

COMS30030 - Image Processing and Computer Vision

www.ole.bris.ac.uk/bbcswedav/courses/COMS30030_2020_TB-1/content



Video Lecture 03

Image Acquisition & Representation

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So what does the human visual system see?

**Or what should an automatic
computer vision system see?**



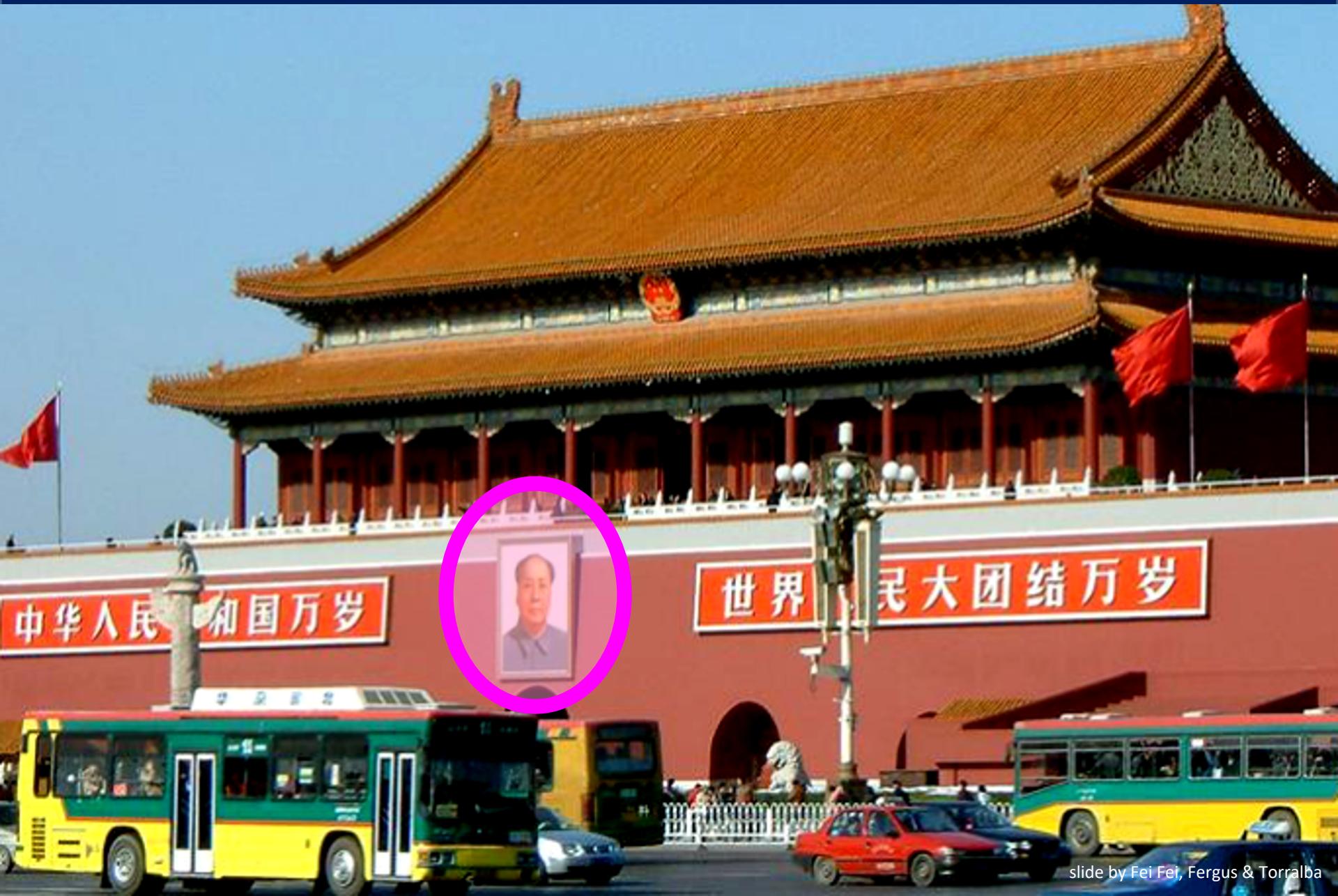
Detection: are there cars?



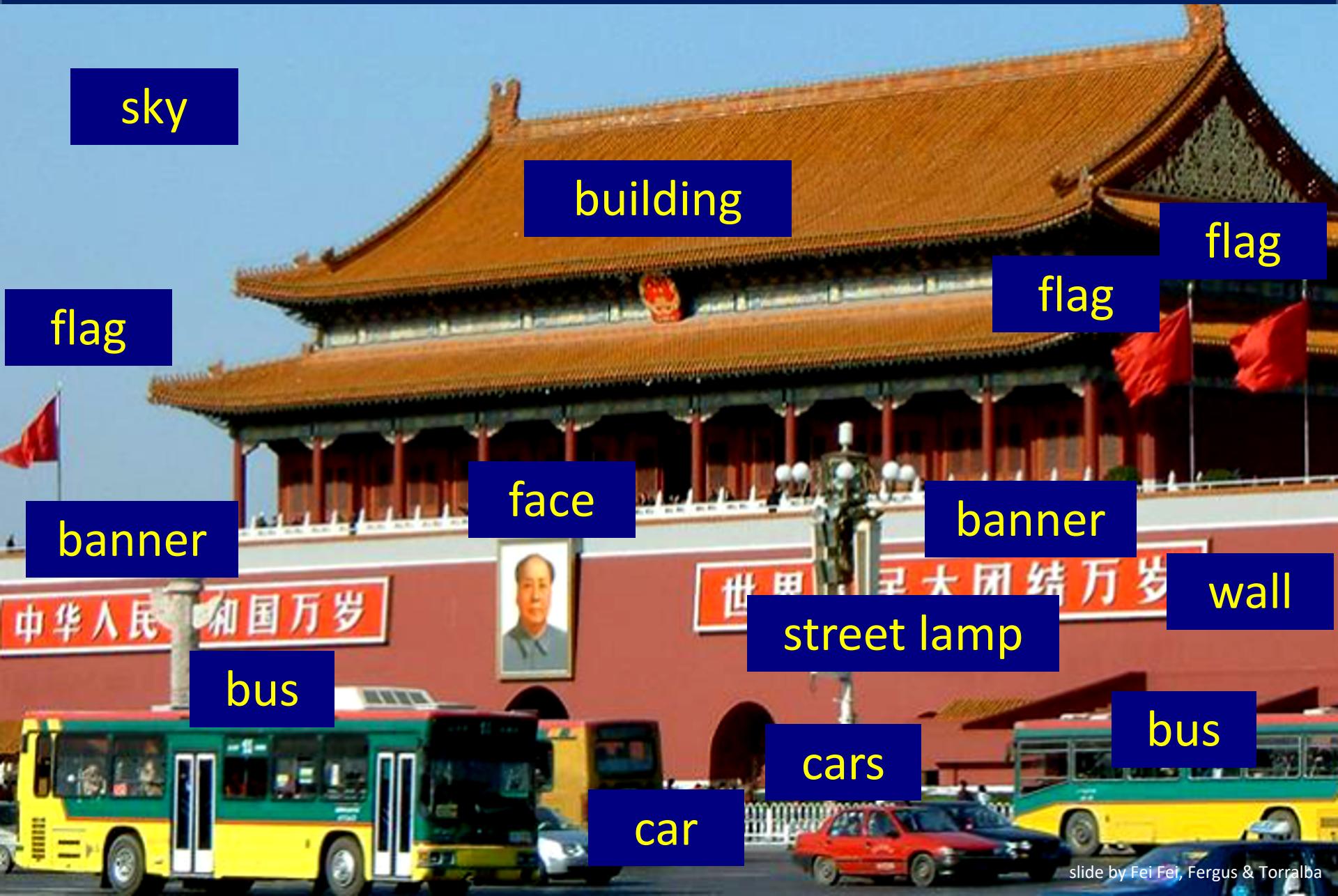
Verification: is that a bus?



Identification: is that a picture of Mao?

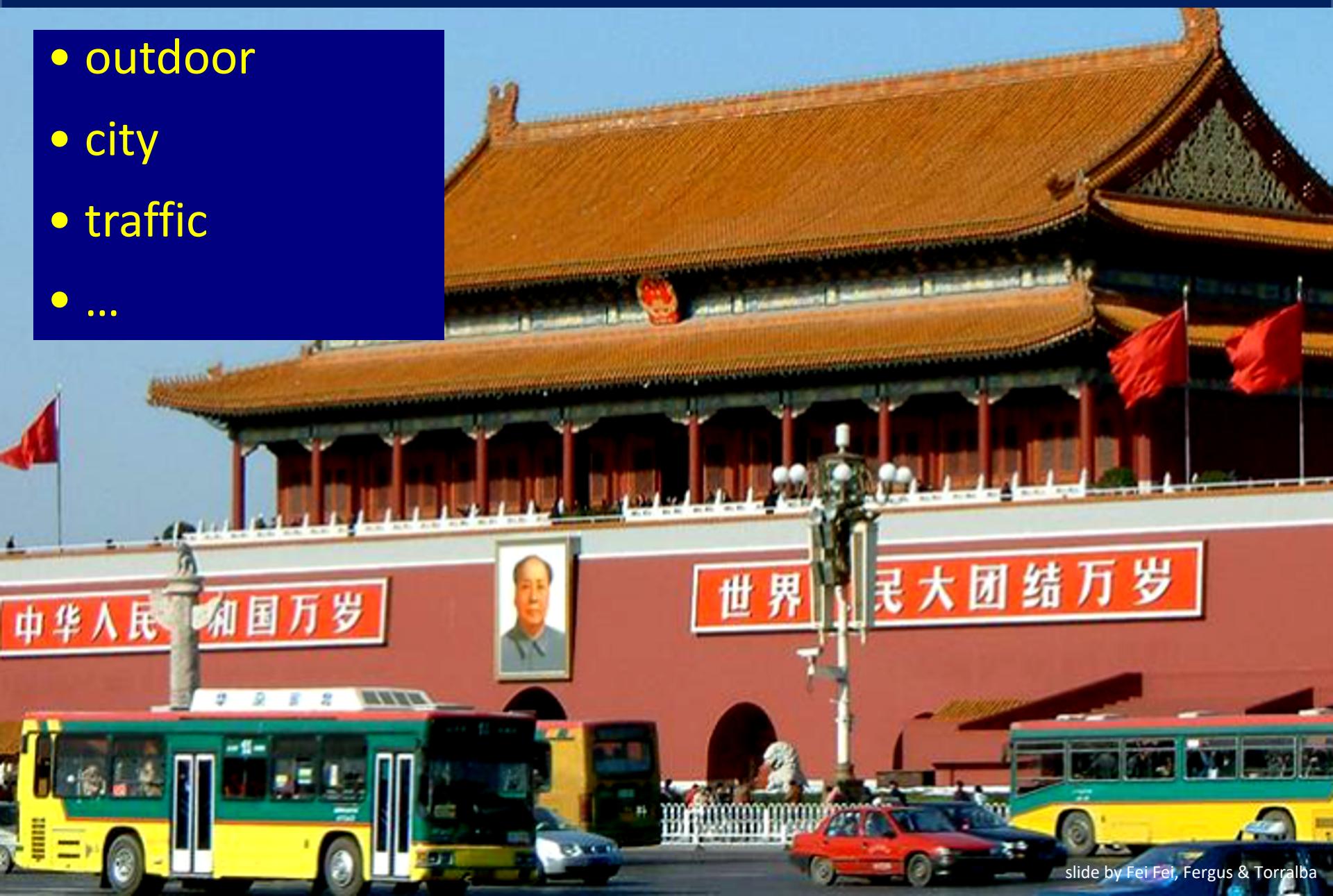


Object categorization



Scene and context categorization

- outdoor
- city
- traffic
- ...



