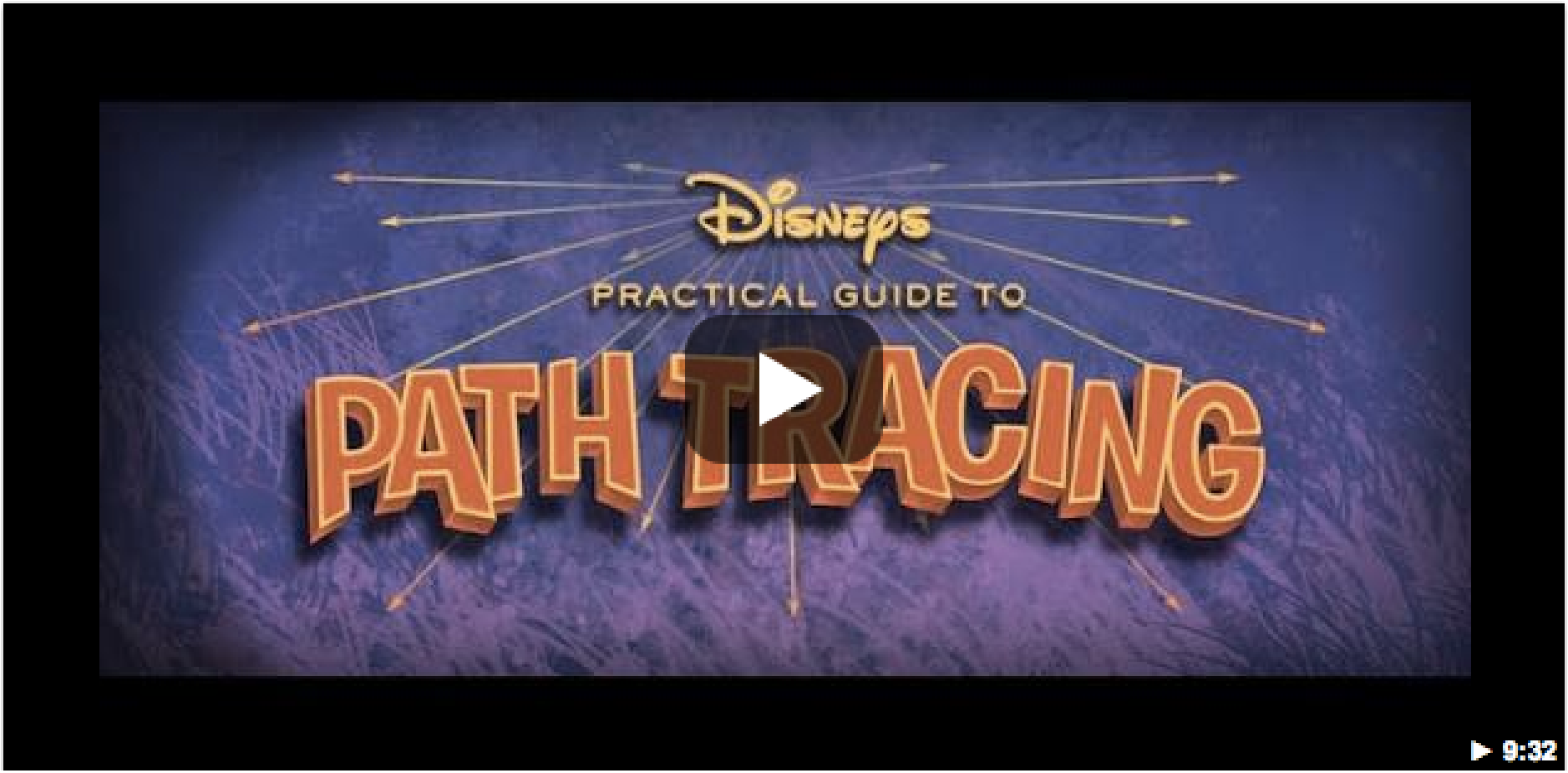
Ray Tracing Basics

COSC342

Lecture 11
4 April 2017

Ray/Path Tracing Summary



Ray Tracing Algorithm

J. Turner Whitted, *An improved illumination model for shaded display*

- Set up a camera – a projection point and an image plane
- For each pixel in the plane:
  - Cast a ray from the projection point through the pixel
  - Determine the first object hit by that ray
  - Cast additional ray(s) to determine lighting
  - Additional rays can be used for reflection, refraction, etc.

