IMAGE FORMATION AND IMAGE MODELS

Light - a carrier of information

- light can be

  absorbed

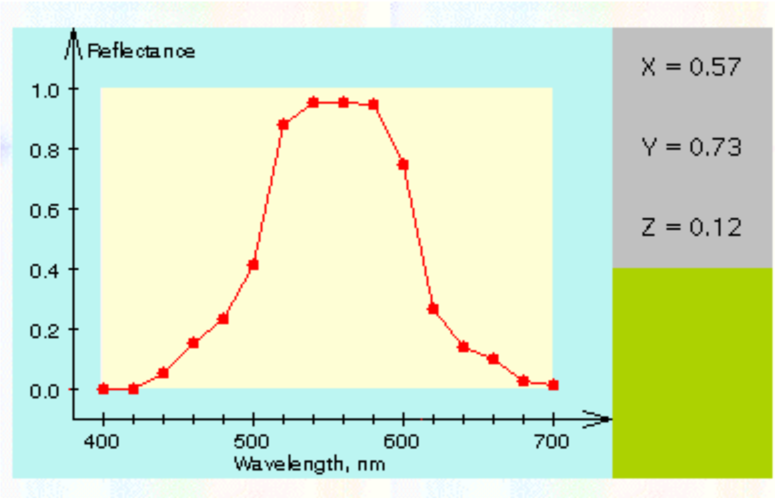
  diffracted

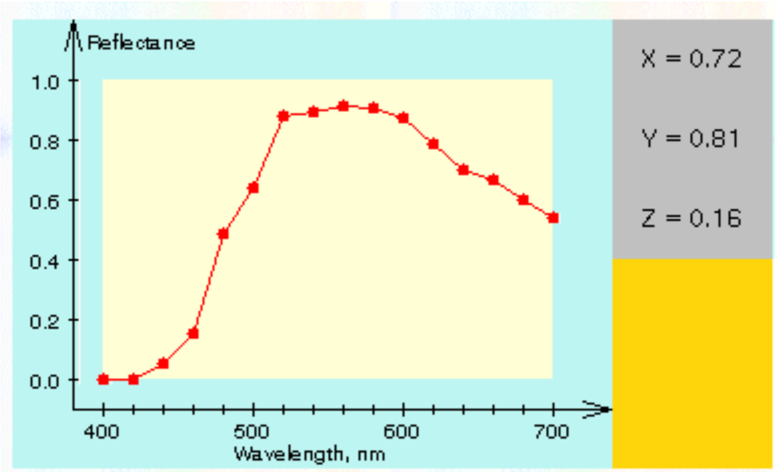
  refracted

  reflected

Light - a carrier of information

- most visual information comes from light reflected from surfaces
    - surface material (colour, fabric) determines which portion of the spectrum is reflected
    - texture - how coherently is light reflected
    - any movement (self or in environment) and any change, changes it
- light detected by receptors (natural or human-made)

