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COMP9517: Co _ sion

Image Formation

Image Formation

- « Image formation occurs when a **sensor** registers **radiation** that has interacted with **physical objects** » Ballard & Brown

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scene

Geometry of image formation

Mapping **world coordinates to image coordinates**

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- Pinhole camera

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- Projective geometry

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- Projection matrix

Image formation

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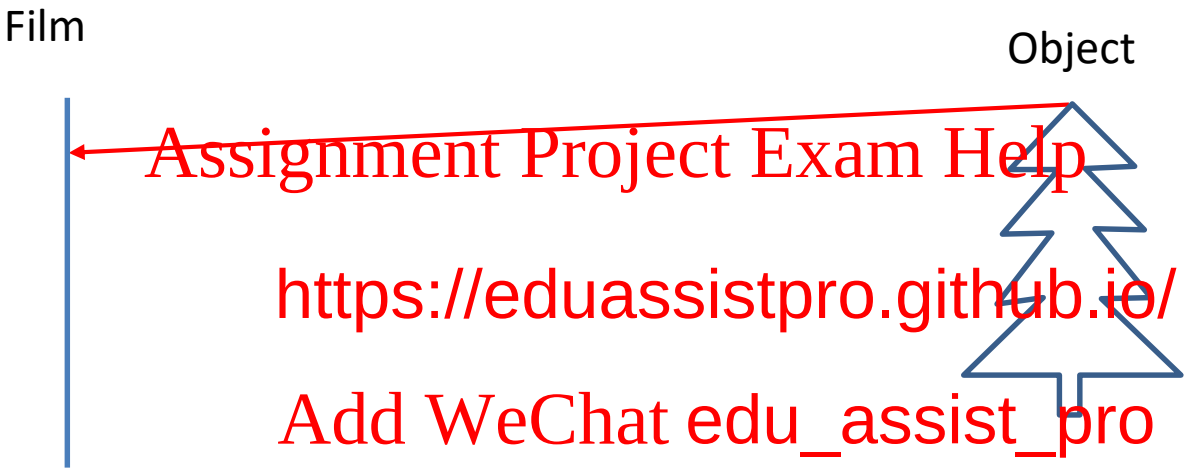
Idea 1: Put a piece of film in front of an object

Do we get a reasonable image?

Image formation



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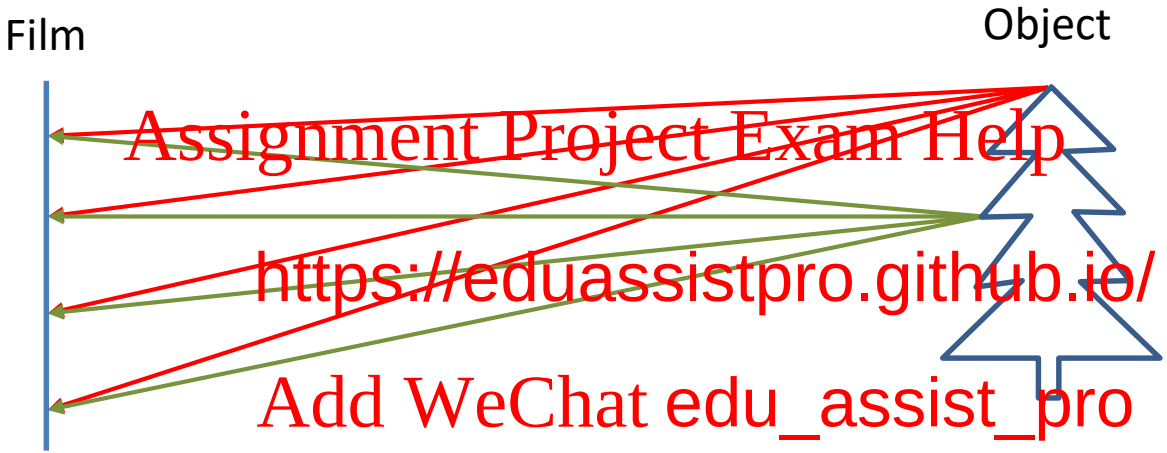

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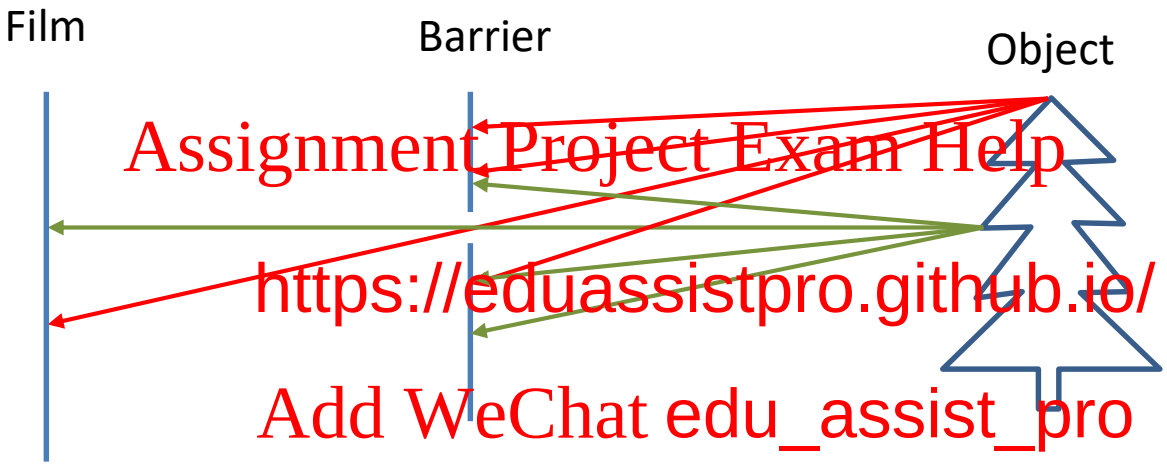