Rough 3D layout, depth ordering



Challenges

**So what are the challenges faced by
a *computer vision system*?**

9 challenges coming up, in no particular order...

Challenge 1: view-point variation



Michelangelo 1475-1564

original Challenge slides by Efros, Ullman, and others

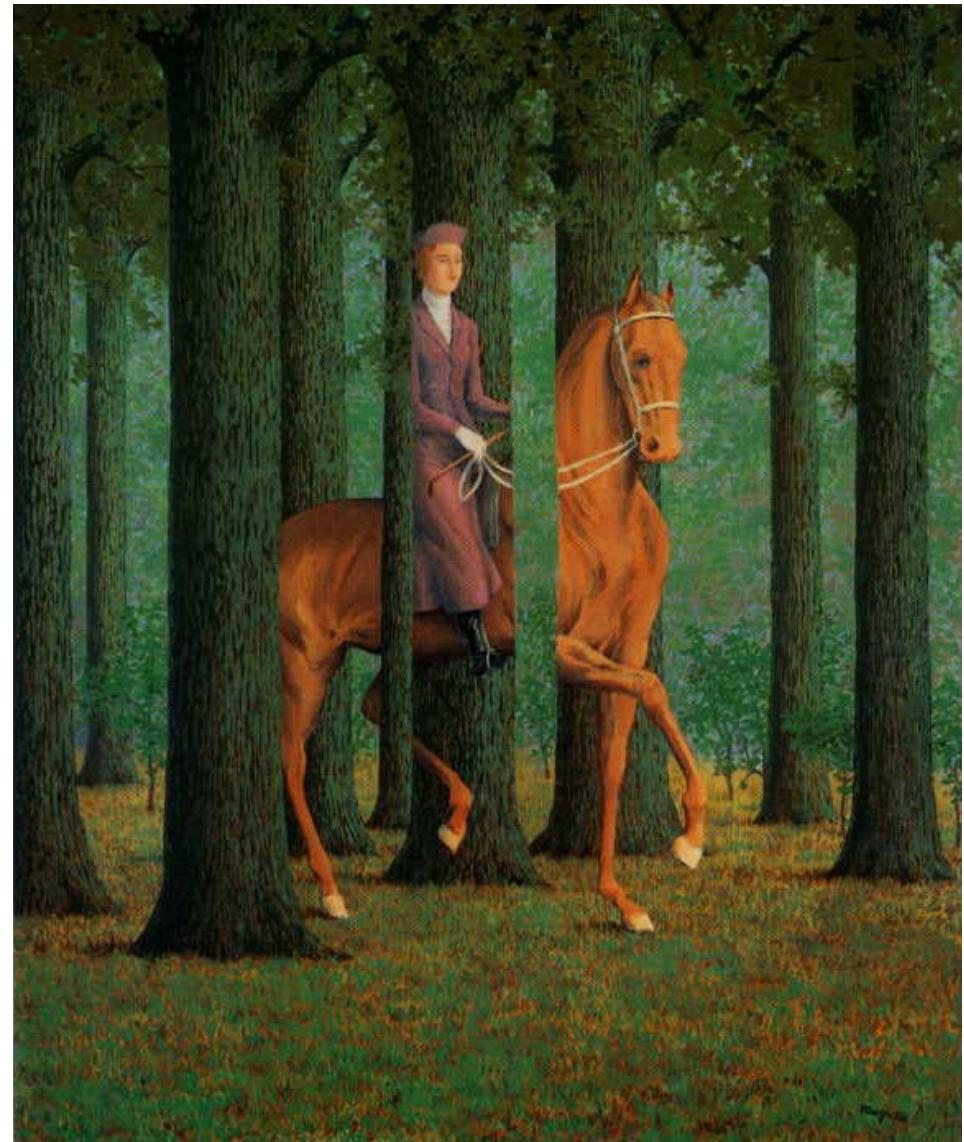
Challenge 2: illumination



original Challenge slides by Efros, Ullman, and others

Challenge 3: occlusion

Magritte, 1957



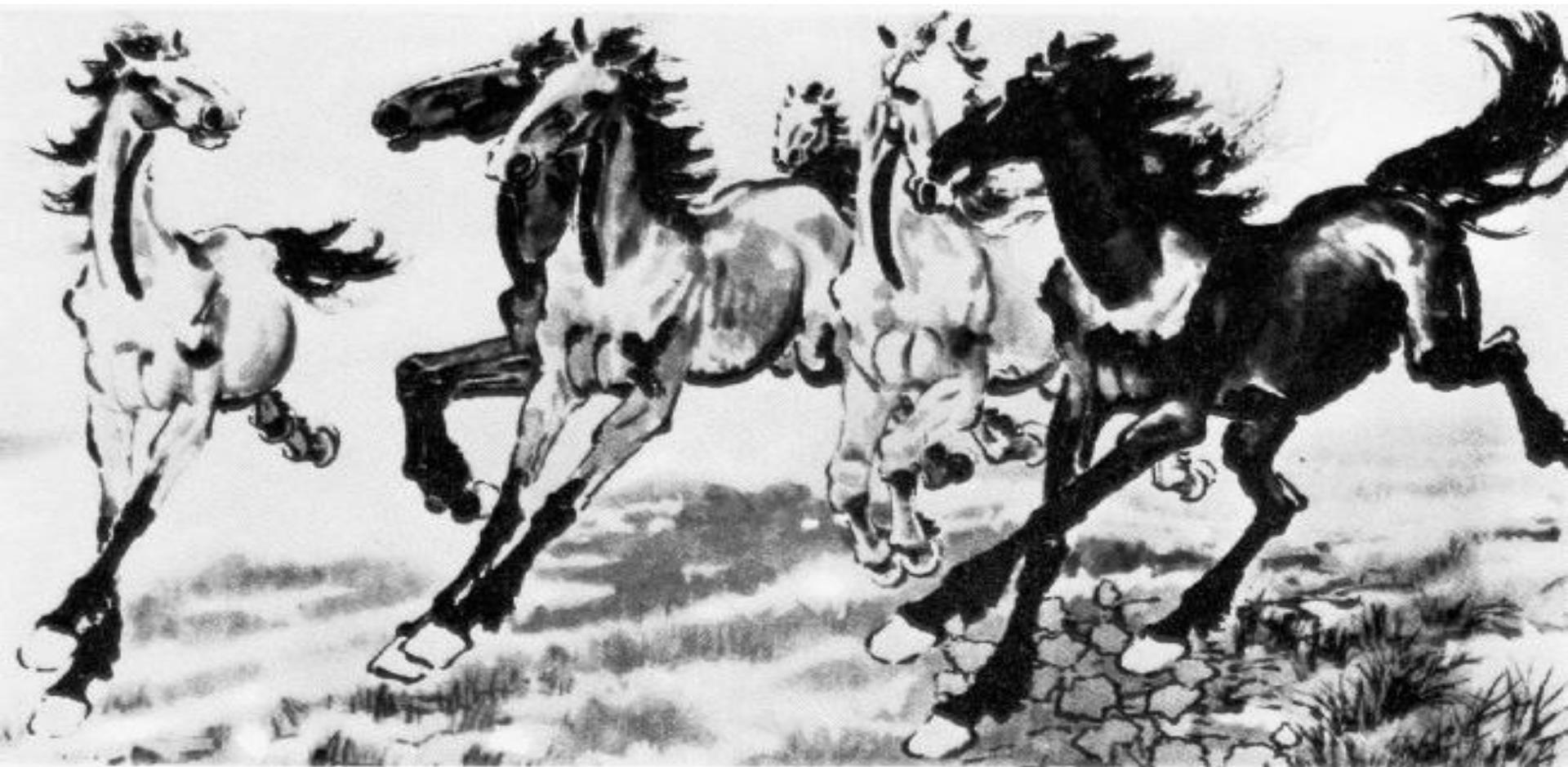
original Challenge slides by Efros, Ullman, and others