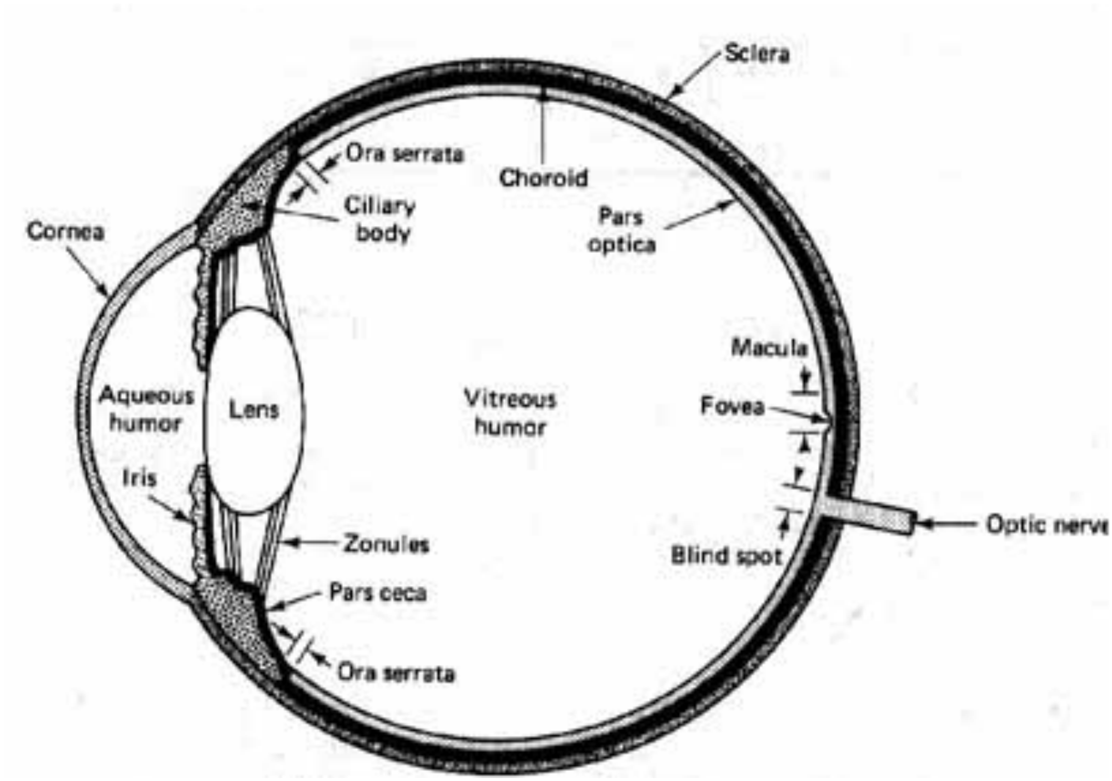

Reflectance
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
Wavelength, nm
X = 0.57
Y = 0.73
Z = 0.12


Reflectance
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
Wavelength, nm
X = 0.72
Y = 0.81
Z = 0.16

Light sensing

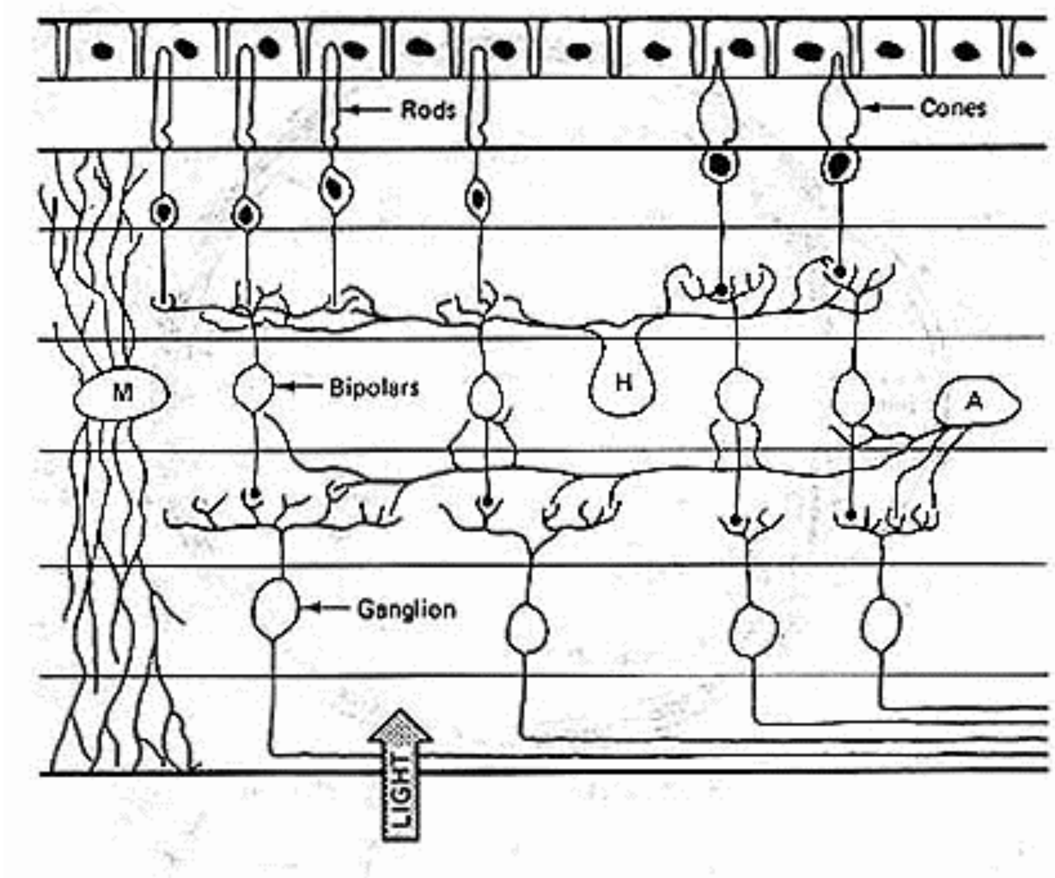
Human retina

- light sensing takes place on the retina
- light photons hitting the receptors
- chemical reaction (*bleaching*)
- electric impulses


Sclera
Ora serrata
Choroid
Ciliary body
Cornea
Pars optica
Macula
Aqueous humor
Lens
Vitreous humor
Fovea
Iris
Optic nerve
Zonules
Blind spot
Pars ceca
Ora serrata

Receptive fields

- polling responses from a number of receptors
- size of receptive fields increases towards the periphery.