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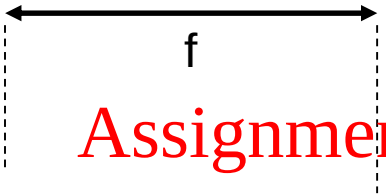
Idea 2: Add a barrier to block off most of the rays

This reduces blurring significantly

Opening known as the **pinhole** or **aperture**

Pinhole camera model



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f = focal length
c = centre of the camera

Figure from Forsyth

Dimensionality reduction machine

3D world

2D image

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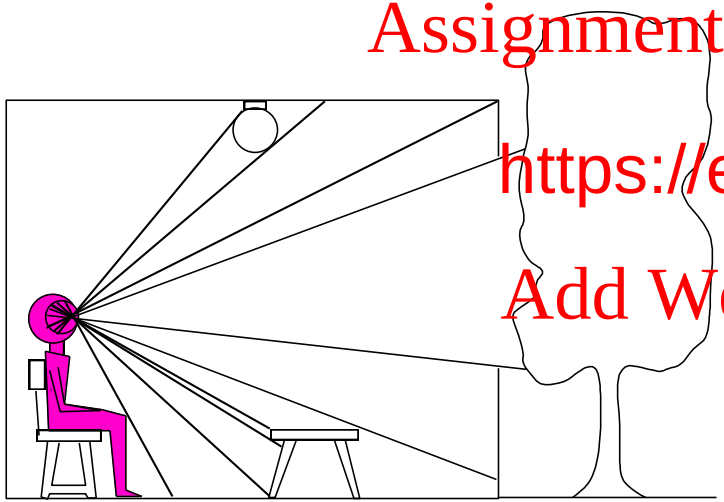

Point of o

bservation

Projection can be tricky…

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Projection can be tricky…

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Projective geometry

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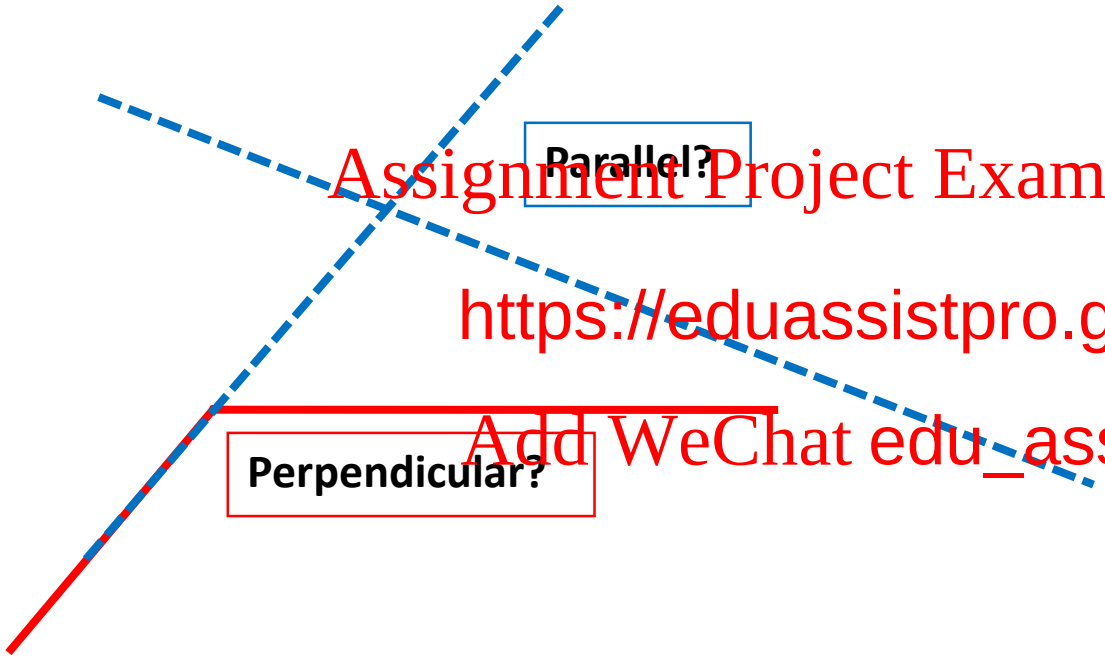
Length and area are not preserved