Challenge 4: scale



original Challenge slides by Efros, Ullman, and others

Challenge 5: deformation



Xu, Beihong 1943

original Challenge slides by Efros, Ullman, and others

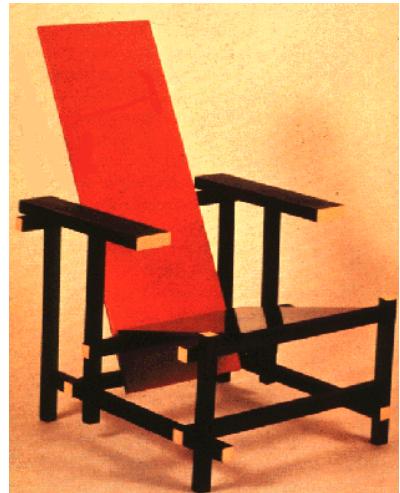
Challenge 6: background clutter



Klimt, 1913

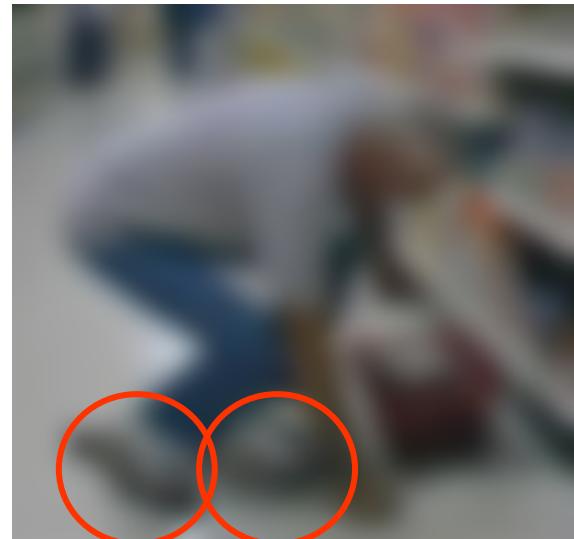
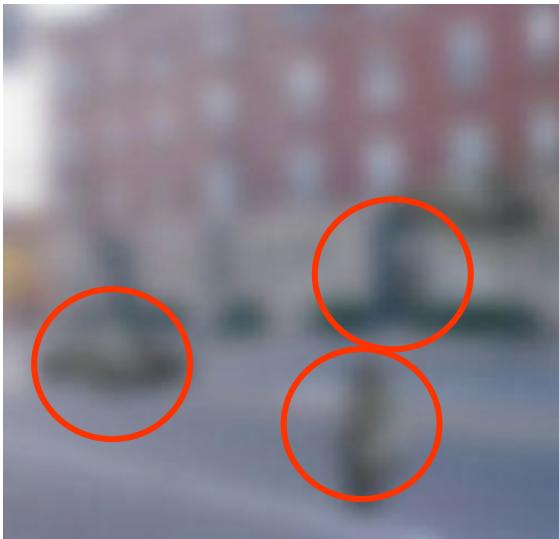
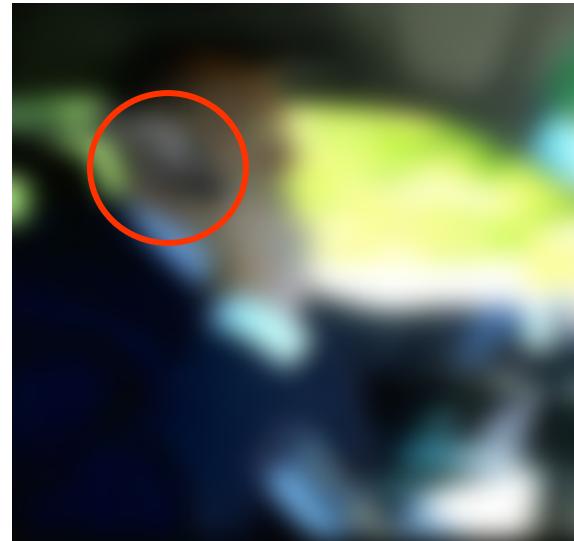
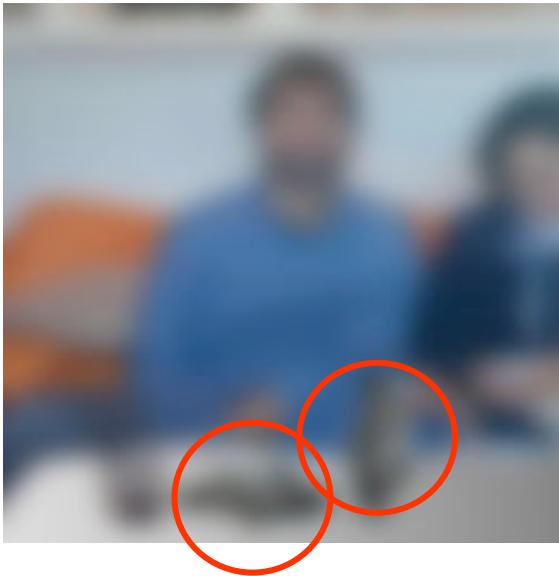
original Challenge slides by Efros, Ullman, and others

Challenge 7: object intra-class variation



original Challenge slides by Efros, Ullman, and others

Challenge 8: local ambiguity



original Challenge slides by Efros, Ullman, and others

Challenge 9: the world behind the image



The Basics of Image Acquisition and Representation

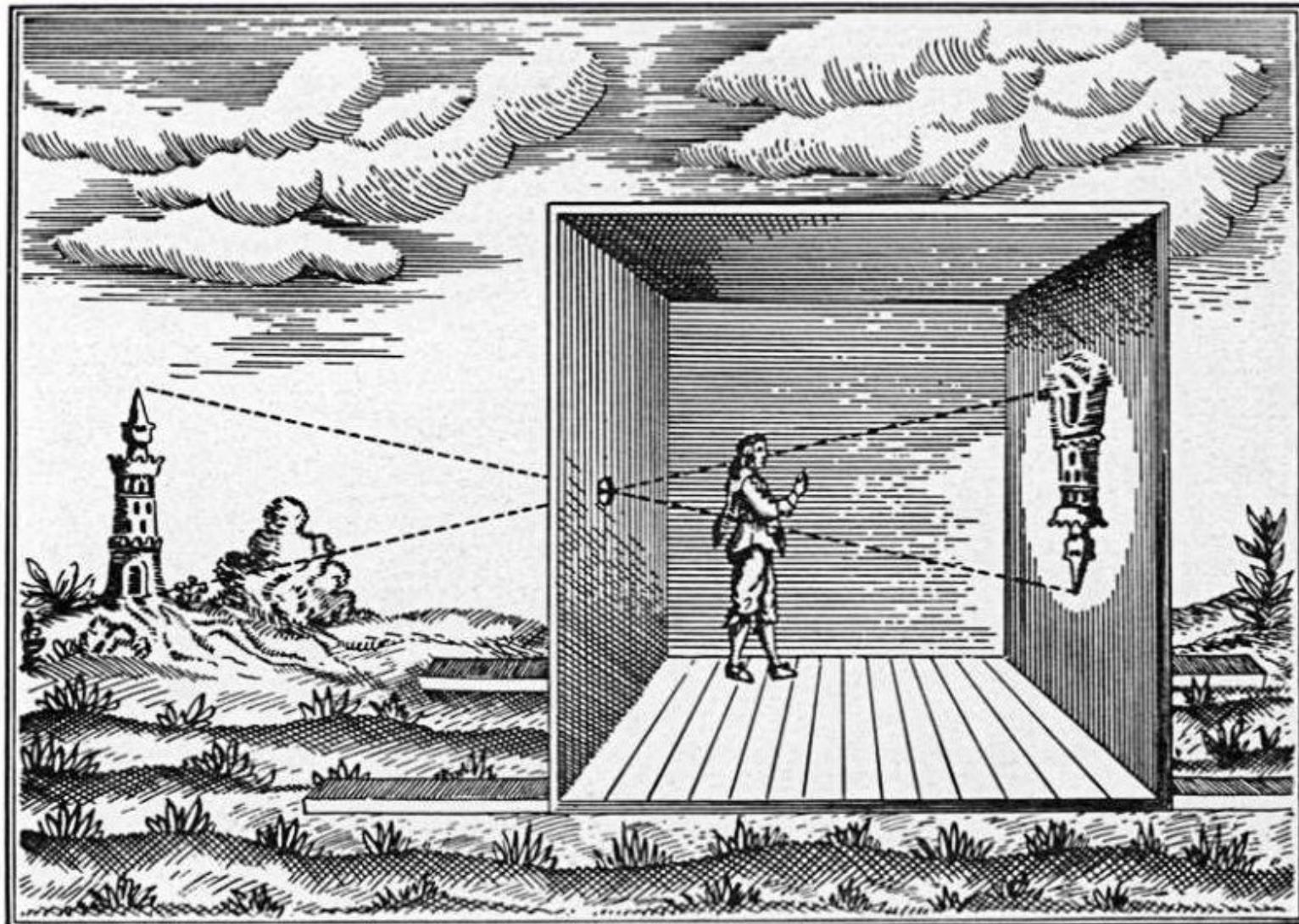
Images as Sensory Data

- How are images acquired?
- Which processes influence digital image formation?

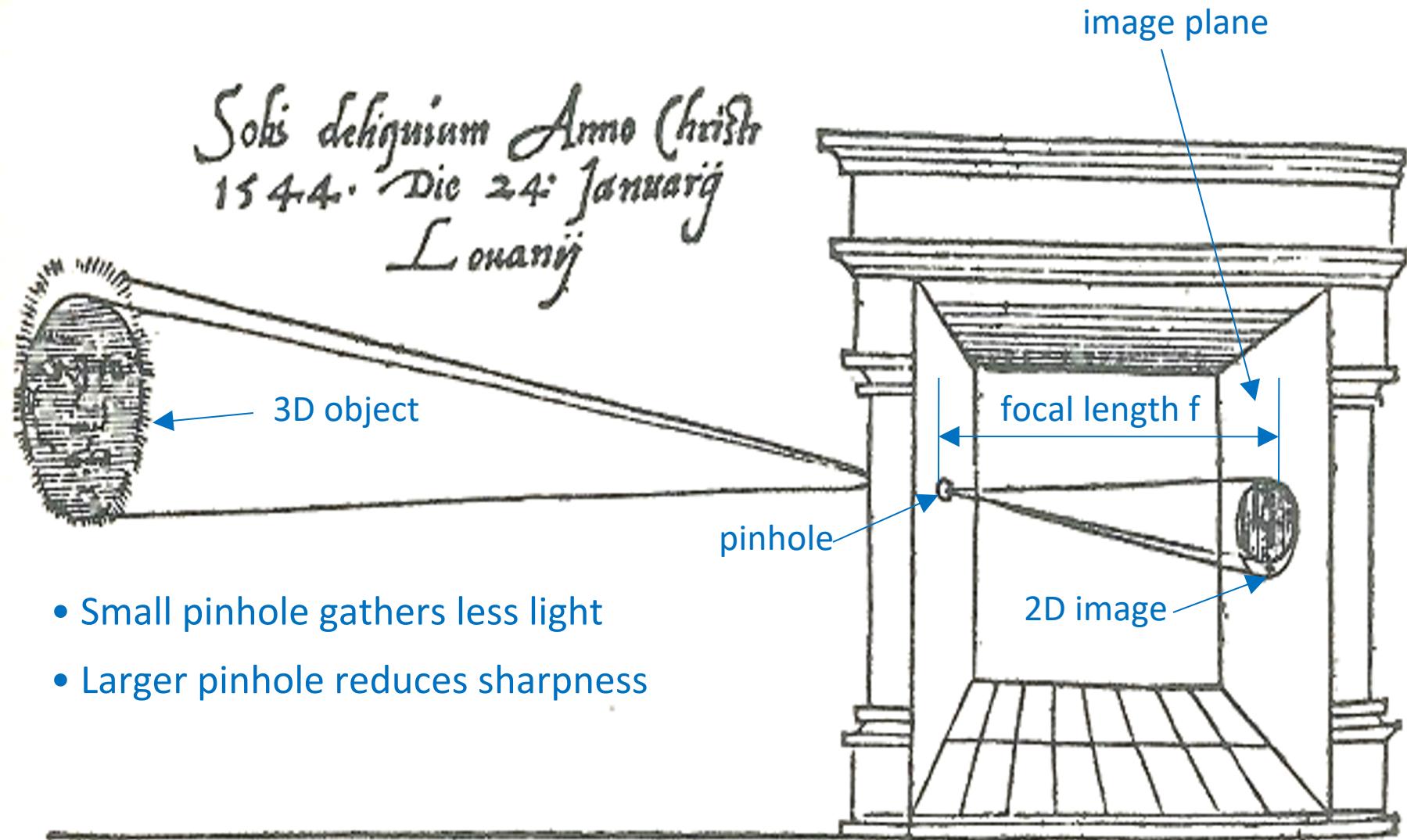
Images as Structured Data

- How can digital images be represented?