M – Muller cell H – Horizontal cell A – Amacrine cell

Electronic receptors

- light sensitive diodes
- electric current in proportion to the amount of light
- Analogue-to-Digital Converters (ADCs) convert the voltage magnitude to a number
- stored in a computer memory
- arranged in a regular rectangular grid (array)

Significant parameters

The most important factors in image formation are:

- the relationship between the amount of light and the sensor response (a *response function*)
- the relationship between the sensor response and the digital value (*brightness sampling*, in digital systems only)
- receptive field sizes (*spatial resolution*)
- geometry of sensors (*spatial sampling*)

Image as a function

fundamental abstraction of an image

2D monochrome image

- a function (**I**) of two spatial variables x,y
- the value (**b**) - image brightness

$$I(x,y) = b$$

colour image

$$I(x,y) = \bar{c} = [\; r \quad g \quad b \;]$$

colour image

$$I(x,y) = \bar{c} = [\; r \quad g \quad b \;]$$

spectral bands

$$I(x,y) = \bar{c} = [\; s_1 \quad s_2 \quad \ldots \quad s_n \;]$$

temporal images

$$I(x,y,t) = b$$

Examples of operations on images

`I(x,y) + 20,  for all (x,y)`

value 20 should be added to all image pixels

`I’(x,y) = I(x,y)+20,    for all (x,y)`

after the addition, image values will be stored in image `I’` at the location `(x,y)`

Digitising model

- A “real” image (a pattern of light falling onto receptors) - a continuous function
- Image capture - taking measurements (samples)
- Spatial sampling - measurements at certain intervals (regularly or irregularly spaced)
- Grey level quantification - quantifying brightness at each sample into a number of different levels

Sampling interval (spatial resolution)

- for a given real height and width of a 2D image, into how many pixels should it be divided into?
- the more pixels, the higher resolution - the closer to the original
- the amount of memory increases

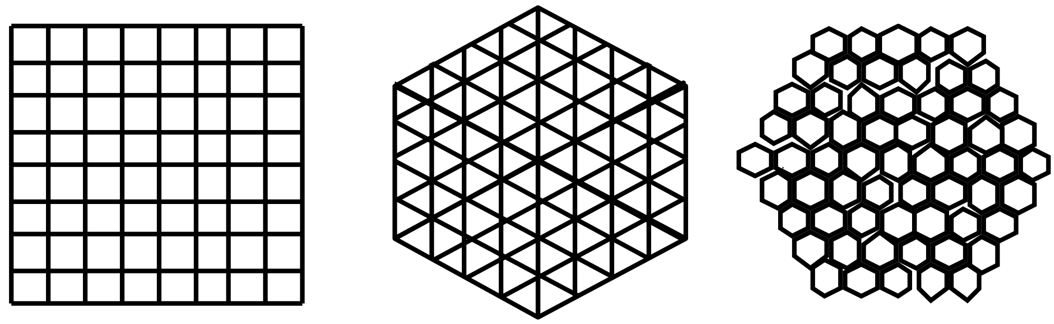
Sampling Theorem (Nyquist Criterion)

To fully represent detail (the rate of brightness change) in an original image, it has to be sampled at a rate at least twice as high as the highest spatial frequency of the detail.

It is wasteful to sample at a rate faster than twice of the finest detail to be resolved in the image

Tessellation

- The spatial arrangement of a sampling grid
- The cells are called pixels
- The most common tessellations are rectangular, triangular and hexagonal:



Grey level quantisation

How many grey levels to chose to represent accurately the image brightness?

Many factors

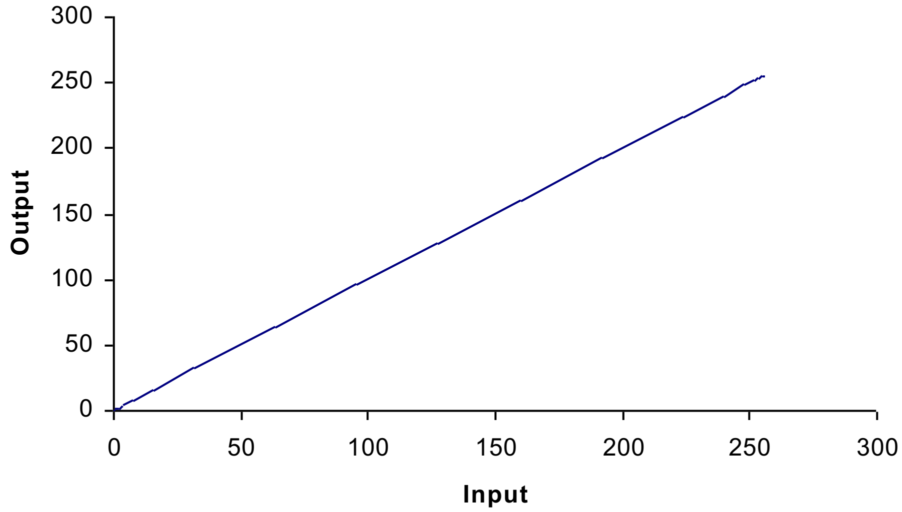
- images for further processing or for viewing?
- accurate representation or detection?
- brightness transfer function