Figure from Forsyth

Projective geometry



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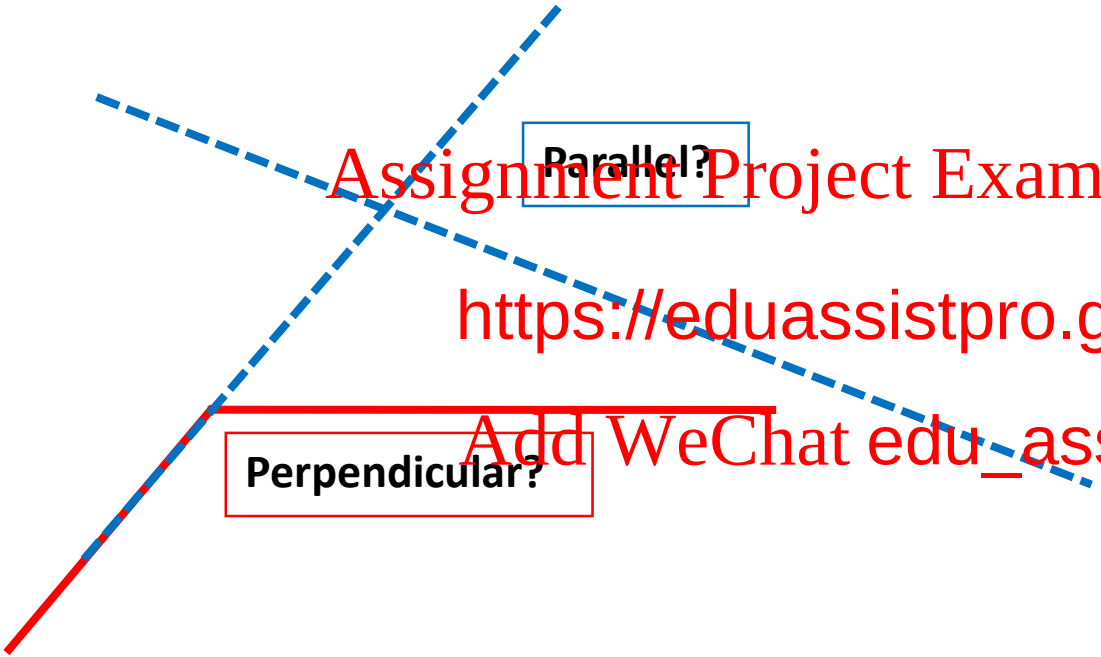
What is lost?

Length and angles are not preserved

Projective geometry



What is preserved?

Straight lines are still straight

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Vanishing points and lines

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es in the world

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the image at a

g point”

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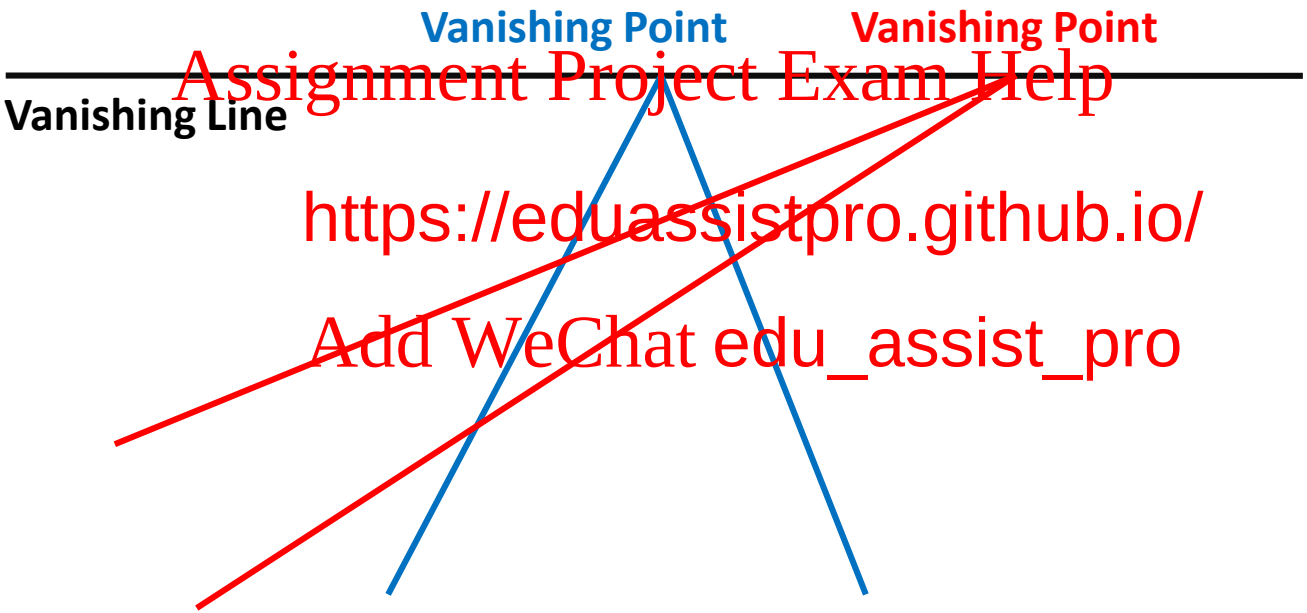
Vanishing points and lines