The Camera Obscura (Pinhole Camera)

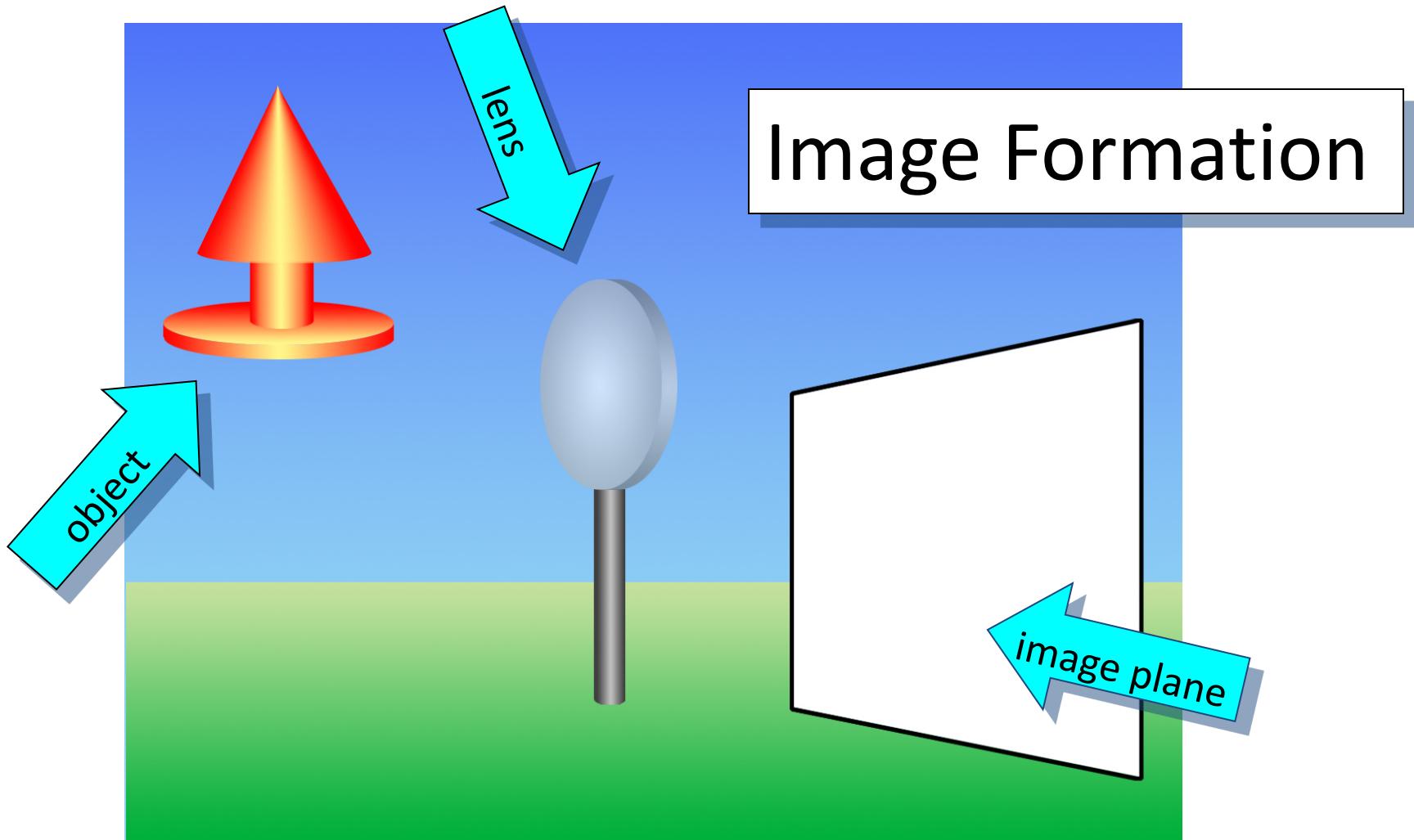


The Camera Obscura (Pinhole Camera)



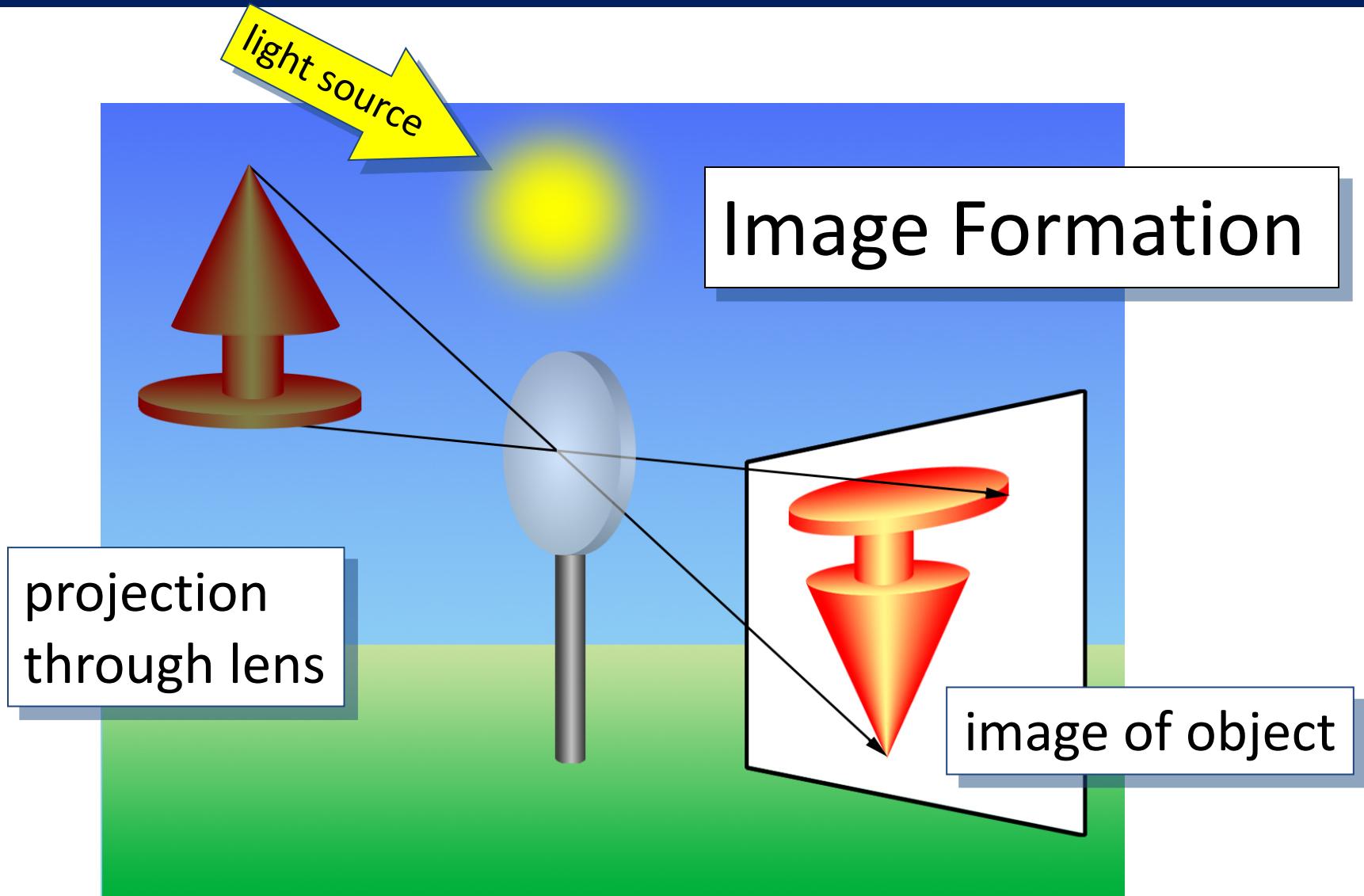
First published picture of camera obscura in Gemma Frisius' 1545 book *De Radio Astronomica et Geometrica*

