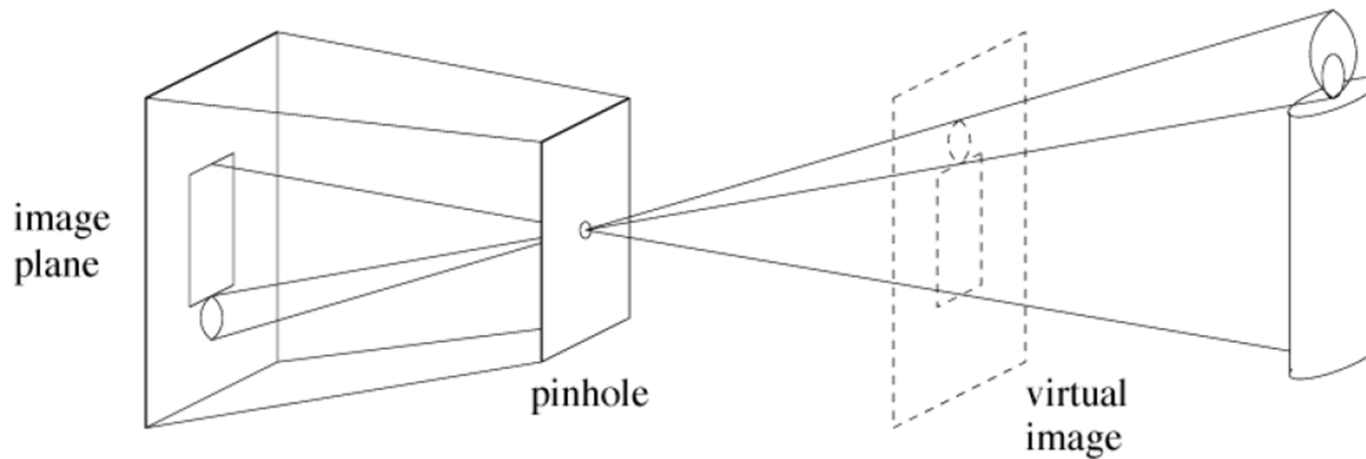


Image: Formation and Analysis

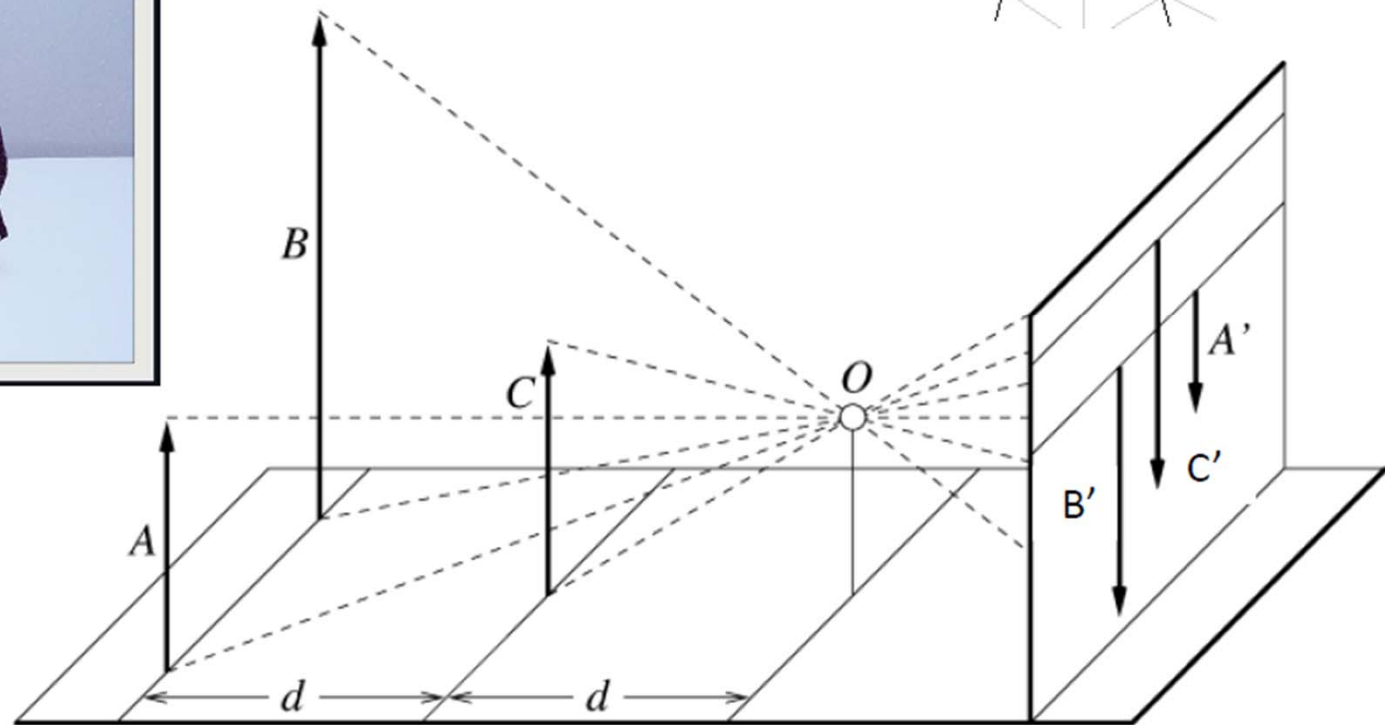
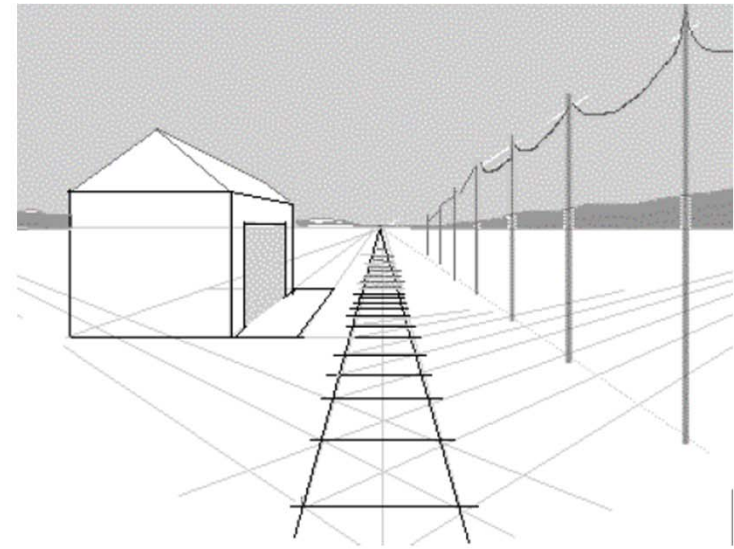
Alamdar

Pin Hole camera



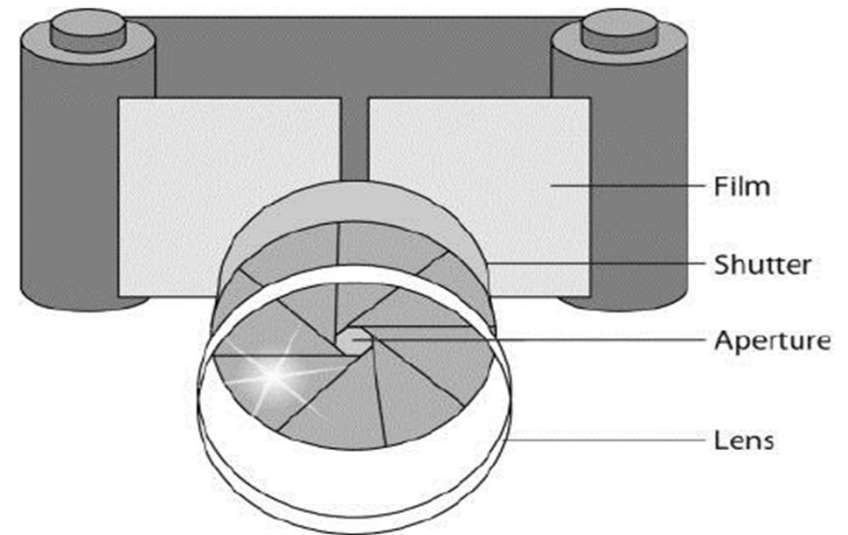