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Vanishing points and lines

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Slide from Efros, photo from Criminisi

Vanishing points and lines

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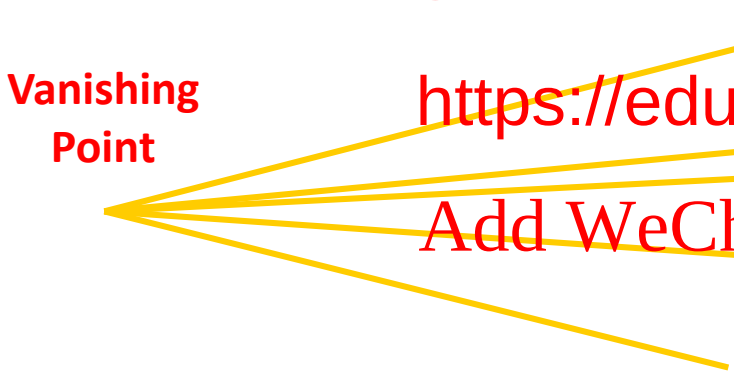

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Vanishing points and lines

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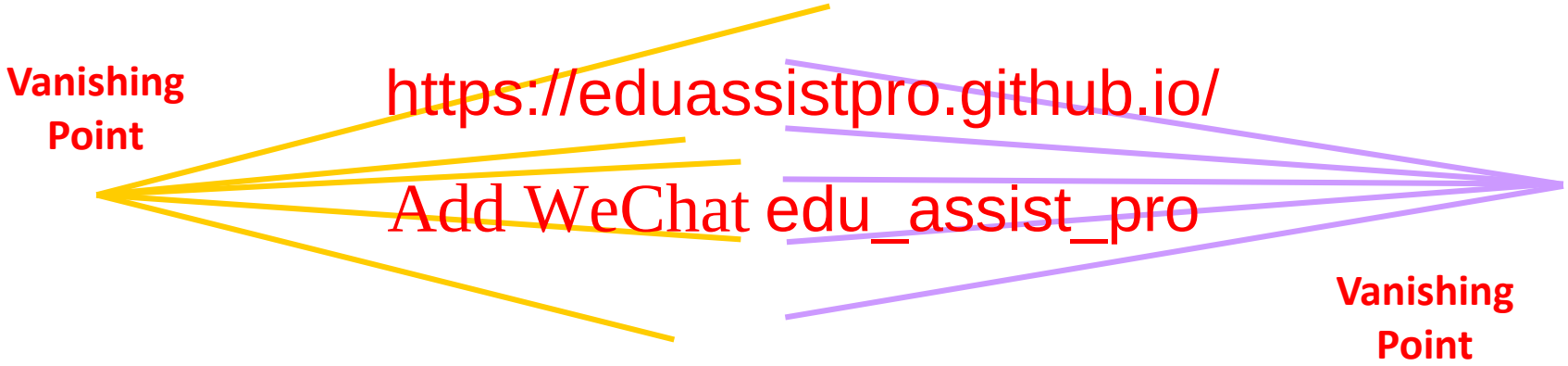

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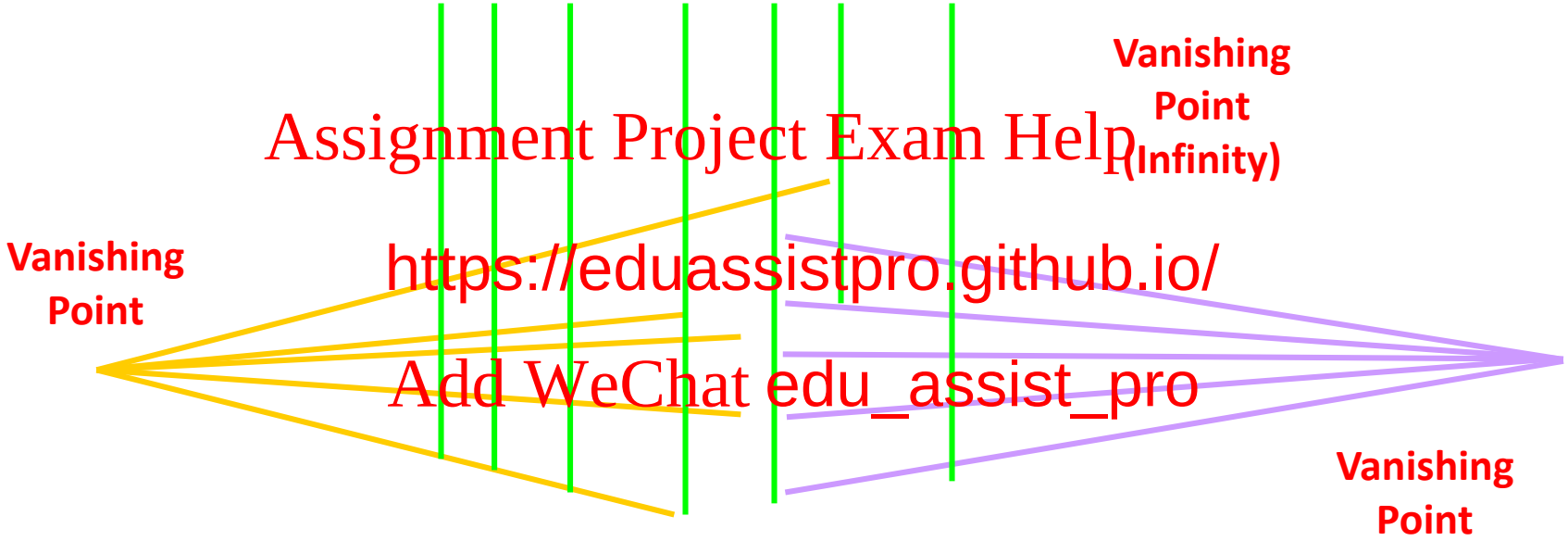
Vanishing points and lines