Digital Image Acquisition



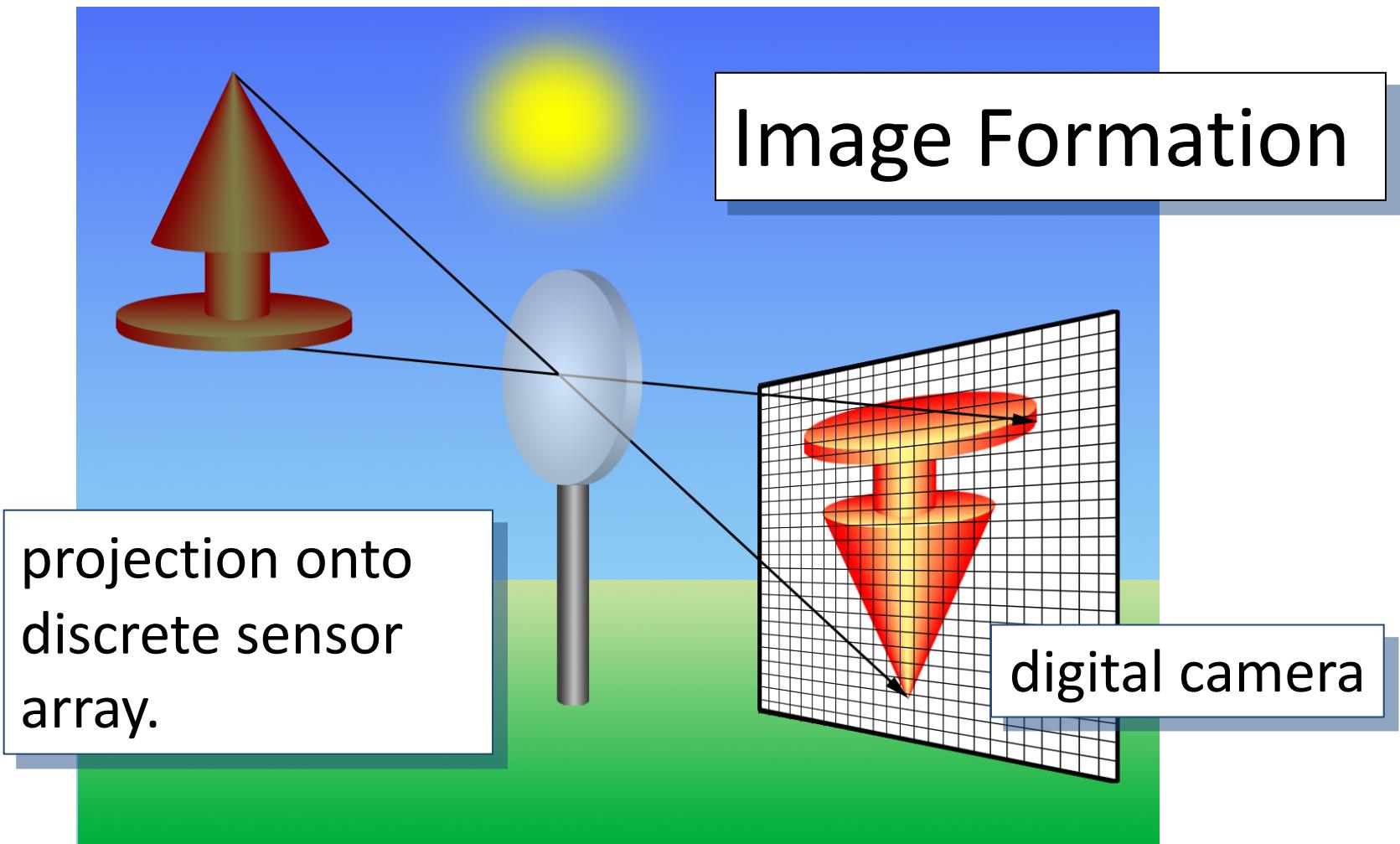
Slide by R A Peters

Digital Image Acquisition



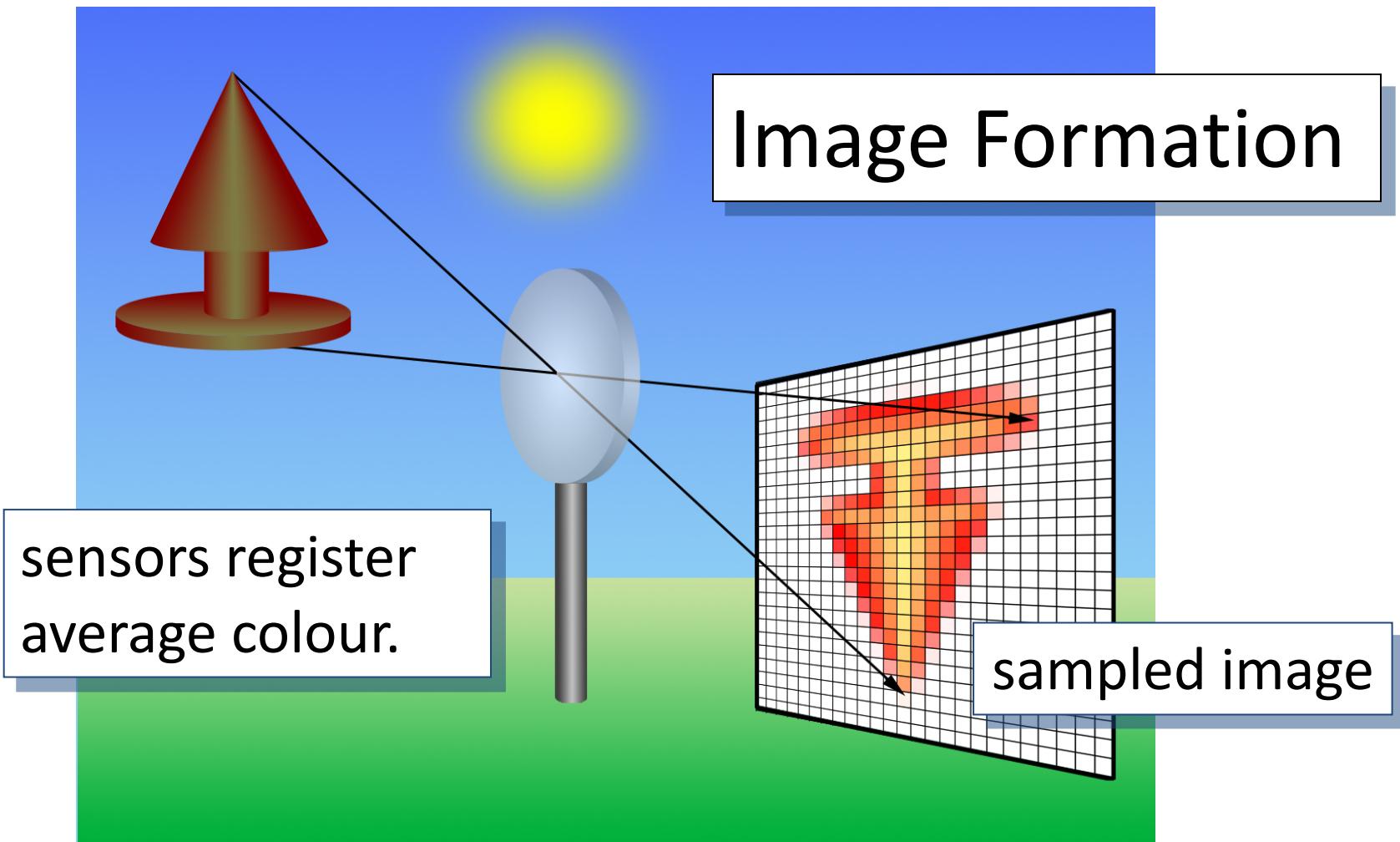
Slide by R A Peters

Digital Image Acquisition



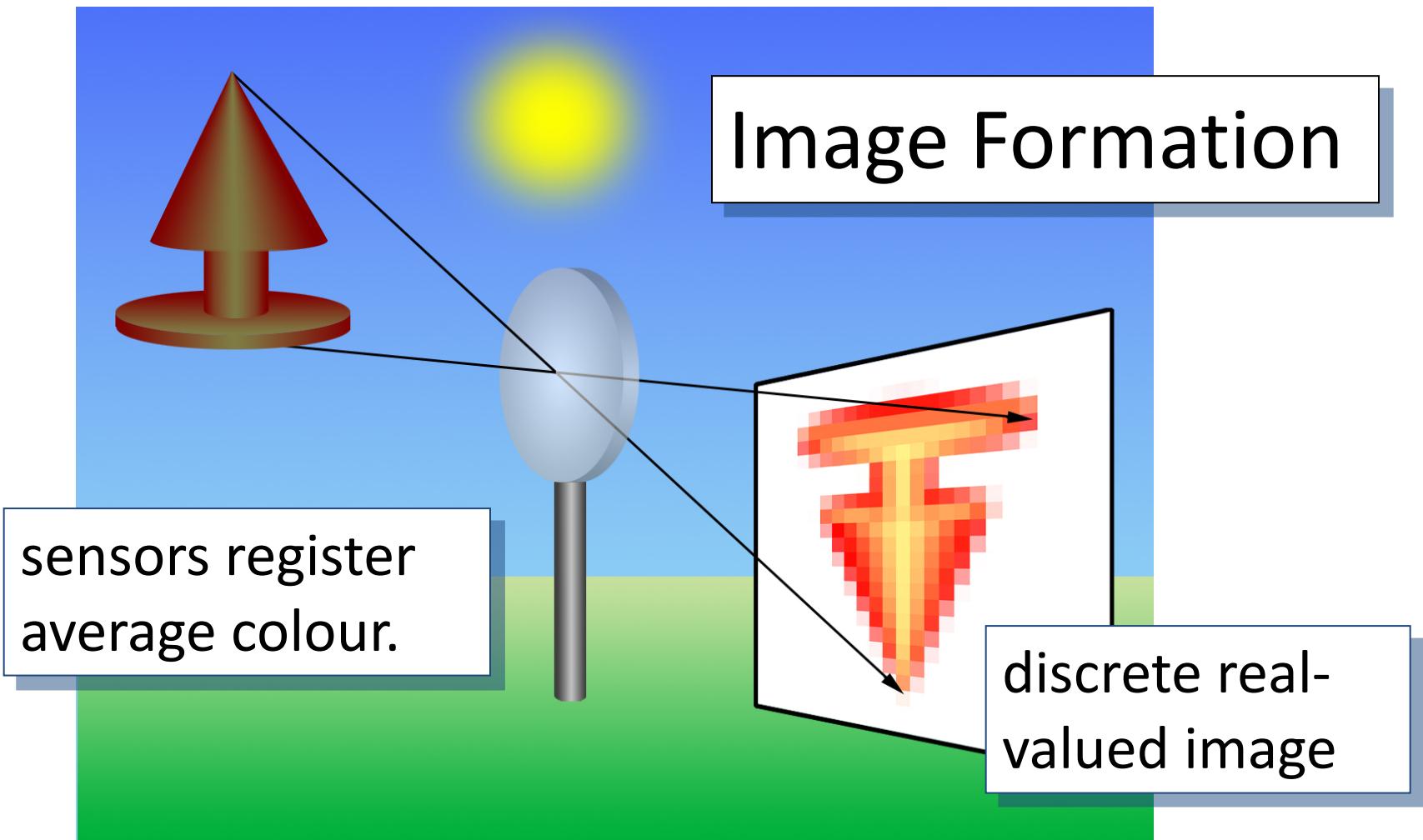
Slide by R A Peters

Digital Image Acquisition



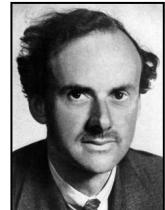
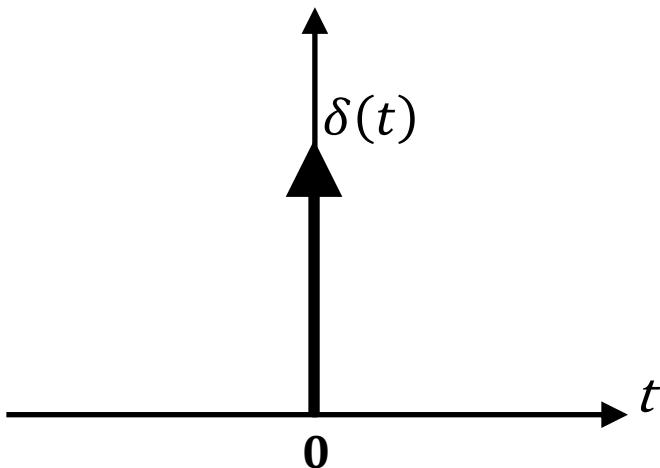
Slide by R A Peters

Digital Image Acquisition



Slide by R A Peters

Modelling a Spatial Brightness Pulse - Dirac Delta-Function

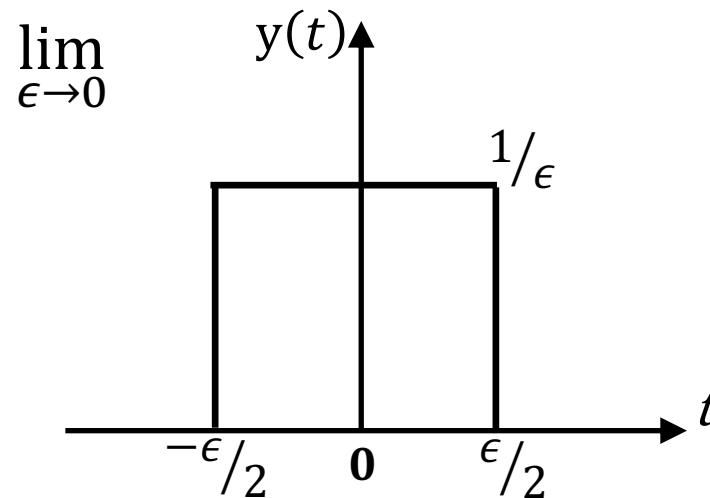
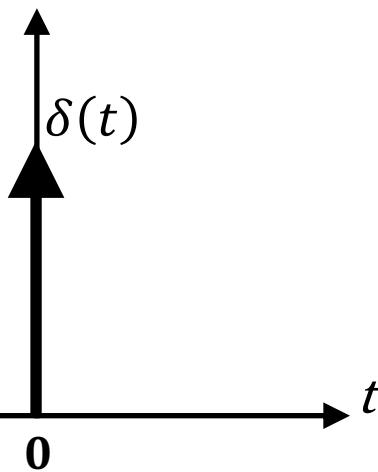