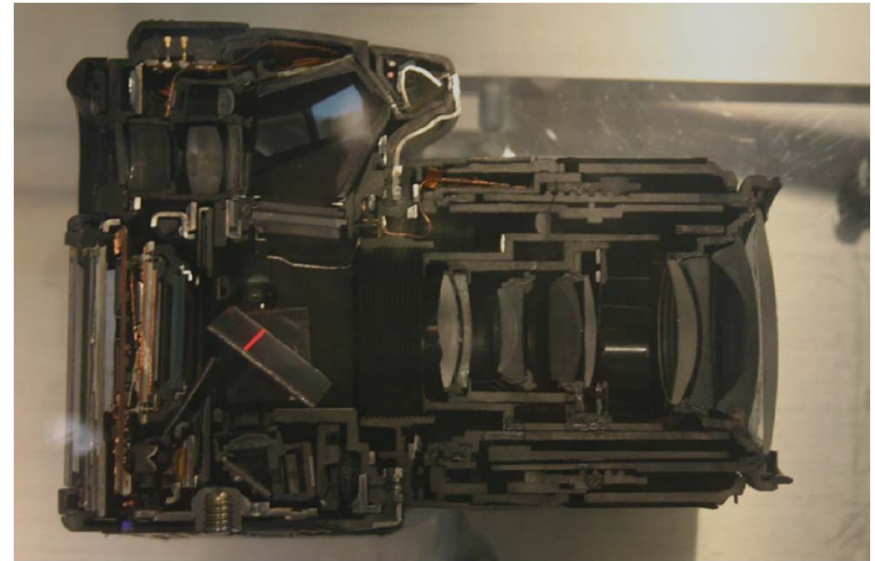
- One of the most basic schemes for imaging.
- The light passes through a pin hole, a very small aperture
- Real image is made on screen or “image plane”

