COMPUTER VISION (ELECTIVE-IV)

(Aug-Dec) 2022

Chingmuankim

Plan of Lecture(August-Chapter 1)

Sun	Mon	Tue	Wed	Thu	Fri	Sat
	1	2	3	4	5	6
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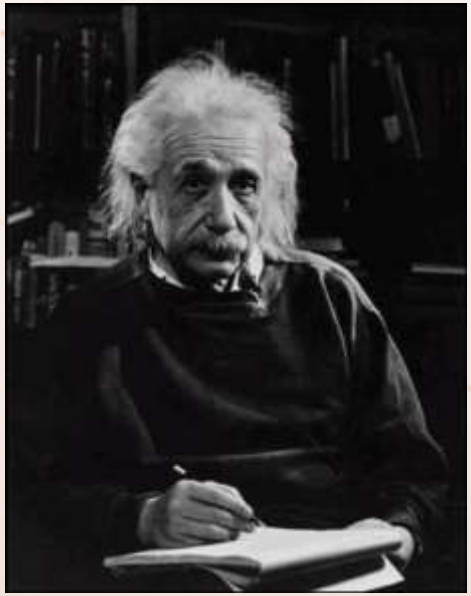
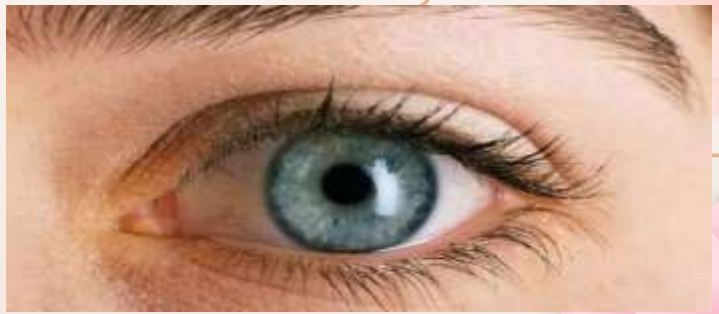
Chapter Overview

What is Computer Vision?

How do Computers perceive the environment?

COMPUTER VISION





OVERVIEW of COMPUTER VISION

What is Vision?

- The ability to see or perceive.
- Humans see through eye.
- Computers see or perceive the environment through camera.

What is Computer Vision?

- Branch of Computer Science that deals with the study of Visual Perception with the help of AI.
- Learning information about the picture such as objects present in the image and location of image.
- Ability of the computer to interpret images of real scene to obtain information useful for tasks such as Navigation, Manipulation and Recognition.

02

Exploring Related Domains

Computer Vision, Computer Graphics, Image Processing

EXPLORING RELATED DOMAINS

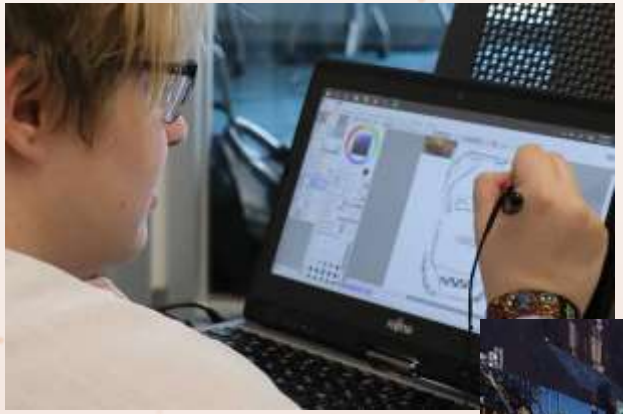
What is Computer Graphics?

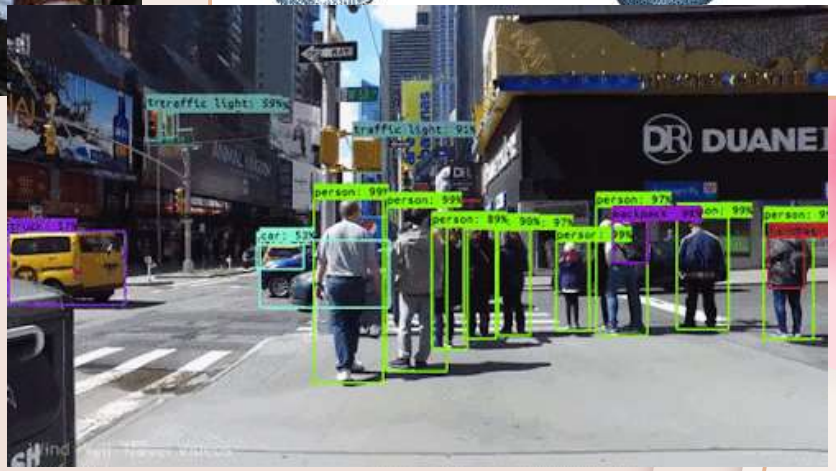
- Subset of Computer Vision
- Deals with modelling and rendering objects using algorithms.
- For example: Modelling a mango

What is Image Processing?

- Subset of Computer Vision
- Task is to enhance image, tune parameters and features.
- Different transformation operations are performed on the image.