Paul Dirac

Definition:

$$\int_{-\infty}^{\infty} \delta(t) dt = 1$$

Modelling a Spatial Brightness Pulse - Dirac Delta-Function



Paul Dirac

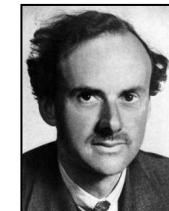
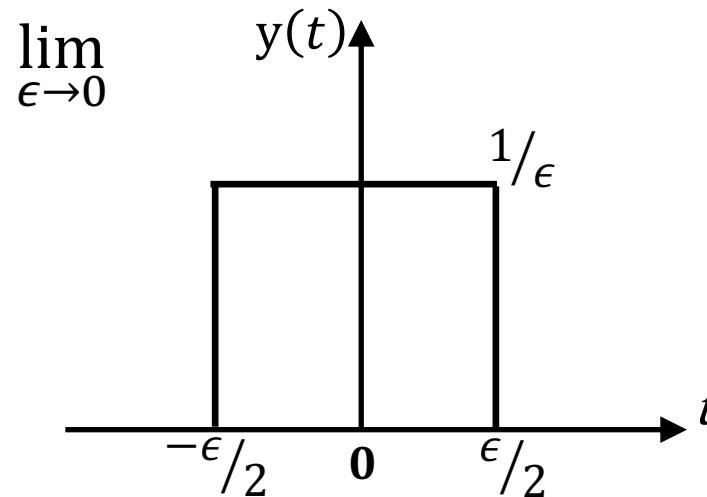
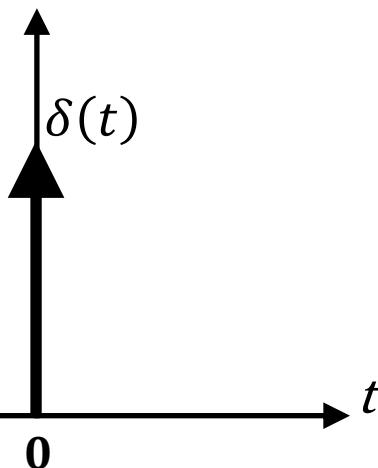
Definition:

$$\int_{-\infty}^{\infty} \delta(t) dt = 1$$

Intuitively:

$$\delta(t) = \lim_{\epsilon \rightarrow 0} [y_\epsilon(t)]$$

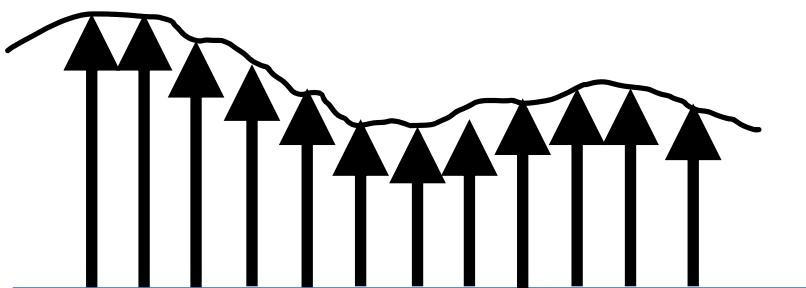
Modelling a Spatial Brightness Pulse - Dirac Delta-Function



Paul Dirac

Definition:

$$\int_{-\infty}^{\infty} \delta(t) dt = 1$$

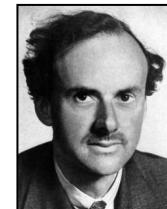
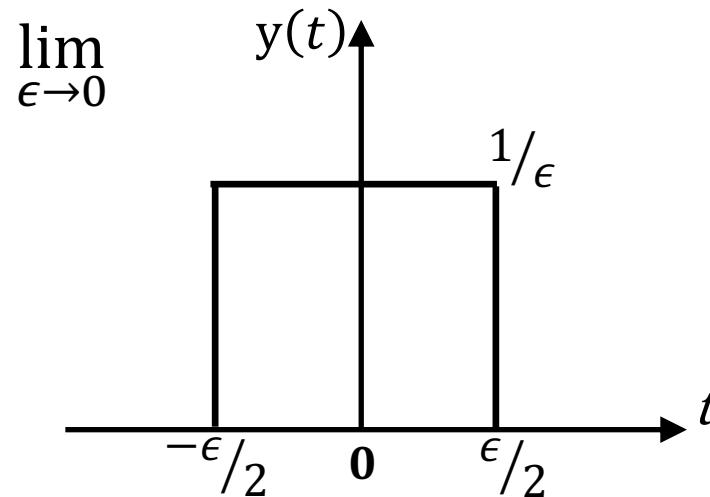
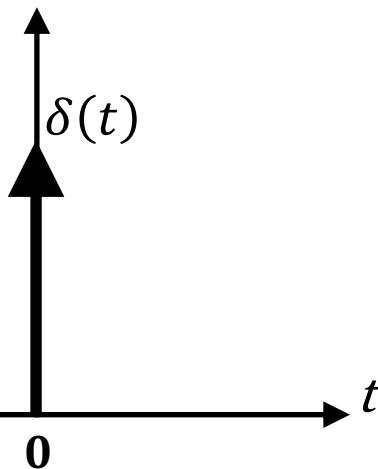


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Modelling a Spatial Brightness Pulse - Dirac Delta-Function



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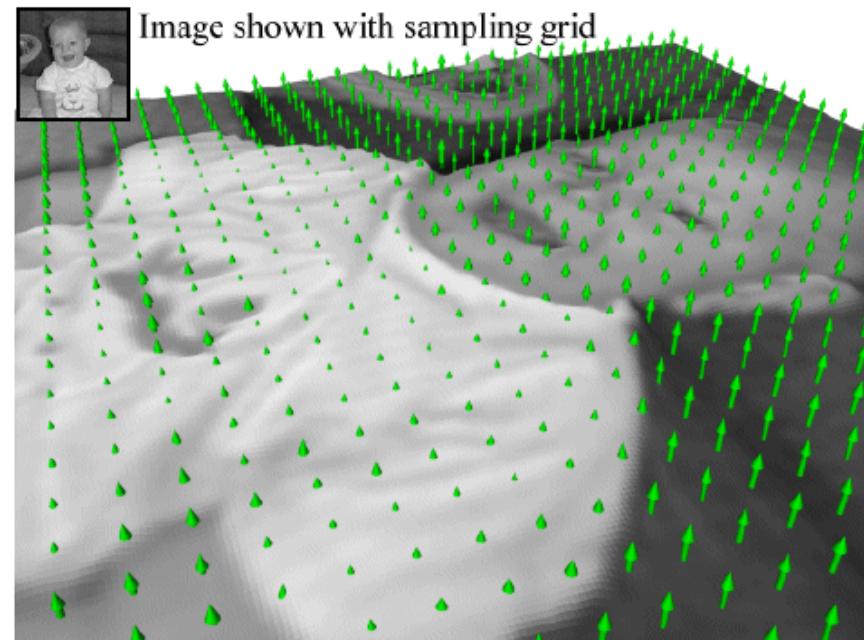
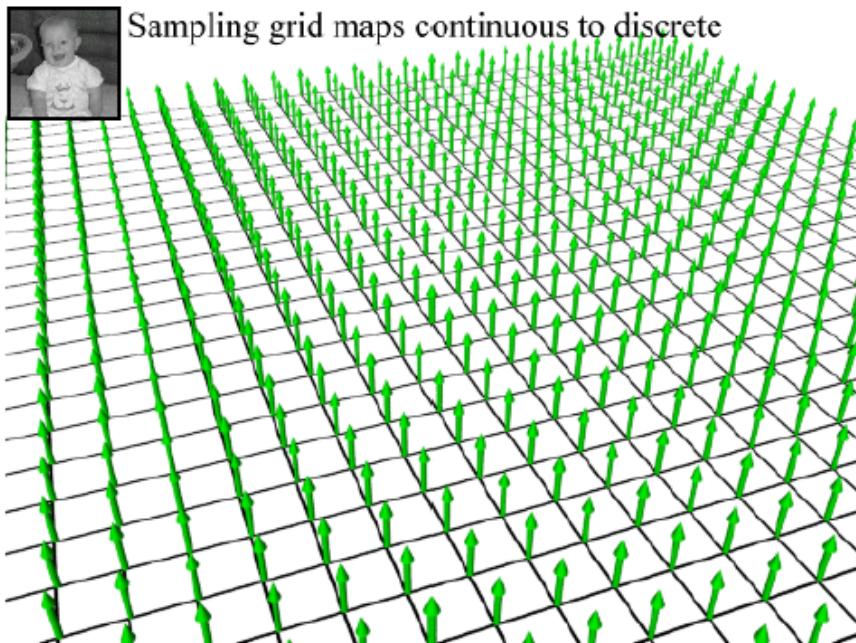
Intuitively:

$$\delta(t) = \lim_{\epsilon \rightarrow 0} [y_\epsilon(t)]$$

Sifting Property:

$$\int_{-\infty}^{\infty} f(t) \delta(t) dt = f(0)$$

Sampling in 2D To Obtain An Image

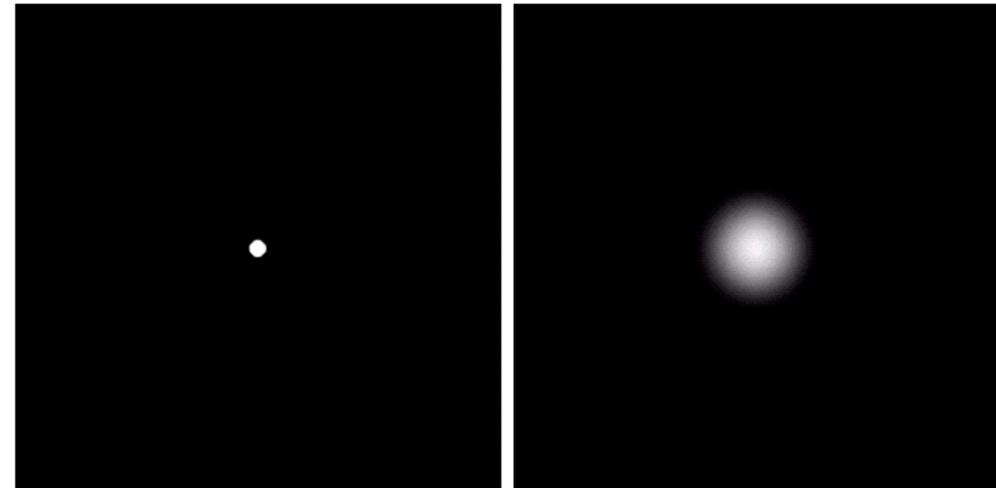


Images from Durand, Cutler and Hanrahan

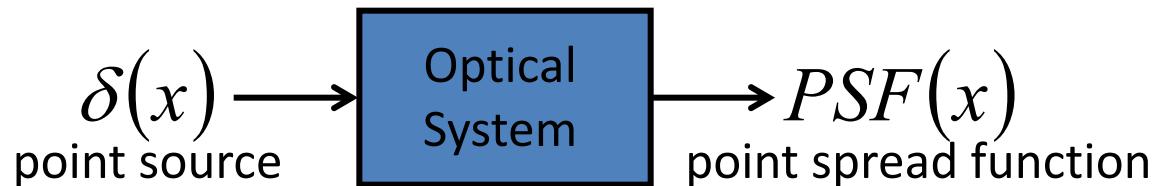
The sifting property can be used to express a 2D ‘image function’ as a linear combination of 2D Dirac pulses located at points (a,b) that cover the whole image plane:

$$\int_{-\infty}^{\infty} \int_{-\infty}^{\infty} f(a,b) \delta(a-x, b-y) da db = f(x,y)$$

The Point Spread Function

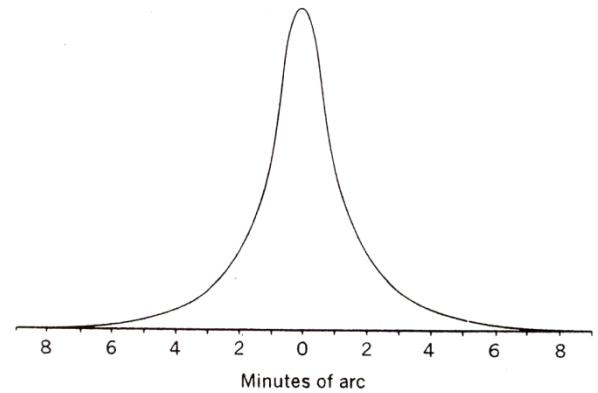


- Ideally, the optical system should be mapping point information to points again.
- However, optical systems are never ideal.