- Every thing is in focus.
- Lines map to lines
- Parallel lines converge,
Perspective Distortion!
- Requires long exposure

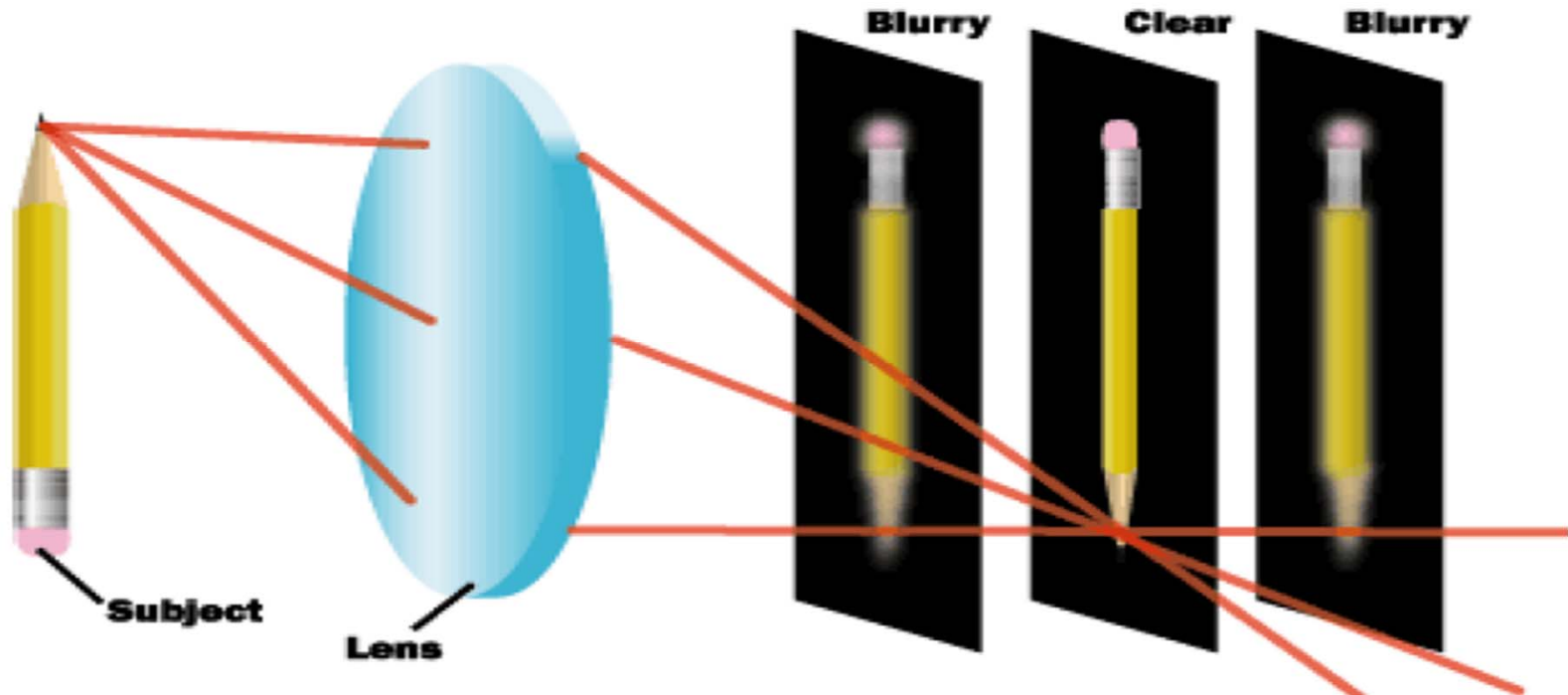


Modern Camera

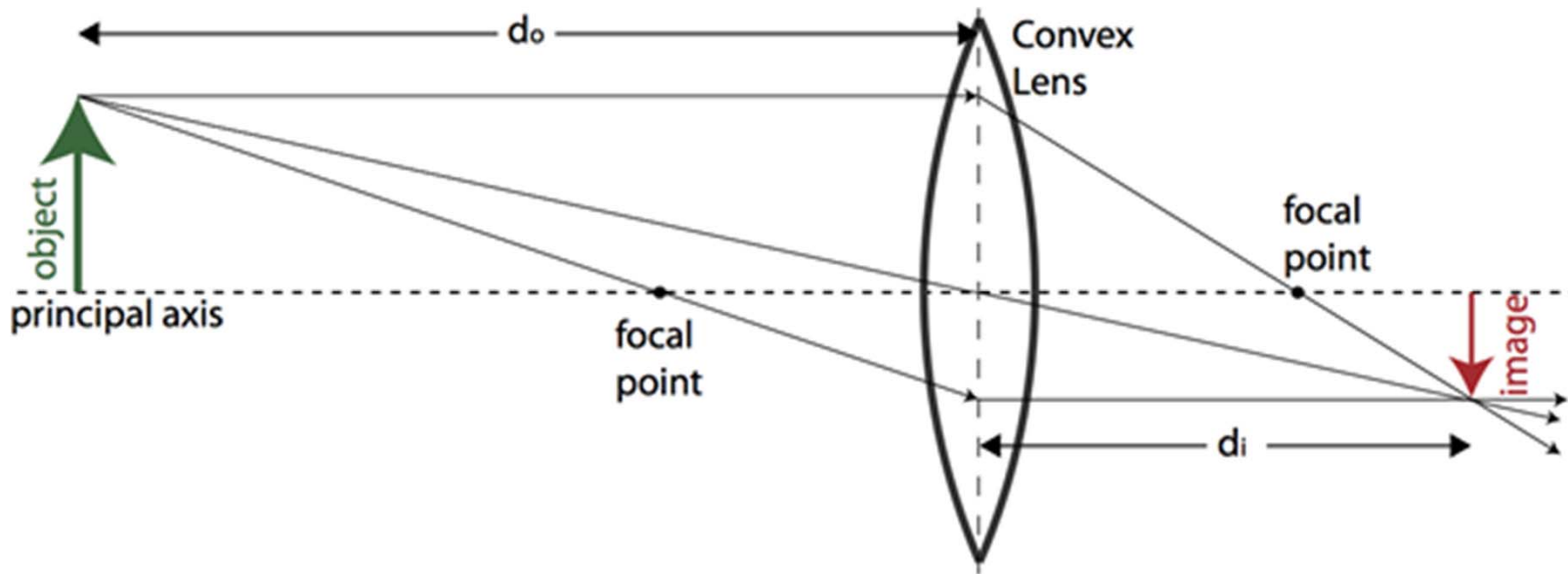
- A lens assembly along with adjustable aperture
- Gathers more light. Requires less exposure
- CCD arrays act as screens
- Cannot focus 'Everything'



- Out of focus blurring



- Lens to CCD distance fixed.
 - Lens assembly must have variable focal length
why?