Exploring related Domains





03

Applications of Computer Vision

Real Life Applications

Applications of Computer Vision

- Self-Driving Cars
- Robotics
- Facial Recognition
- Medical Imaging
- Handwritten Digit Recognition
- Mobile-Visual Search

Quick Recap

-Computer Vision
-Related Domains
-Applications

(CV vs CG vs IP)

Computer Vision

- Superset of Computer Graphics and Image Processing.
- Automation of human visual process
- Ability to make the machines seethe surroundings and take actions by making use of Artificial Intelligence.
- Extracting information from the image
- Can surpass human eye capability

Computer Graphics

- Subset of Computer Vision.
- Deals with creation, manipulation and storage of geometric objects and their images.
- Modelling and Rendering of objects.

Image Processing

- Also a subset of Computer Vision.
- Enhances the image quality.
- Application of three transformation operations- namely sharpening, smoothening, stretching

Applications of Computer Vision

- Factory Automation
- Optical Character Recognition(OCR)
- Biometrics
- Vending Machine
- Object Tracking
- Optical mouse
- Self-Driving cars
- Robotics
- Facial Recognition
- Medical Imaging
- Handwritten Digit Recognition
- Mobile-Visual Search

04

Image Formation Models

30-08-2022

Image Formation Models

Image

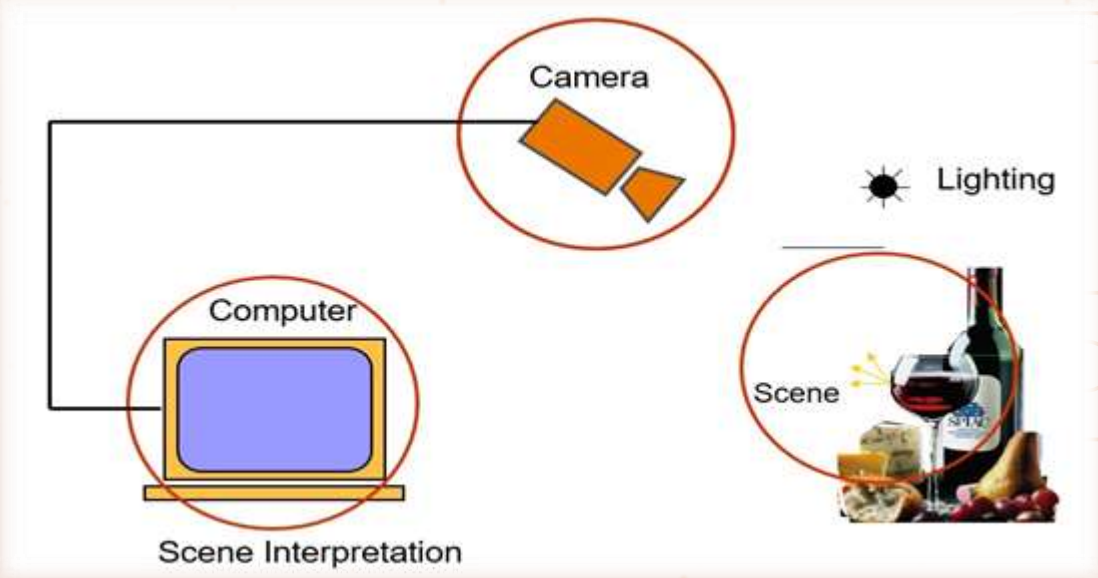
- Image is an array of pixels.
- Each pixel contains information about corresponding point in the scene.
- Projection of 3-D scene onto 2-D plane.

But wait!!! How are digital images created?

Image Formation

- First step of Computer Vision.
- Process in which the 3-D images are projected onto 2-D plane.
- Mapping of real-world scene to image.
- Knowledge about relation of the geometric position and photometric between the scene and image.

Components of Computer-Vision System



Monocular Imaging System:

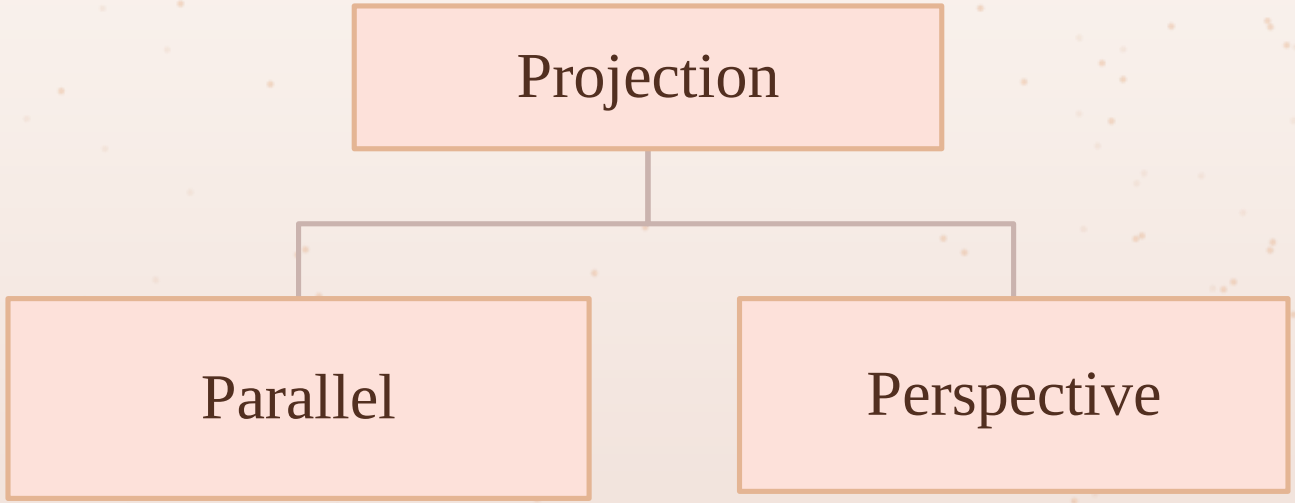
What is Monocular Vision?