- Superposition Principle:
An image is the sum of the PSF of all its points.

- Point spread function of Human Eyes



PSF Example

$$g(x, y) = f(x, y) * h(x, y)$$

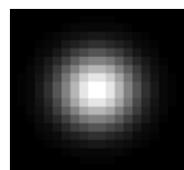
$f(x, y)$ Original



Blurry outcome $g(x, y)$



$$h(x, y)$$

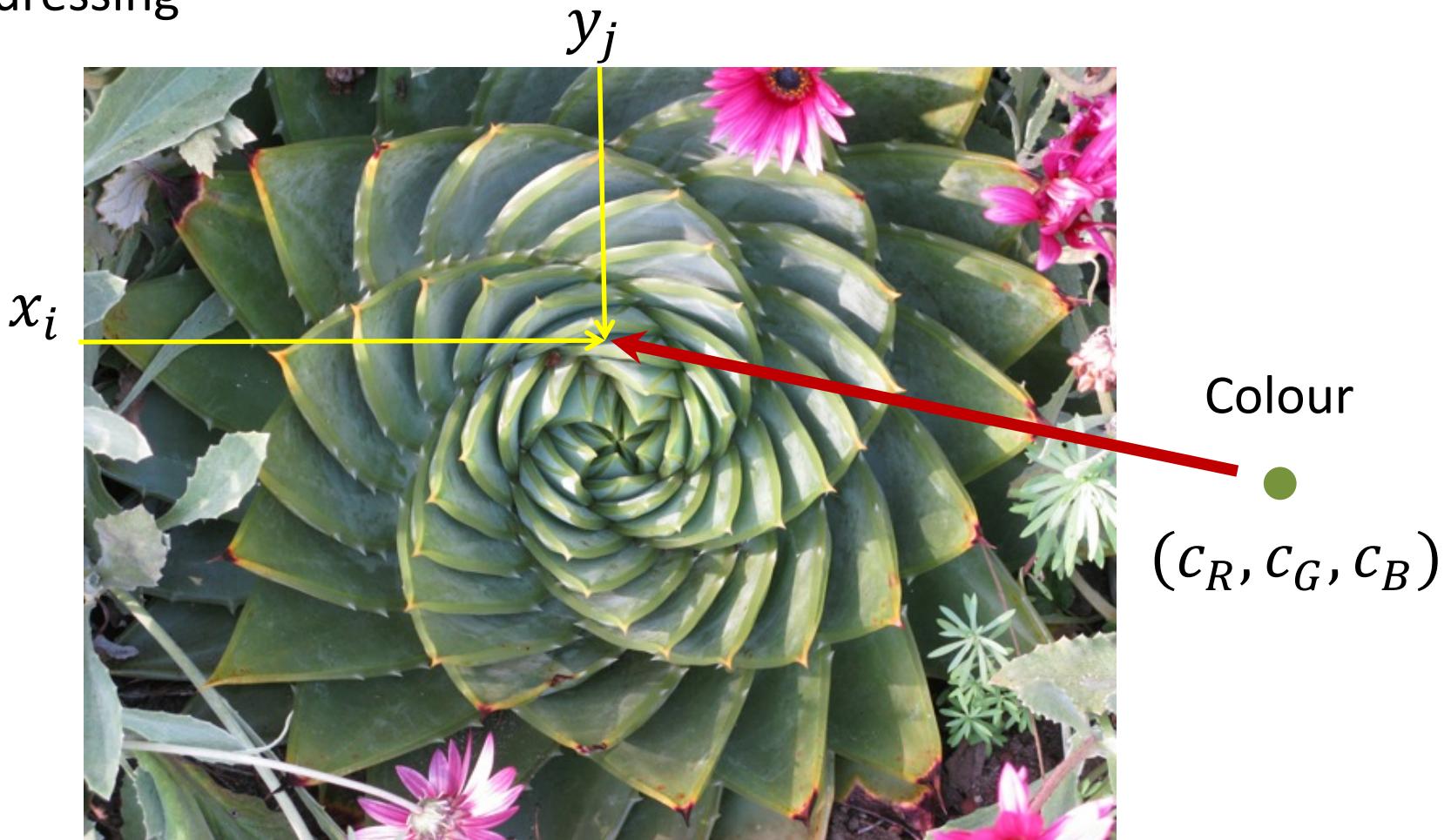


$h(x, y)$ is the PSF of the imaging device.

Adapted from a slide by A. Zisserman

How to model an image?

Addressing



How to represent a digital image?

$$f[x, y] = \begin{bmatrix} f[0, 0] & f[0, 1] & \dots & f[0, N - 1] \\ f[1, 0] & f[1, 1] & \dots & f[1, N - 1] \\ \vdots & \vdots & \ddots & \vdots \\ f[M - 1, 0] & f[M - 1, 1] & \dots & f[M - 1, N - 1] \end{bmatrix}$$

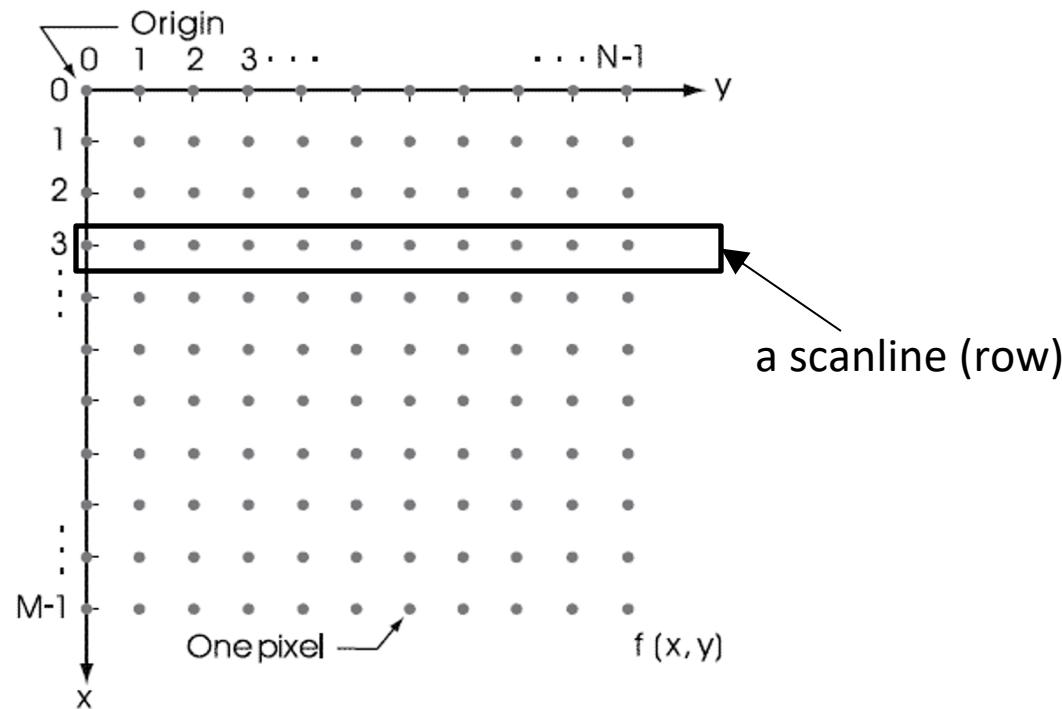


Image Representation: Colour Spaces

$$f(x, y) = (R, G, B)$$

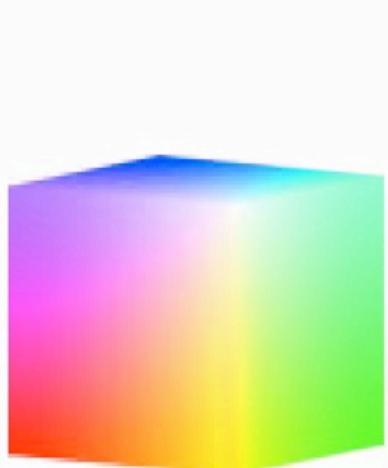
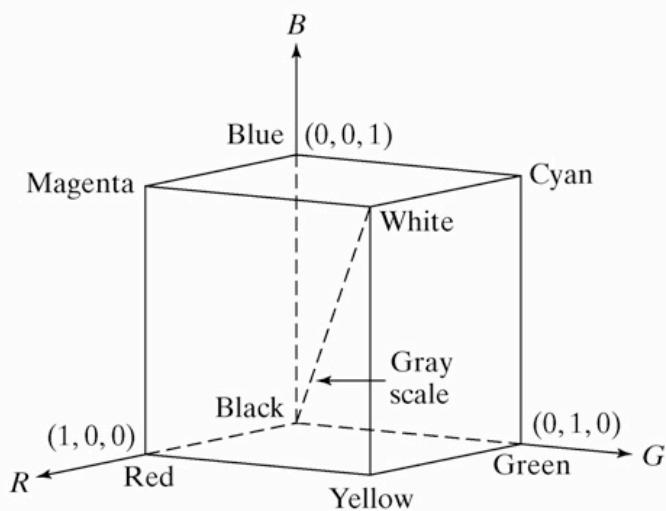
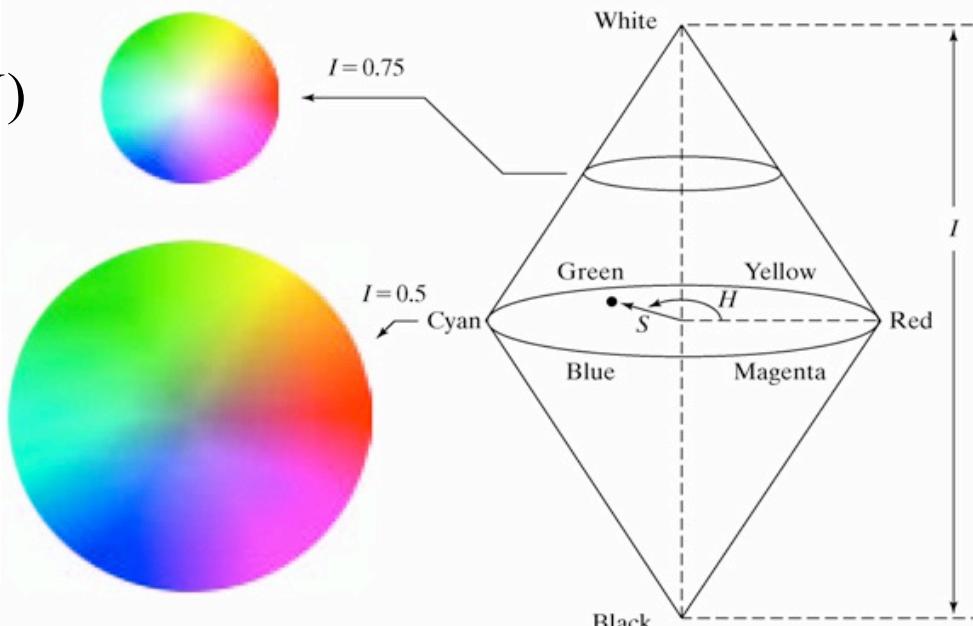
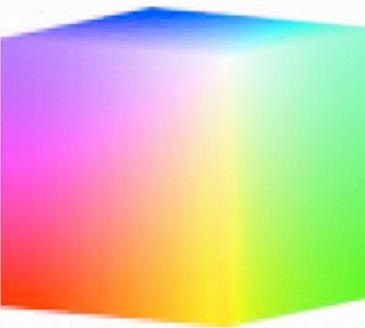
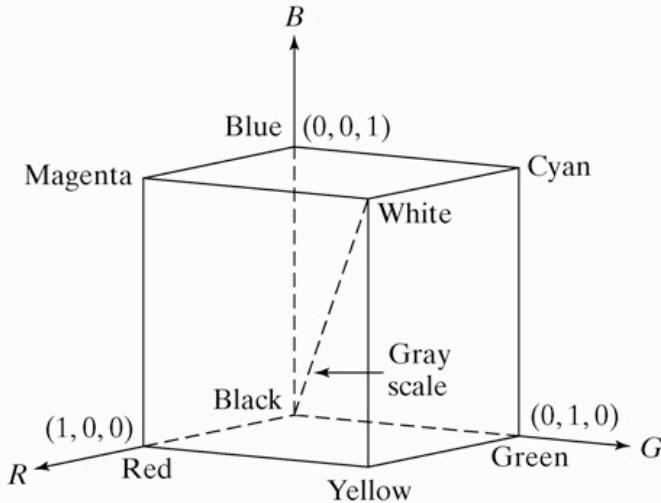