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Slide from Efros, photo from Criminisi

Projection maths

world coordinates => image coordinates

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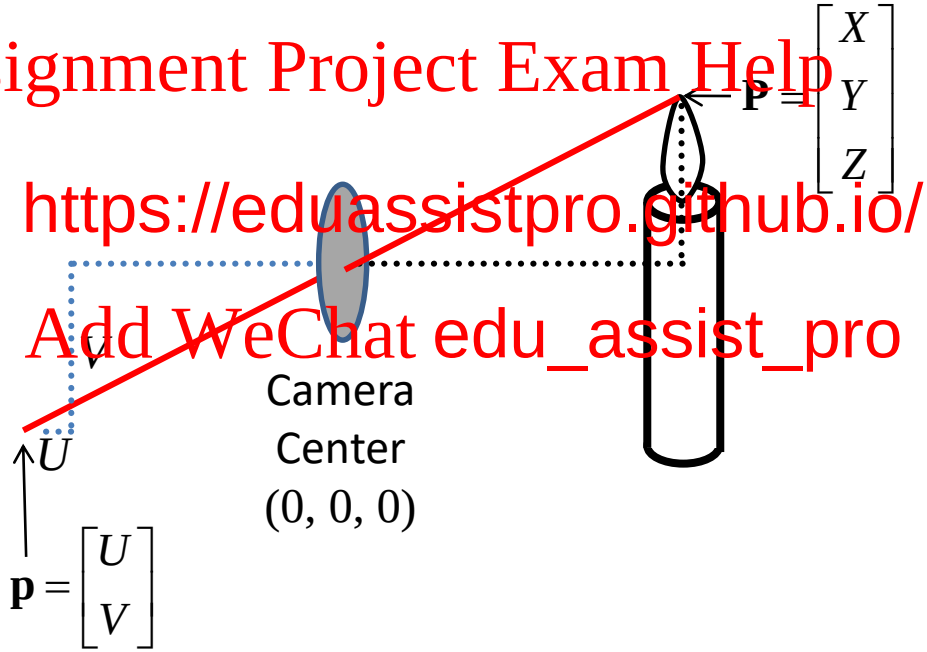

Projection maths

world coordinates => image coordinates

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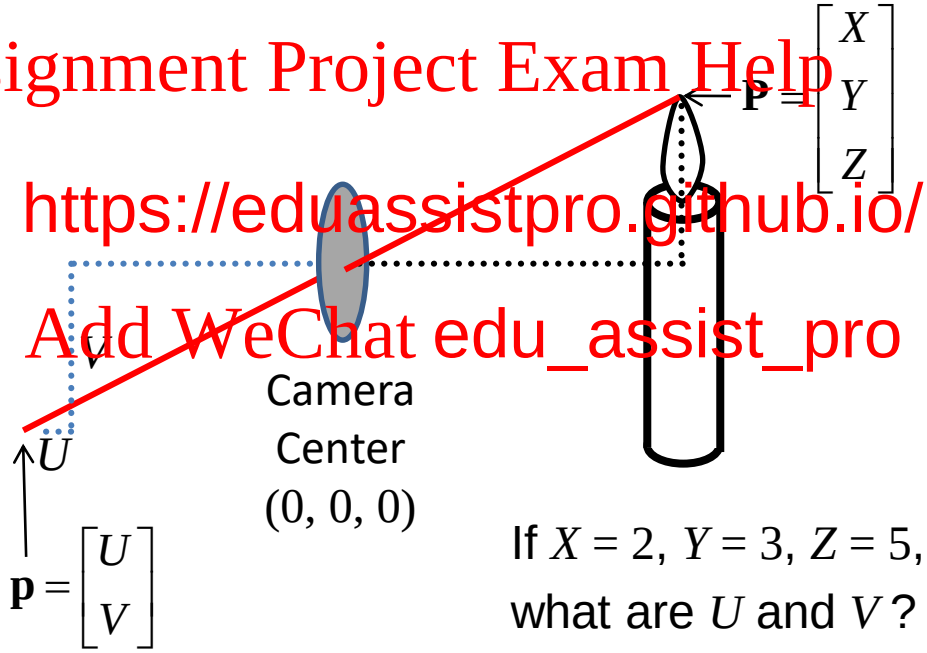

If $X = 2$, $Y = 3$, $Z = 5$, and $f = 2$, what are U and V?