- See with one eye.
- Eye is located at the side of the head.
- Animals such as Birds, Lizards, Rabbits, Goats, Cows and Deers have this type of Vision and can see lot of areas with one eye, much better than humans.
- Distance often gauged incorrectly.

What is Monocular Imaging System?

- Monocular Imaging System follows the principle of Monocular Vision.

Projection



Terminologies

- **Projection**: Process of mapping 3-D image onto a projecting display by specifying the viewing volume using world-co-ordinate and then map it over the view port.
- **World Co-ordinate**: a co-ordinate for displaying the window to display the picture.
- **View Port:** area on a display device to which a window is mapped.

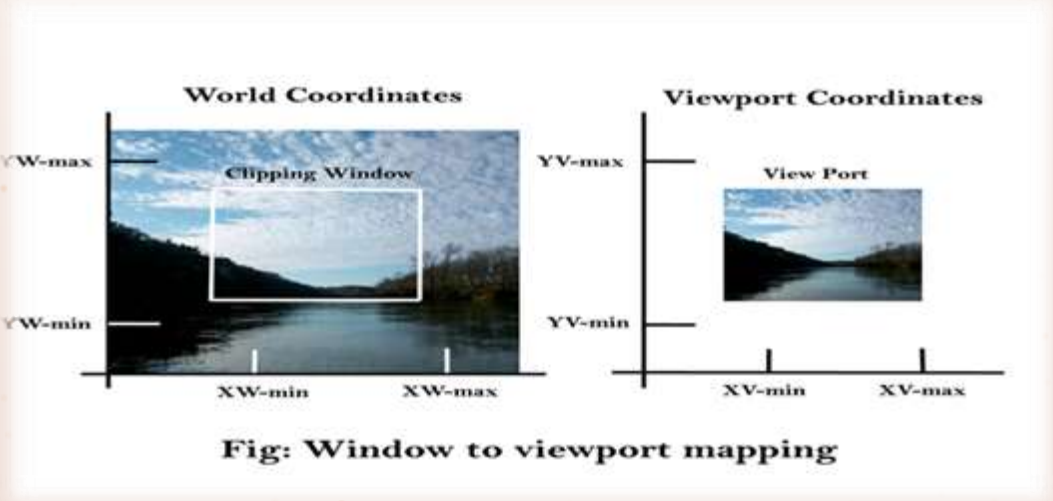
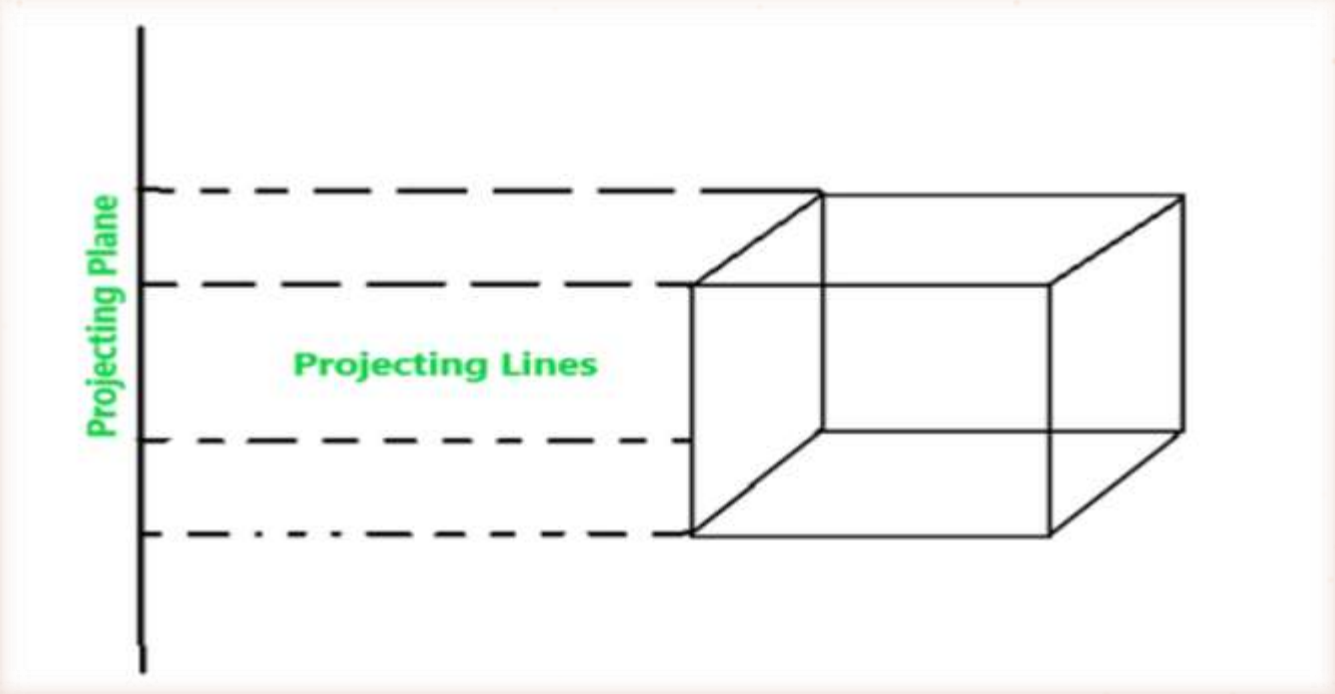