Image Representation: Colour Spaces

$$f(x, y) = (H, S, I)$$



$$f(x, y) = (R, G, B)$$



Other examples are:

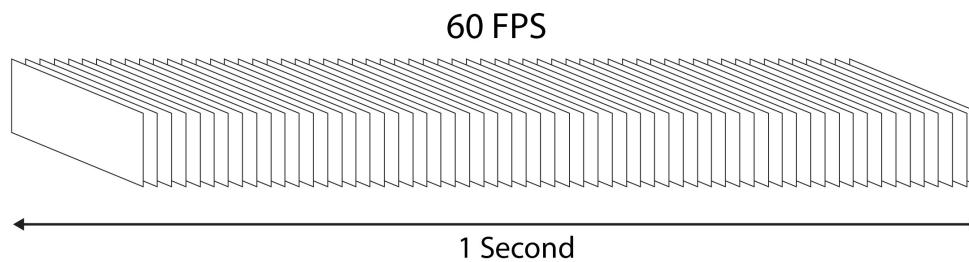
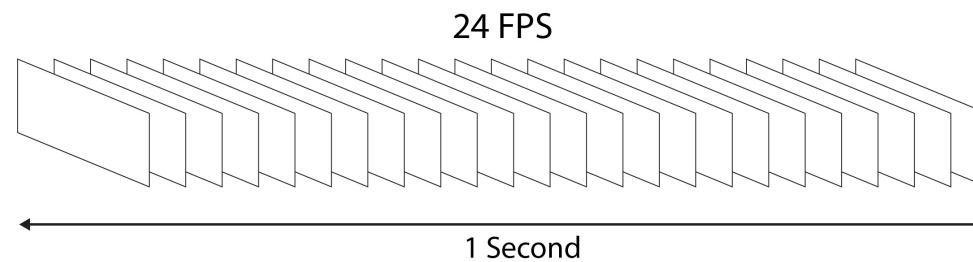
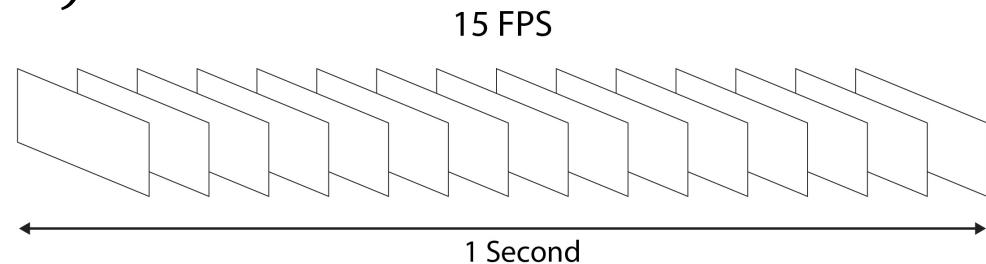
$$f(x, y) = (L, a, b)$$

$$f(x, y) = (Y, U, V)$$

...

How to represent a video?

$$f[x, y, t] = (R, G, B)$$



From quora.com

Quantization of the Image Function

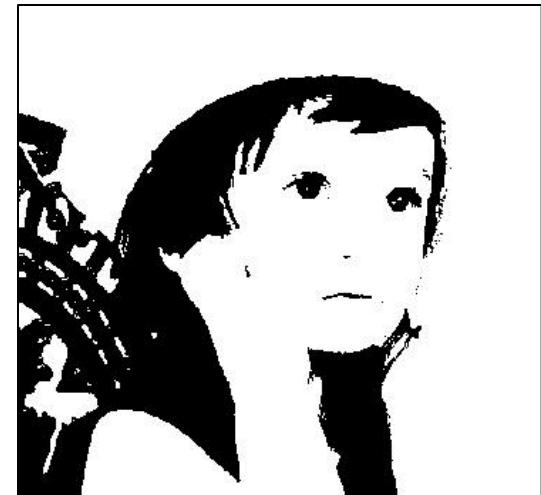
Representing a continuously varying single channel image function $f(x, y)$ with a discrete one using quantization levels:



16 levels



6 levels



2 levels

Spatial Sampling in Practice

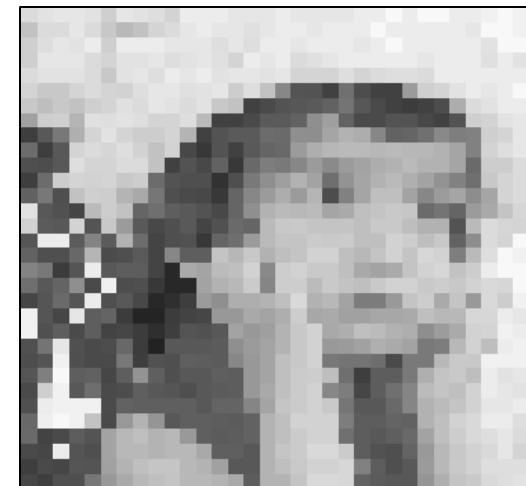
The effect of very sparse sampling ... is often ALIASING



256 x256



64x64

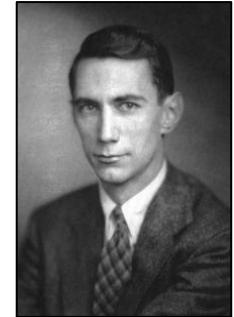


32x32

Anti-aliasing can be achieved by removing all spatial frequencies above a critical limit (so-called Shannon-Nyquist Limit).

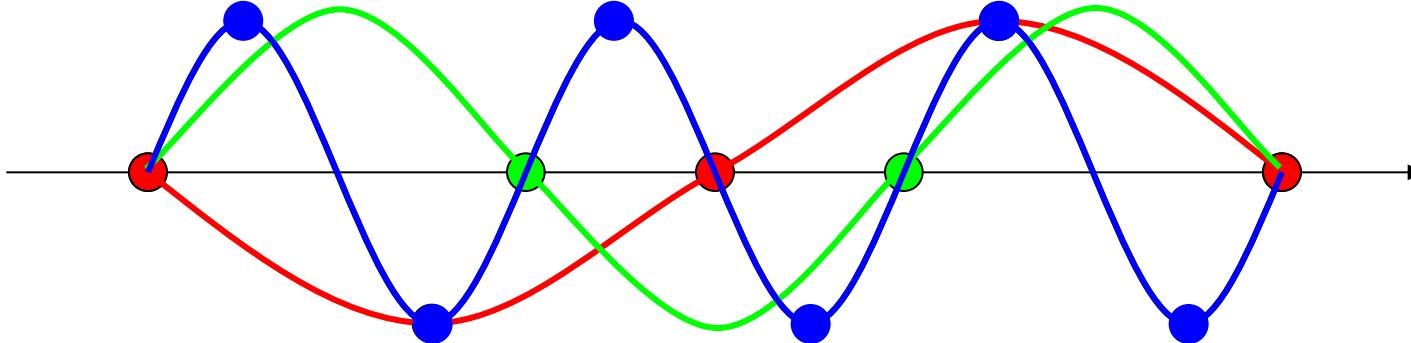
Shannon's Sampling Theorem

“An analogue signal containing components up to some maximum frequency u may be completely reconstructed by regularly spread samples, provided the sampling rate is above $2u$ samples per second.”



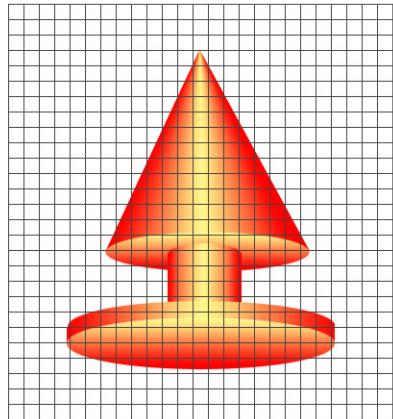
Claude Shannon

Also referred to as the Shannon-Nyquist criterion:
Sampling must be performed above twice the highest (spatial) frequency of the signal to be lossless.

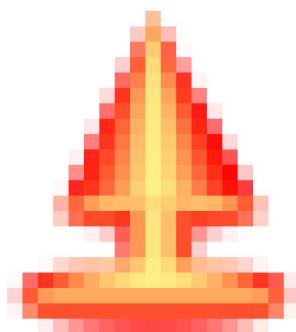


Sampling and Quantization Summary

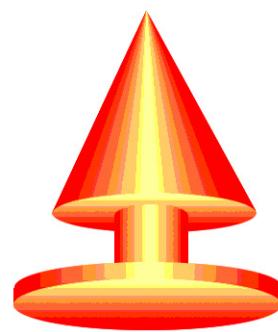
pixel grid



real image



sampled



quantized



**sampled &
quantized**

Slide by R A Peters

Next Week's Lectures

Convolution

The Fourier Domain