Projection maths

world coordinates => image coordinates

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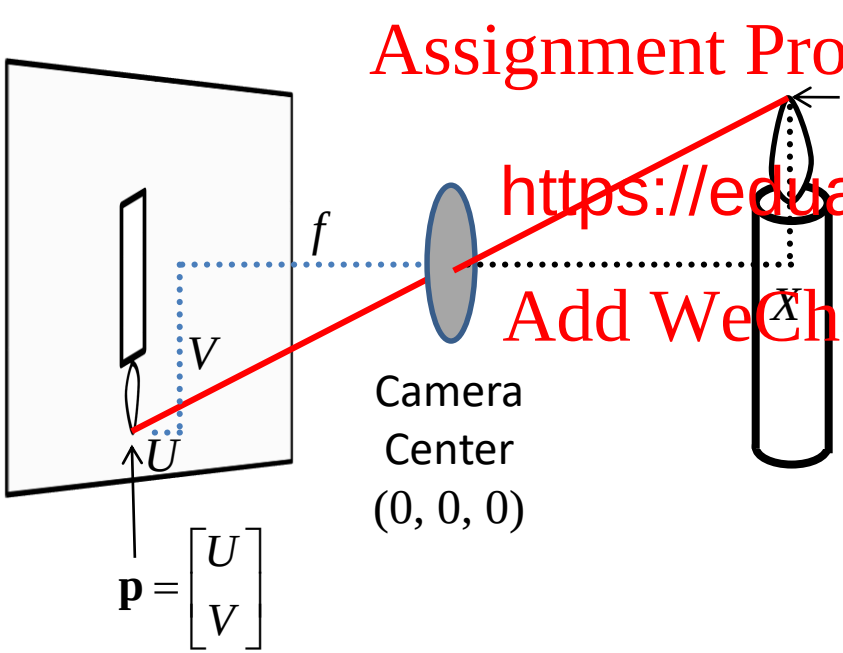

$$U = -X * \frac{f}{Z}$$

$$V = -Y * \frac{f}{Z}$$

Projection maths

world coordinates > image coordinates

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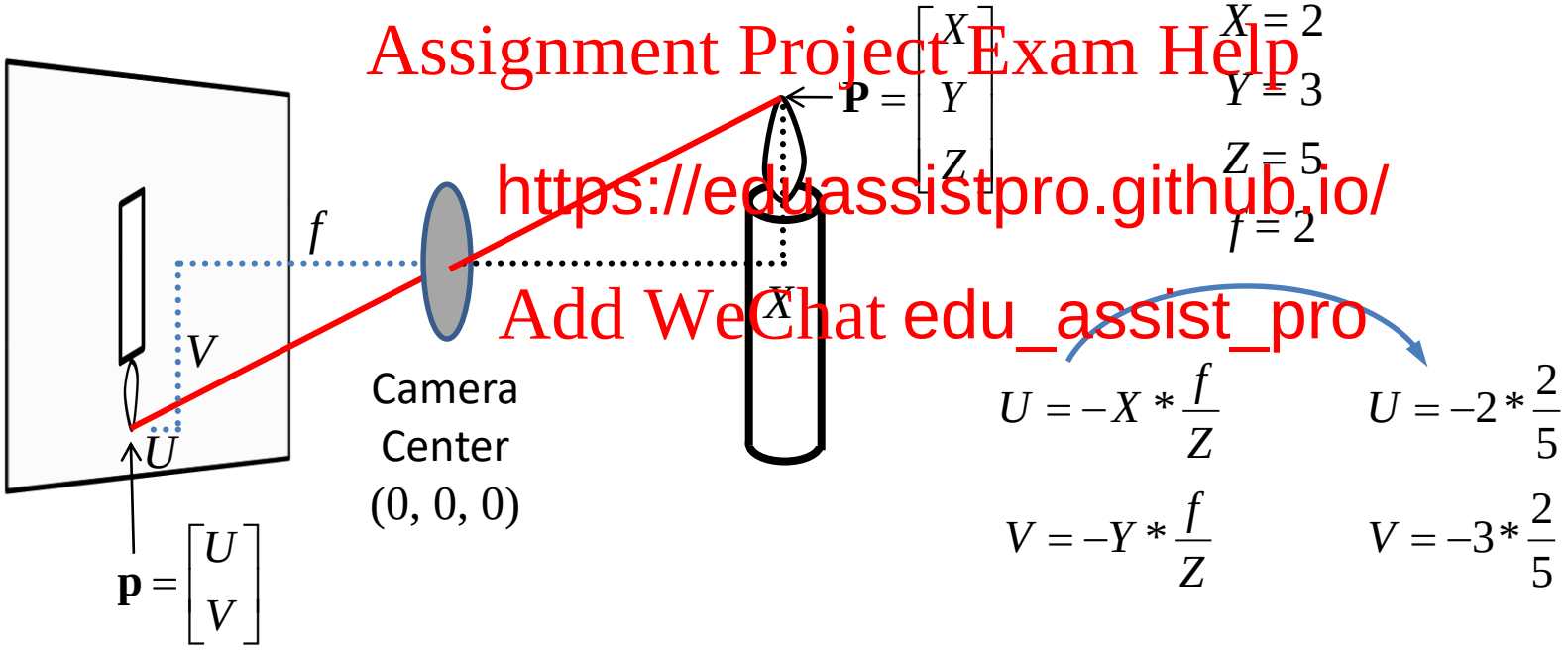