Various refinements lead towards *path tracing*

- Multiple rays per pixel – average or accumulate results
- Repeated reflections for indirect lighting
- More accurate surface reflection models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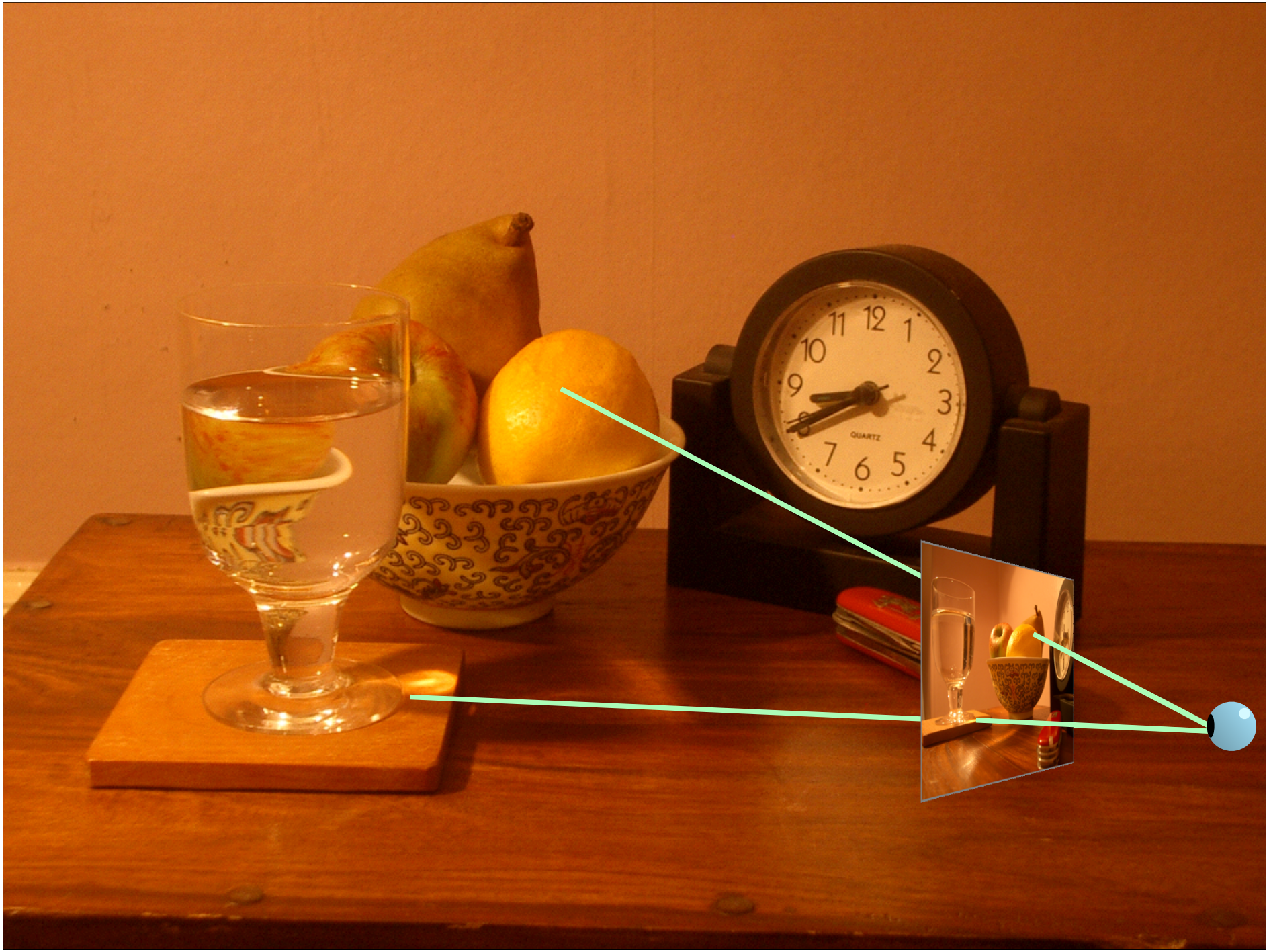
QUARTZ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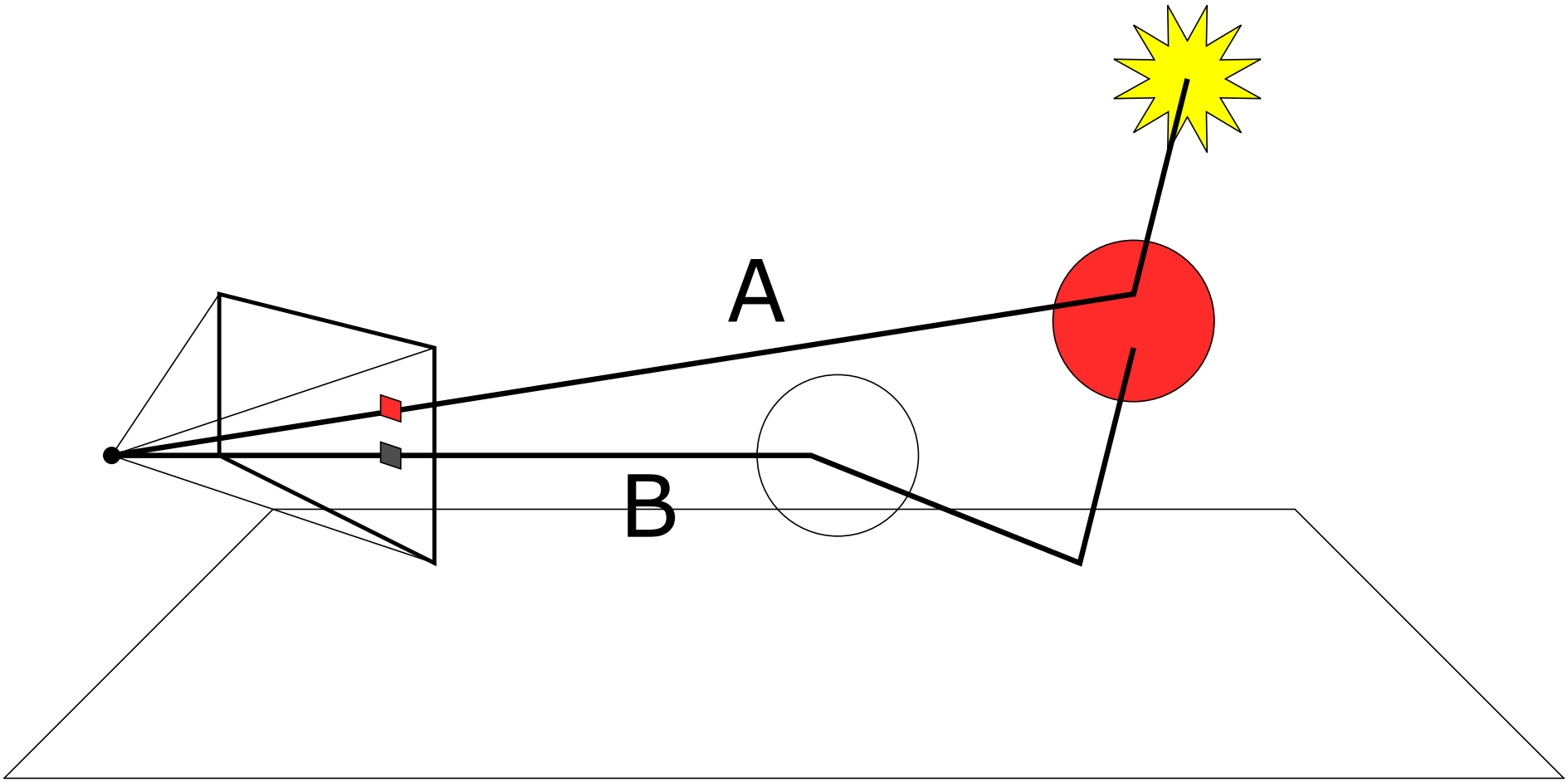
QUARTZ