Fig: Window to viewport mapping

Orthographic Projection



Orthographic Projection

Orthographic Projection

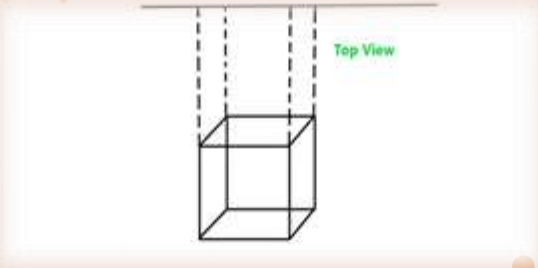
Multi-View Projection

Axonometric Projection

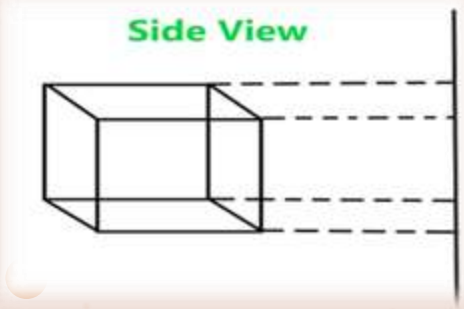
Multi-view Projection

Multiview Projection

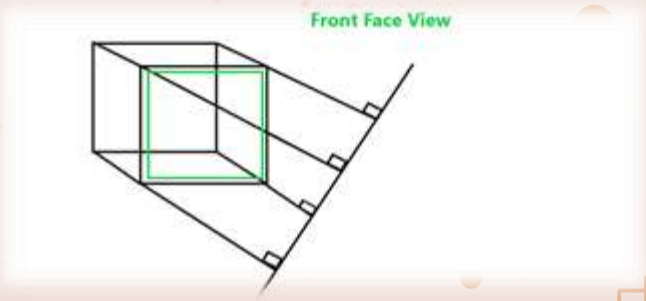
Top-View



Side-View



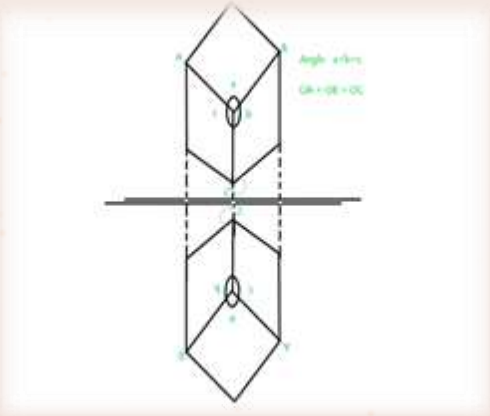
Front-View

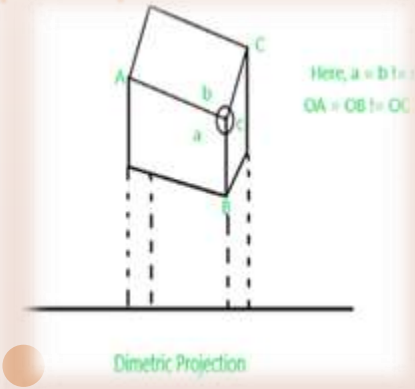


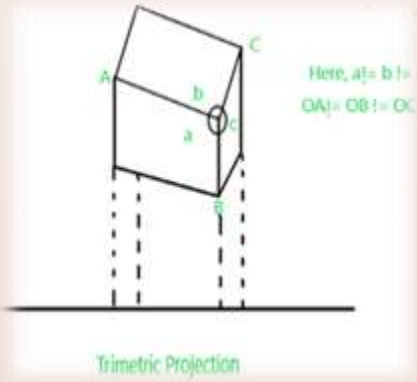
Axonometric Projection

Axonometric Projection

- Iso-metric
- Di-metric
- Tri-metric







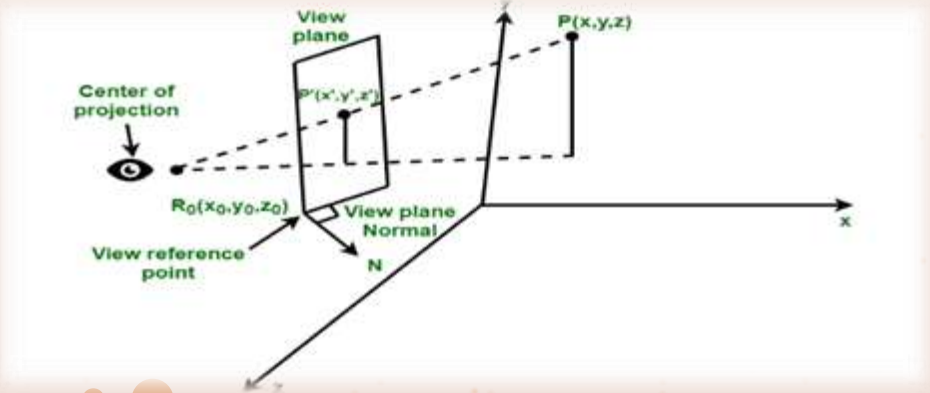
Components of a Perspective Projection

Center of Projection: It is a point where lines or projections that are not parallel to projection plane appear to meet.