Perspective projection

- Apparent size of object depends on its distance: far objects appe
- By similar triangl

$$(x', y', z') = (f\frac{x}{z}, f\frac{y}{z}, -f)$$

- Ignore the third coordinate

$$(x', y') = (f\frac{x}{z}, f\frac{y}{z})$$

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Affine projection

- Suitable when scene depth is small relative to the average distance from the camera
- Let magnificatio $m = -f'/z_0$ constant, treat all points in the sce z_0 from camera
- Leads to weak perspective proje

$$(x', y') = (-mx, -my)$$

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Affine projection

- Camera always remains at roughly constant distance from the scene
- Orthographic pr ised to 1

$$(x', y') = (x, y)$$

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Beyond pinholes: radial distortions

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Corrected barrel distortion

Image from Martin Habbecke

Comparing with human vision

- Cameras imitate the frequency response of the human eye, so it is good to know som
- Computer vision probably would not get as much attention if biological vision (especially human vision) had not proven that it is possible to make important judgements from 2D images

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The Eye

Electromagnetic spectrum

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https://sites.google.com/site/chempendix/em-spectrum

Normalized responsivity spectra of human cone cells (S, M, L types)

Colour represented by RGB images

Red

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Green

Blue

Colour spaces: RGB

Default colour space

R

(G=0,B=0)

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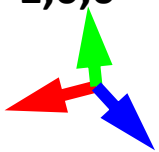
0,1,0

1,0,0

0,0,1



Drawback: strongly correlated channels

G

(R=0,B=0)

B

(R=0,G=0)

Colour spaces: HSV

Intuitive colour space

H

(S=1,V=1)

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S

(H=1,V=1)

V

(H=1,S=0)

Colour spaces: YCbCr

Fast to compute, good for compression, used by TV

Y

(Cb=0.5,Cr=0.5)

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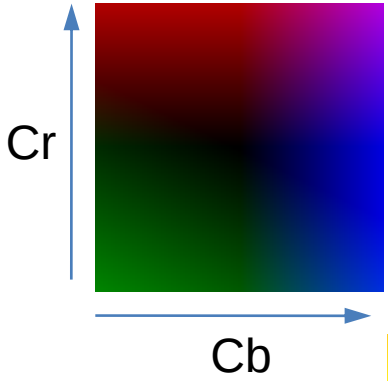
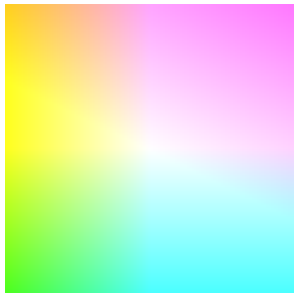


Y=0



Y=1

Cb

(Y=0.5,Cr=0.5)

Cr

(Y=0.5,Cb=0.5)

Colour spaces: L*a*b*

“Perceptually uniform” colour space

L

(a=0,b=0)

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a

(L=65,b=0)

b

(L=65,a=0)

Digital image formation

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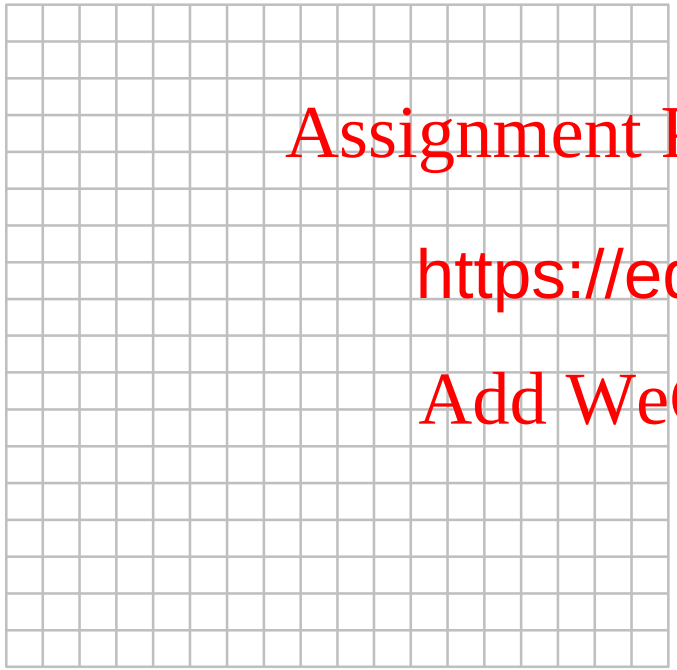
Digital image