$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

- A look at human eye
 - Real image formed on Retina
 - Constant lens to retina distance

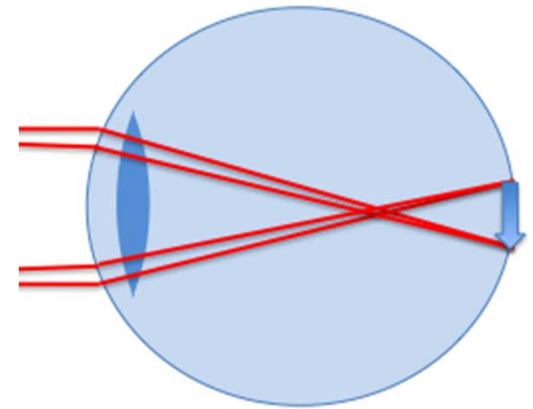


Image Artifacts

- Motion Blur
 - Exposure

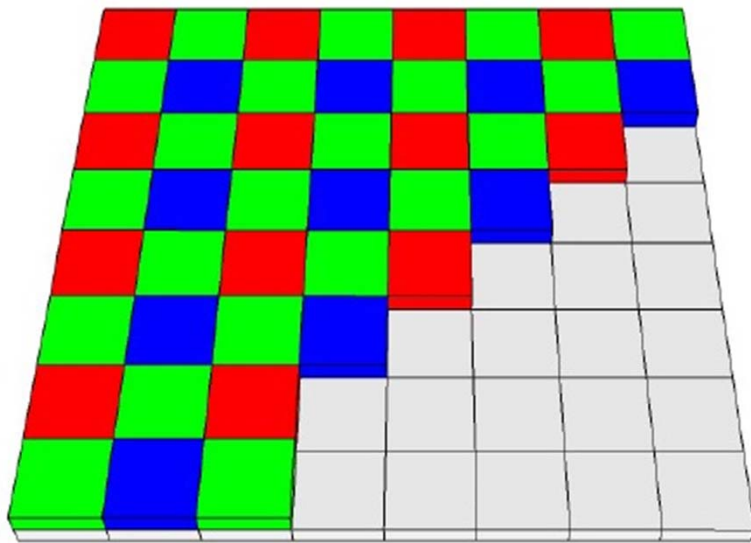


- Depth of field (DOF)
 - Aperture

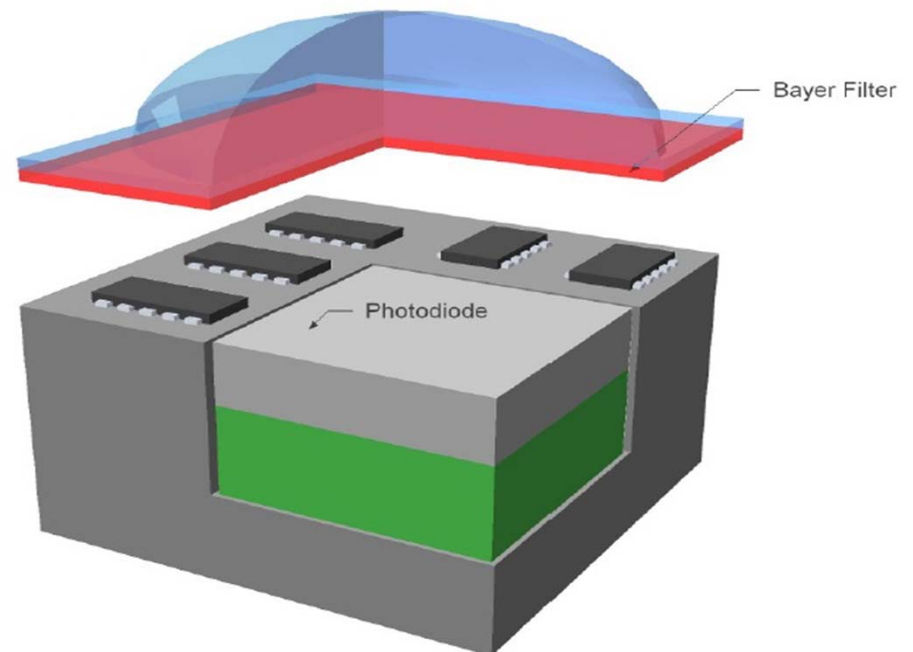


CCD : The retina of camera

- Each pixel a photodiode
- Considerable response to all visible light
- Colors produced by filters on pixels
 - Normal scheme: 2 Green, 1 Red and 1 Blue