A Simpler Example...



What Happens to the Rays?

Ray A is the 'typical' case

- The ray hits the coloured sphere
- A secondary ray is cast towards the light
- That secondary ray doesn't hit anything, so there is no shadow
- The colour of the hit point on the sphere is used for the pixel

Ray B is more complicated

- The ray hits a glass sphere which bends the ray, so a new ray is cast
- The ray bends again as it leaves the sphere, then hits the ground plane
- A ray is then cast to check for shadows
- This hits the coloured sphere so the point is in shadow
- The pixel is, therefore, black (should it be?)

Ray Tracing Basics, the Primary Ray

The *primary ray* for each pixel

- Starts at the camera center, $\mathbf{c}$
- Goes through the *middle* of the pixel

We make some simplifying assumptions

- The camera is at the origin, looking along $+Z$
- The (image) U and V axes are aligned with the (world) X and Y axes
- The image plane is two 'world units' wide
- We are given a focal length, f, and a rendered image size, $w \times h$
- Our pixels are given integer co-ordinates (u, v) starting from $(0, 0)$

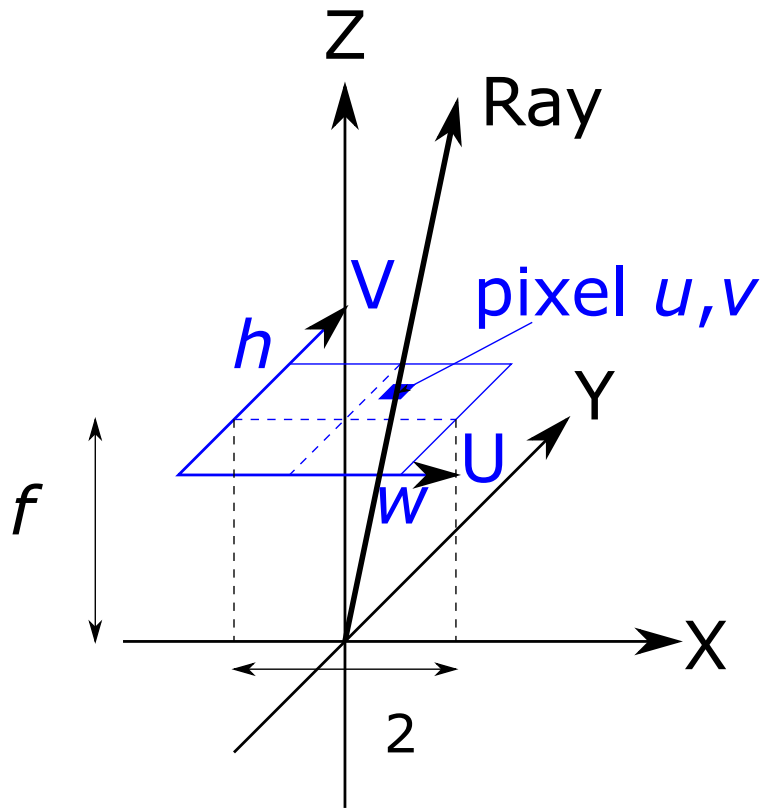
The Primary Ray

The ray is defined by two points

- The camera centre, $[0, 0, 0]^{\mathsf{T}}$
- The centre of the pixel (u, v)

Pixel/image co-ords are (U, V)

- Need world (X, Y, Z) co-ords
- Where is the image origin?
- How big is each pixel?



The Primary Ray

Image origin:

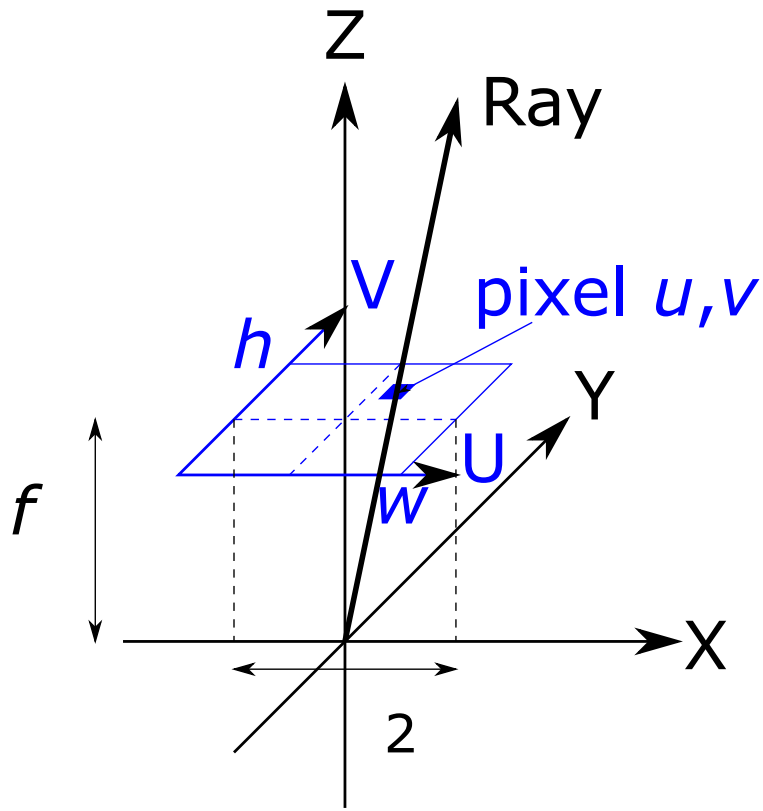
- Z value is focal length, f
- X value is -1
- Y value is $\frac{h}{w}$

Size of each pixel in world units:

- Width of image is 2
- So pixels are $\frac{2}{w}$ on a side

Co-ordinates of pixel (u, v):

$$\left[-1 + u\frac{2}{w}, \frac{-h}{w} + v\frac{2}{w}, f\right]^{\mathsf{T}}$$



The Primary Ray

This is not quite right, we should use:

$$\left[-1+\left(u+\frac{1}{2}\right)\frac{2}{w}, \frac{-h}{w}+\left(v+\frac{1}{2}\right)\frac{2}{w}, f\right]^{\mathsf{T}}$$

Where did the extra $\frac{1}{2}$s come from?

The primary ray is now given (in homogeneous form) by

$$\begin{bmatrix}0\\0\\0\\1\end{bmatrix}+\lambda\begin{bmatrix}-1+\left(u+\frac{1}{2}\right)\frac{2}{w}\\ \frac{-h}{w}+\left(v+\frac{1}{2}\right)\frac{2}{w}\\ f\\ 0\end{bmatrix}$$