View Plane/Projection Plane: View plane is determined by:

- *View Reference point $R_0(x_0, y_0, z_0)$*
- *View plane normal*

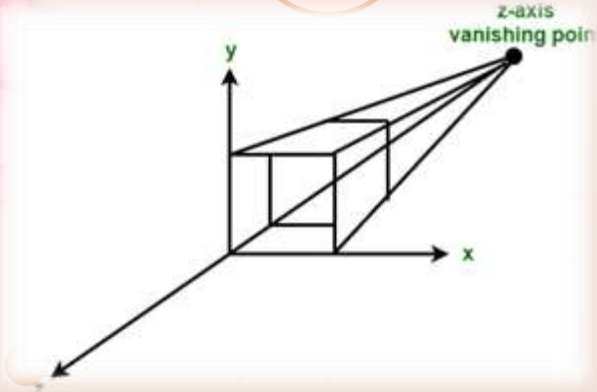
Location of an object: It is specified by the point P that is located in the world co-ordinates at (x,y,z) location. The objective of perspective projection is to determine the image point P' whose co-ordinates are (x', y', z')



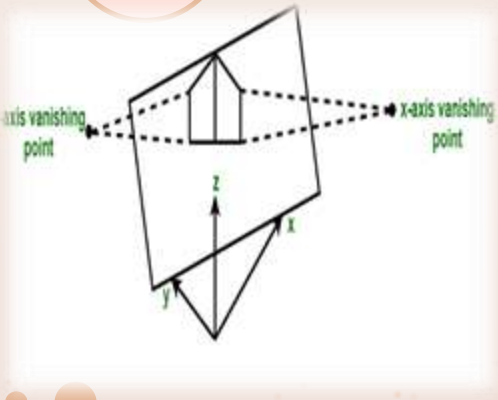
Perspective Projection

Perspective Projection

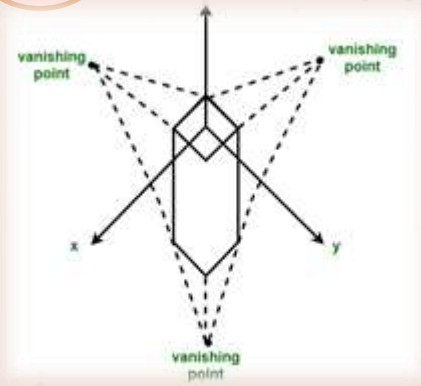
One-point Perspective



Two-point Perspective



Three-Point Perspective



Next Lecture:

- Types of Camera
  - -Pinhole Camera
  - -Wide angle Camera
- Types of projection performed by the camera
  - - Perspective Projection
  - - Parallel Projection
- Lenses
- - Why do we use it?
- - Image formation using Lenses
- - Image Magnification
- - Challenges of using Lens
- Sensors
- Image Sensors
- Types of Image Sensors

Quick Recap

- Image Formation Models
- Working of a Computer Vision
- Monocular Imaging System
- Projection

Types of Camera

Pinhole Camera

- Camera with a pinhole aperture and . no lens [Oxford dictionary]
- Simple optical device that forms an image without lens or mirror.
- Have a small view yet sharp image.
- Performs perspective projection.
- Though it produces a sharp image, it doesn't gather much light.
- What would be the effect on the image if the size of the pinhole is small?

Wide-angle Camera

- Another term for Camera with lens
- Have large fields of views.
- Will be discuss in the coming slides.

Illustration of working of Pinhole Camera

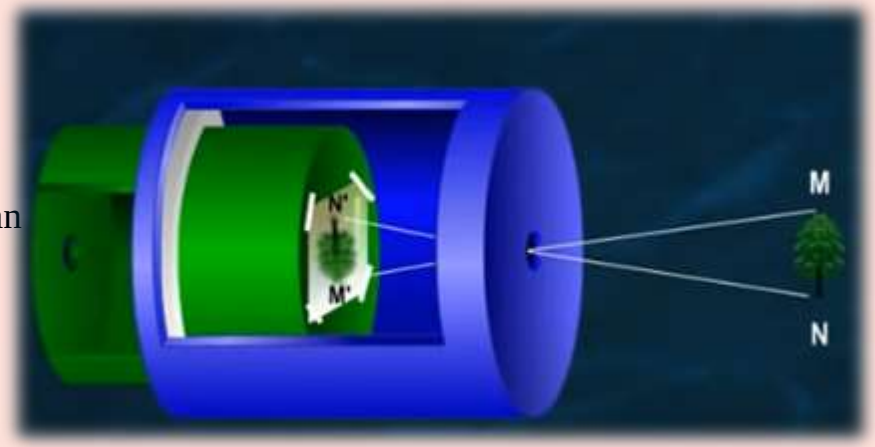
Requirement(s) : 2 hollow cylindrical boxes of different diameters such that one box can just slide with the other.

Step(s):

1) Join the 2 boxes.
2) Create a small hole in the larger cylinder and also make two holes in the smaller one, such that the inner hole of the smaller cylinder is rectangular and the outer hole is circular.
3) Fix a translucent paper(tracing paper) at the inner hole for the screen.
4) The two cylinders must be enclosed so that light is prevented from entering the larger cylinder. Otherwise, our image can be messed up.
5) Our pinhole camera is ready.