Bayer RGB filter pattern



Digitizing Images

- Linear

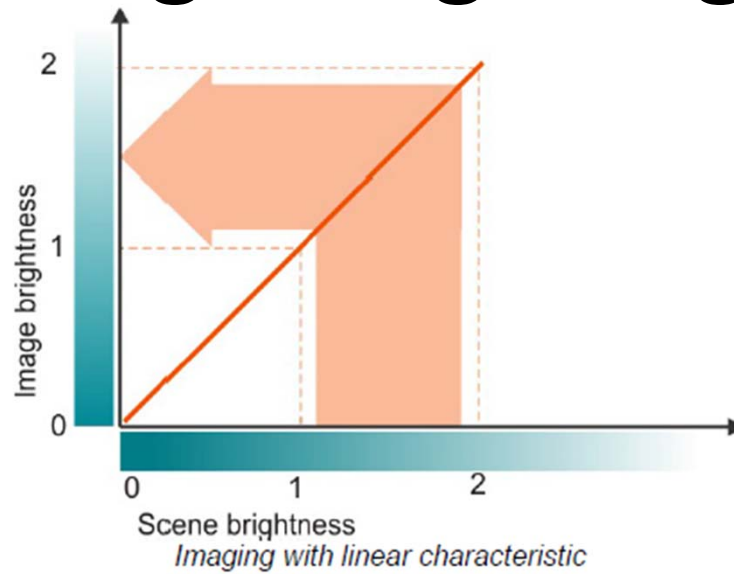


Image with linear characteristic

- Gamma

$$y = x^{\frac{1}{\gamma}}$$