Grey level quantisation

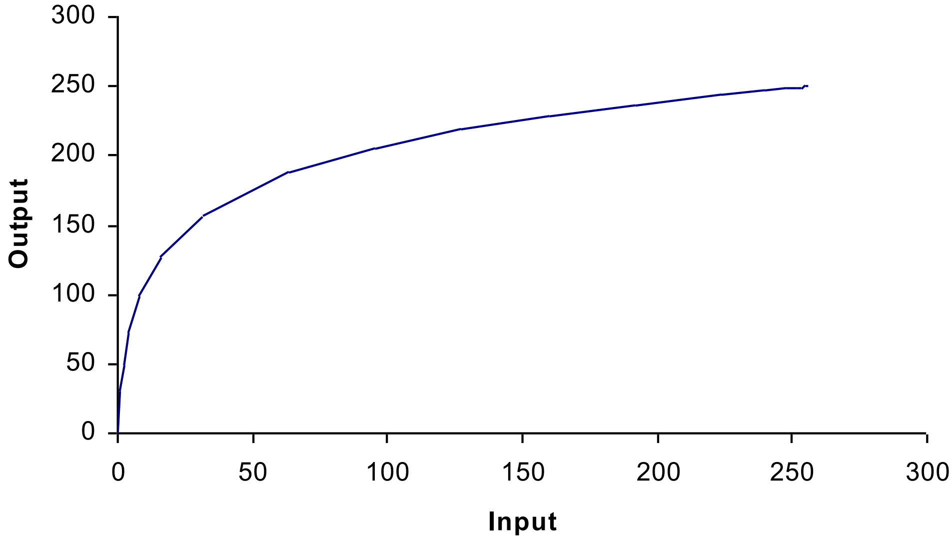
grey level resolution determined by the number of bits per pixel (bpp), e.g.

- 8 bpp => 28 = 256 levels (typical for digital images)
- increment by one bit doubles brightness resolution

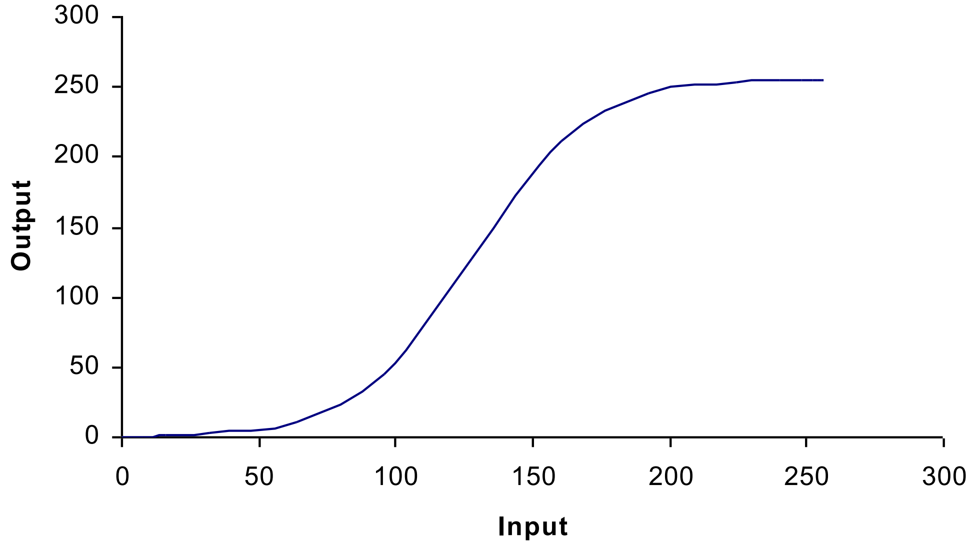
Response function (brightness transfer function)



Linear



Logarithmic



Gamma

Other mathematical models of the image

Statistical model :	describes the image in terms of statistics of its grey levels
Geometric model :	describes how three dimensions are projected into two.
Radiometric model :	shows how the imaging geometry, light sources and reflectance properties of objects affect the light measurement at the sensor.
Spatial frequency model:	describes how spatial variations of the image may be characterised in a transform domain.
Colour model :	describes how different spatial frequencies are related to image colours.