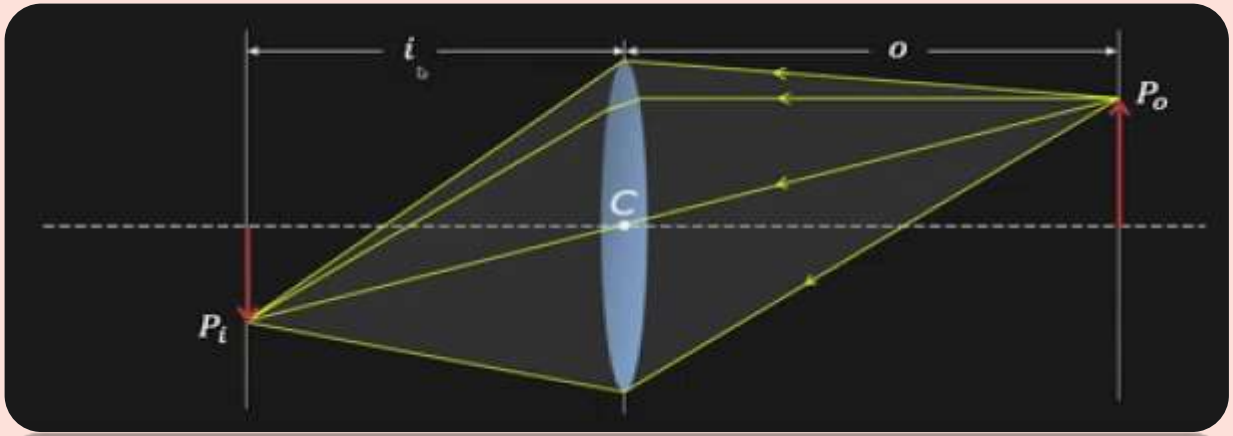
Illustration of working of Pinhole Camera

1) Use the created pinhole camera and try looking at an object.
2) What do you observe?
3) What if you slide the smaller cylinder back and forth?
4) What is the size of the image Obtained on the screen?
5) What are the parameters that can affect the size and contrast of the image?



Lenses- Image formation using Lenses

Lenses have same projection as pinhole camera, but gathers more light.



Gaussian Lens- Thin Lens Law

What is the relationship between the position of the object and the position of its image?

f: focal length
i: image distance
o: object distance

$$\frac{1}{i}+\frac{1}{o}=\frac{1}{f}$$

Focal length is the distance between focussed image and the object.
Focal length defines the bending power of the lens and is determined by few factors: Refractive Index of the material the lens is made of and shape of the lens.

Gaussian Lens- Thin Lens Law

The shape of the lens has two surfaces:

- curved surfaces
- spherical surfaces

The radii of two surfaces also determines the focal length of the lens

Image Magnification

Image Maginification due to lens:

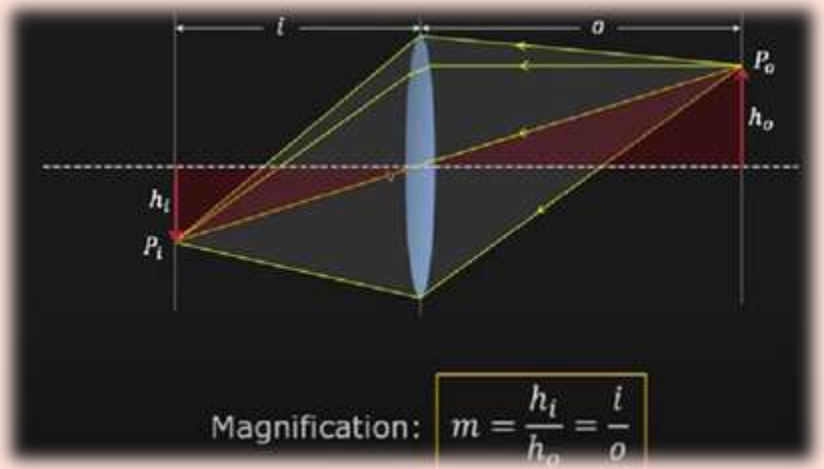
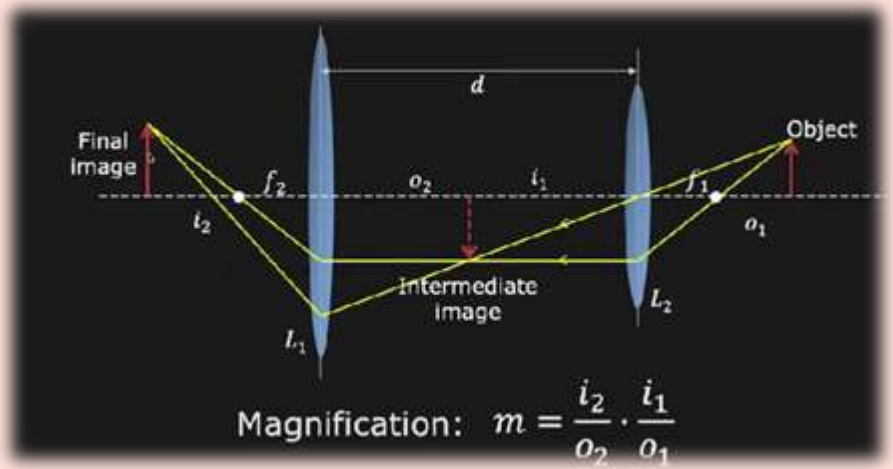