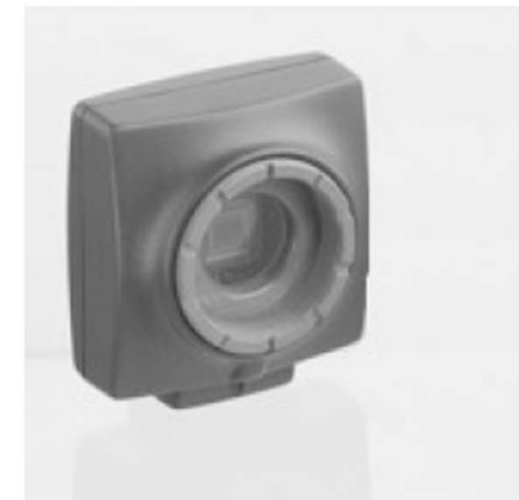
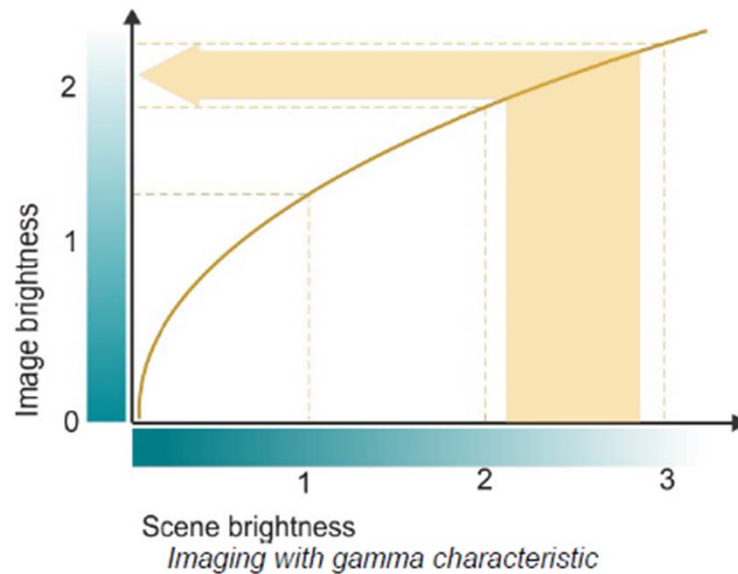
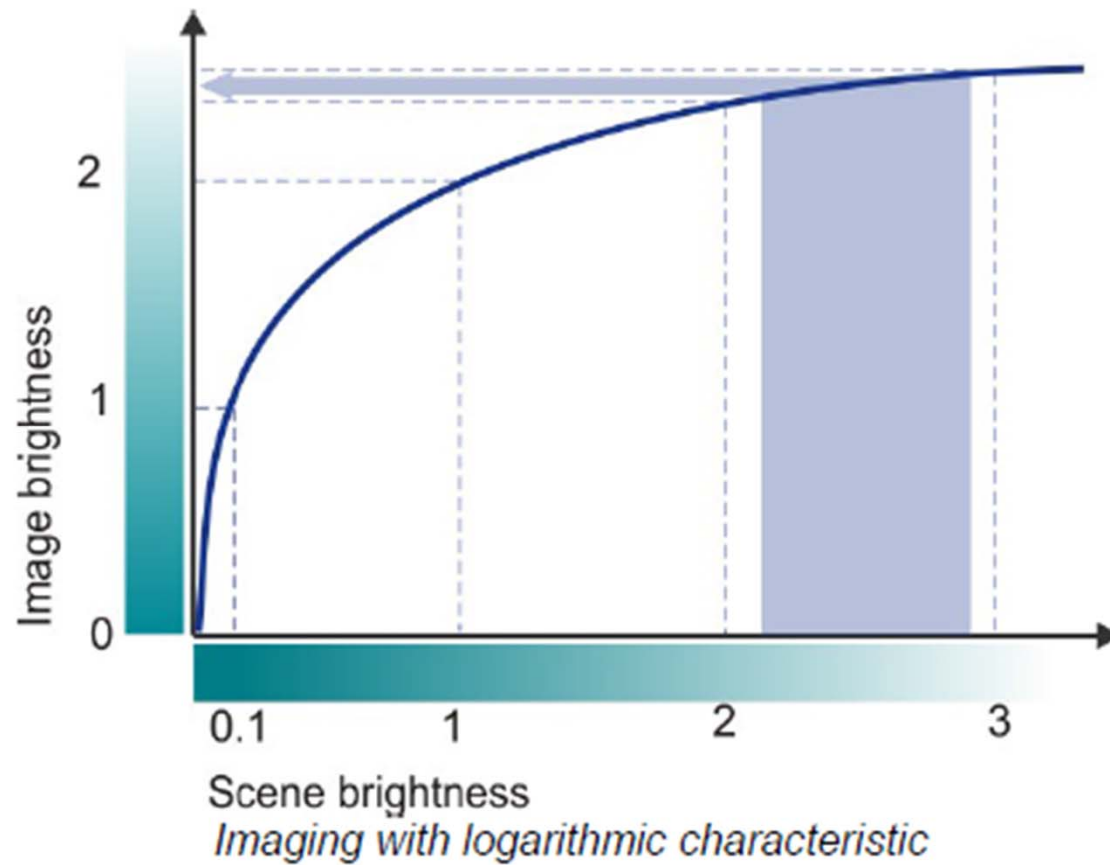
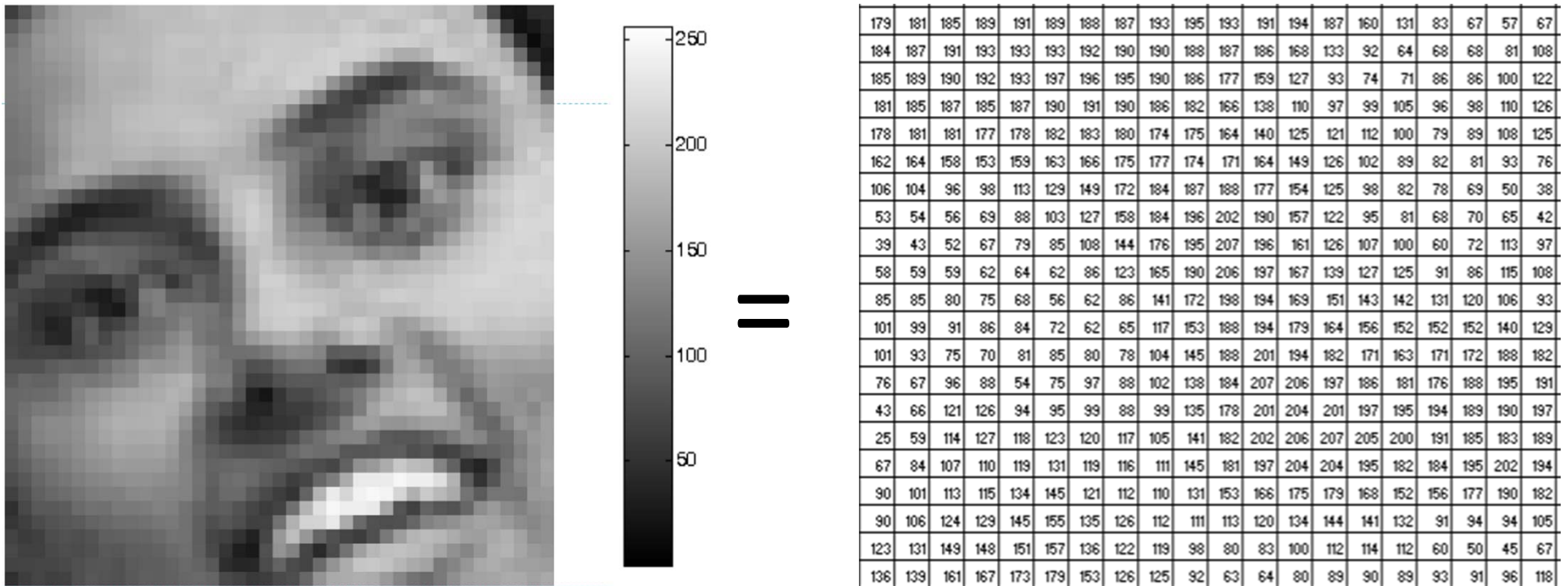