Digital image formation



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Digitisation by spatial sampling

- **Digitisation** converts an analog image to a digital image by sampling the image space

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- Sampling digitise

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  - Spatial discretisation of a picture f

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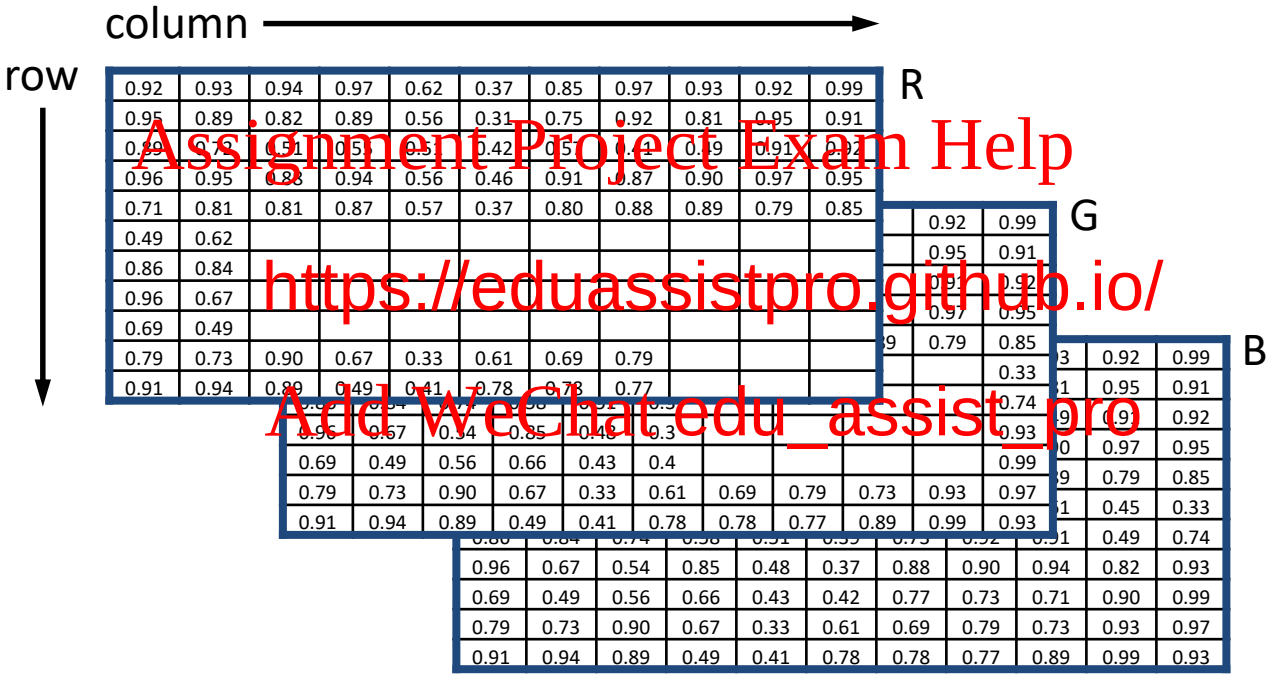
  - Uses a (typically rectangular) grid of sampling points:

    $x = j\Delta x, y = k\Delta y \quad | \quad j = 1...M, k = 1...N$

  - The $\Delta x, \Delta y$ are called the **sampling intervals**

Digital colour images



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Spatial resolution

- Spatial resolution: number of pixels per unit of length
- Example: resolution decreases by one half each time (
- Human faces can be recognized in 64 x 64 pixels images
- Appropriate resolution is essential:
  - Too little resolution, poor recognition
  - Too much resolution, slow and wastes memory

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Quantisation

- Quantisation digitises the intensity or amplitude values $F(x,y)$
  - Called intensity or gray level quantisation
  - Gray-level resolu
    - For example 1
    - Number of levels should be high an perception of shading details… re 100 levels for a realistic image

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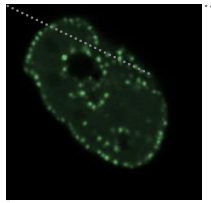
Quantisation and bits/pixel



→ **Pixel** (picture element)

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er pixel:

^{8} = 256

^{2}= 4,096

16 bits = 2^{16} = 65,536

24 bits = 2^{24} = 16,777,216

Further reading

- Chapter 2 of Szeliski
- Chapter 2 of Shapiro and Stockman

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Acknowledgements

- Several slides from Derek Hoiem, Alexei Efros, Steve Seitz, David Forsyth and Erik Meijering
- Image s sible
- Some material, includin tables, were drawn from the re xtbooks and associated online resources

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