Image with gamma characteristic

- Logarithmic
 - Human Eye
 - Rich Range of tones



It's all a game of numbers



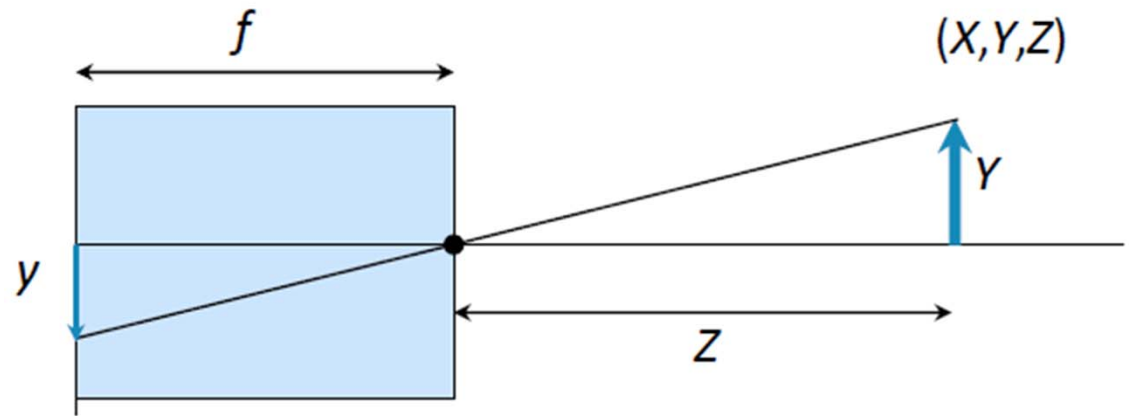
- Mathematical Model for Camera?

Camera Model

- A matrix relating world coordinates to image coordinates.

$$\frac{-y}{Y} = \frac{f}{Z}$$

$$y = -\frac{fY}{Z} \quad x = -\frac{fX}{Z}$$



- Negative sign shows inversion of image
- Assumptions
 - Camera is a pin hole camera
 - Placed at world origin

$$\begin{bmatrix} hx \\ hy \\ h \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -\frac{1}{f} & 0 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

$$\begin{aligned} hx &= X & x &= -\frac{fX}{Z} \\ hy &= Y & y &= -\frac{fY}{Z} \\ h &= -\frac{Z}{f} \end{aligned}$$

h is a scaling factor, x and y are image pixel coordinates and (X, Y, Z) are world coordinates

$$\text{Camera Matrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -\frac{1}{f} & 0 \end{bmatrix}$$

Advantages of Matrix Model

- Transformations can be applied
 - For example, Perspective distortion can be removed!
- Mathematical manipulations for matrices can now help in image analysis.

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