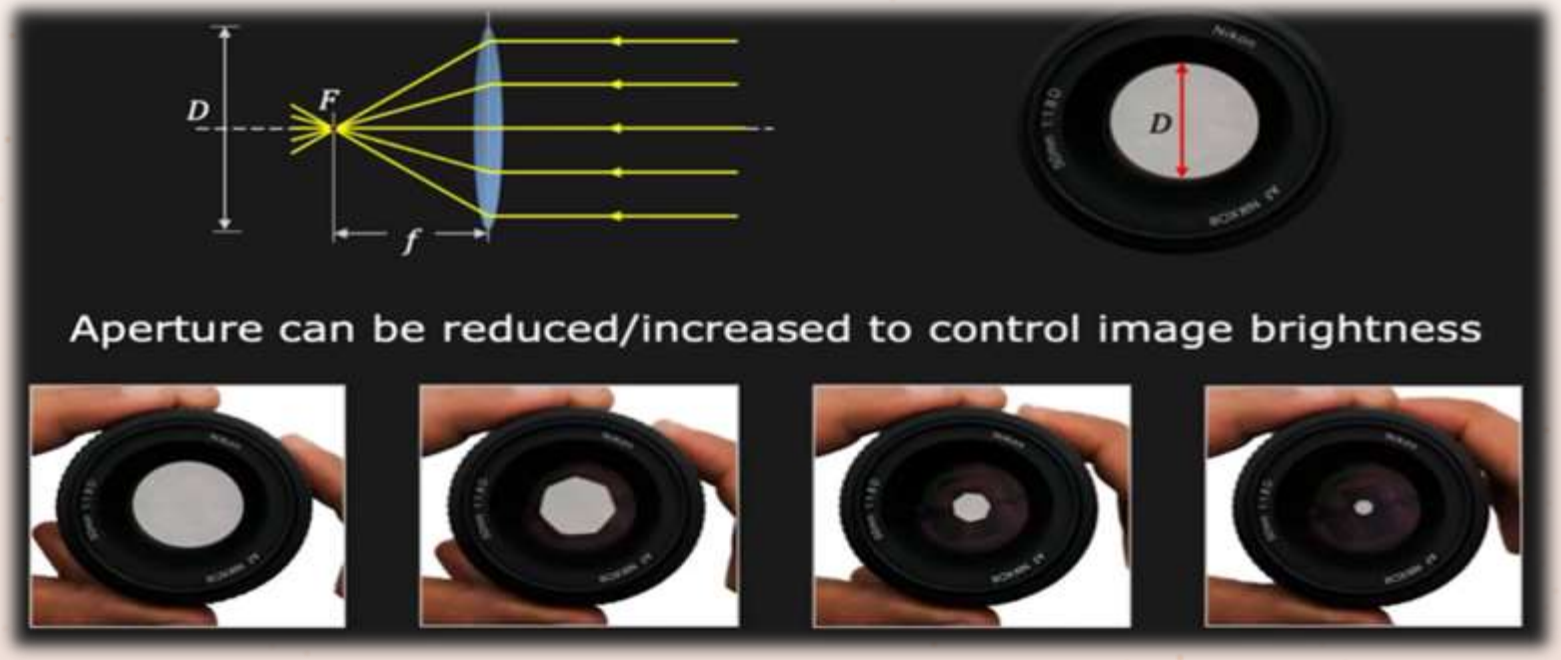
Image Magnification

Image Maginification due to multiple lens:



Aperture of the lens

- Light receiving area of lens
- This Aperture is indicated by a lens diameter D
- Aperture is responsible for Image brightness.



Aperture of the lens in terms f-number

- f-number is the fraction of the focal length.
- f-number(f-stop, f-ratio) of lens
- Mathematically Aperture is given by:

$$D=\frac{f}{N}$$

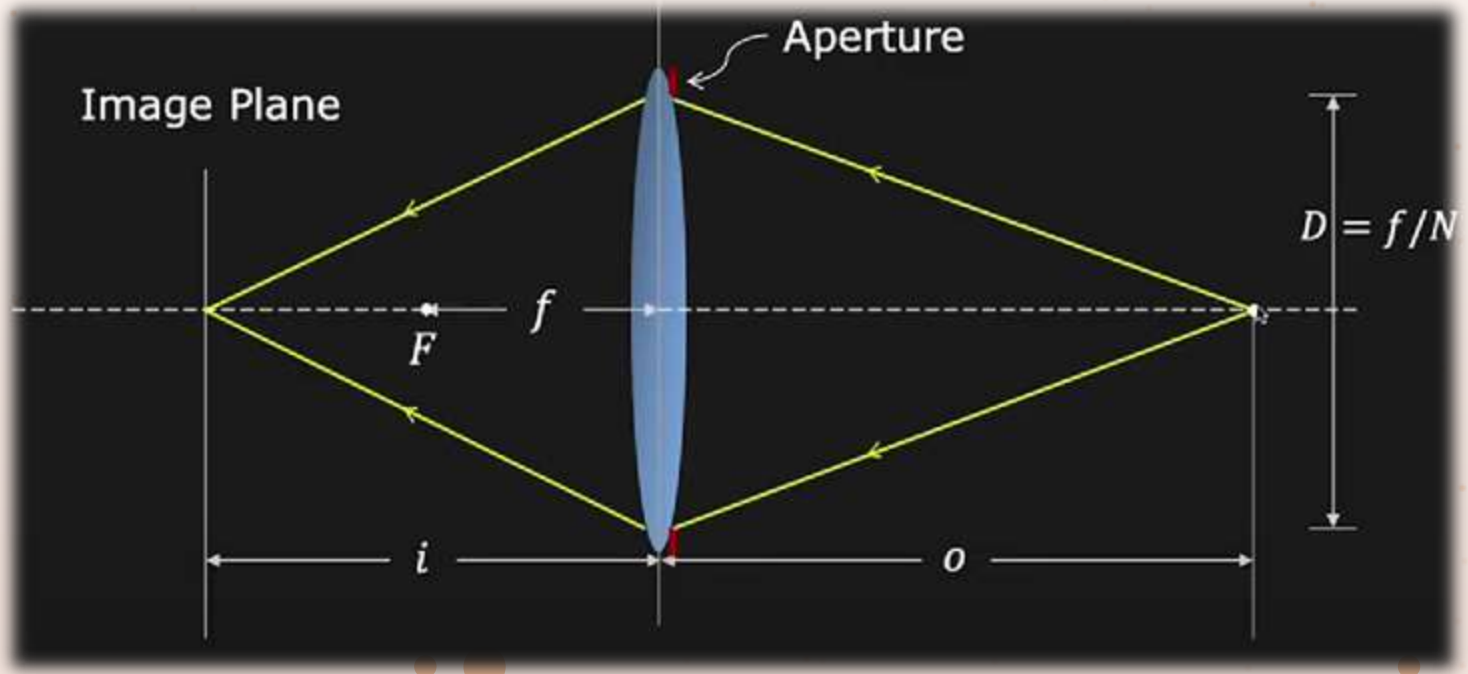
- And f-Number is denoted as N, given by:

$$N=\frac{f}{D}$$

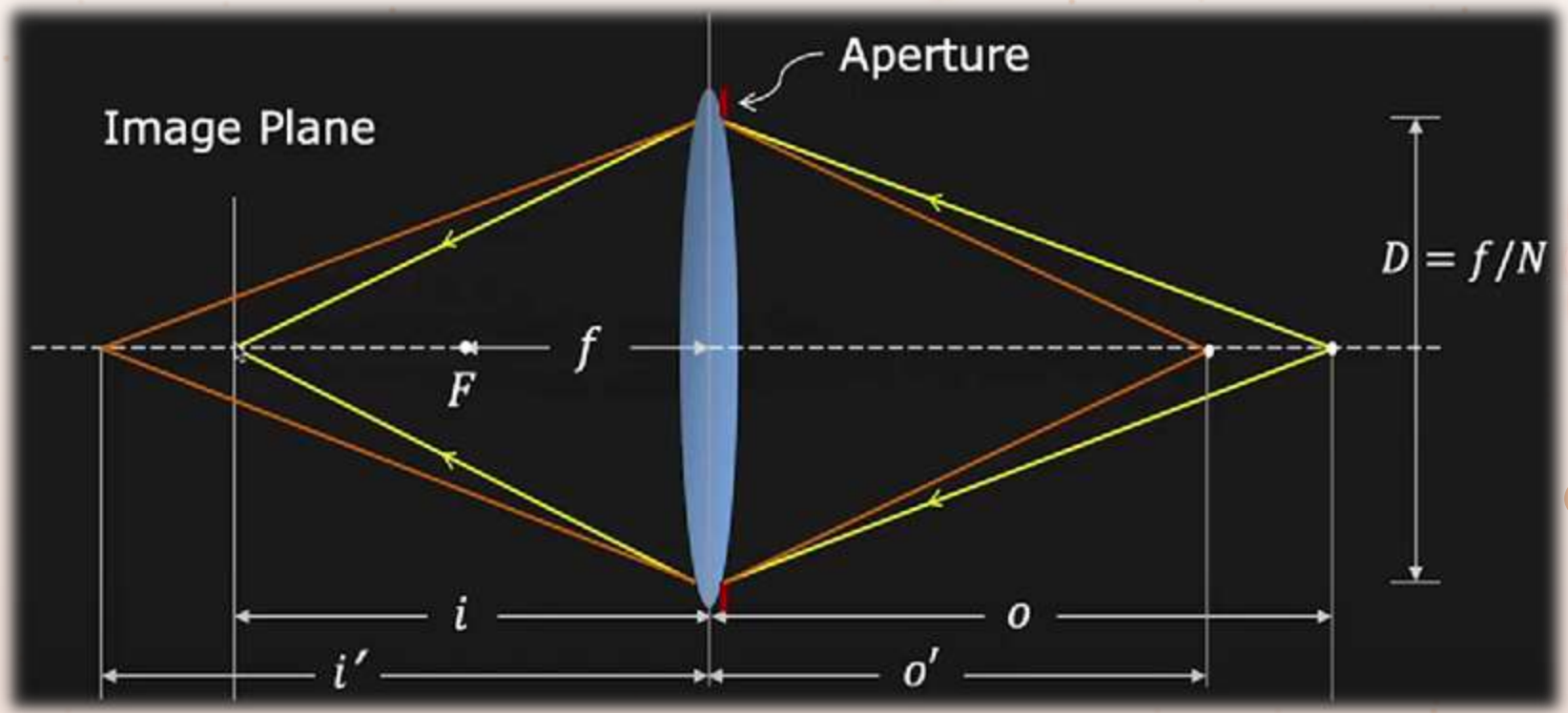
- *What is f, D and N here?*
- *If your camera lens have a focal length of 50mm, and an f-number of 1.8, can you determine whether the aperture is open or close using the given information? If so, then what is the condition of the aperture?*
- *What is the relationship between the aperture diameter(D) and the F-number(N)?*

Demerit of using Lens

- ***Lens De-focus****: only one plane in the scene(P_0) is perfectly focussed onto the image plane(P_i) by the lens.*



What if it lies out of the plane of focus?



Contd…

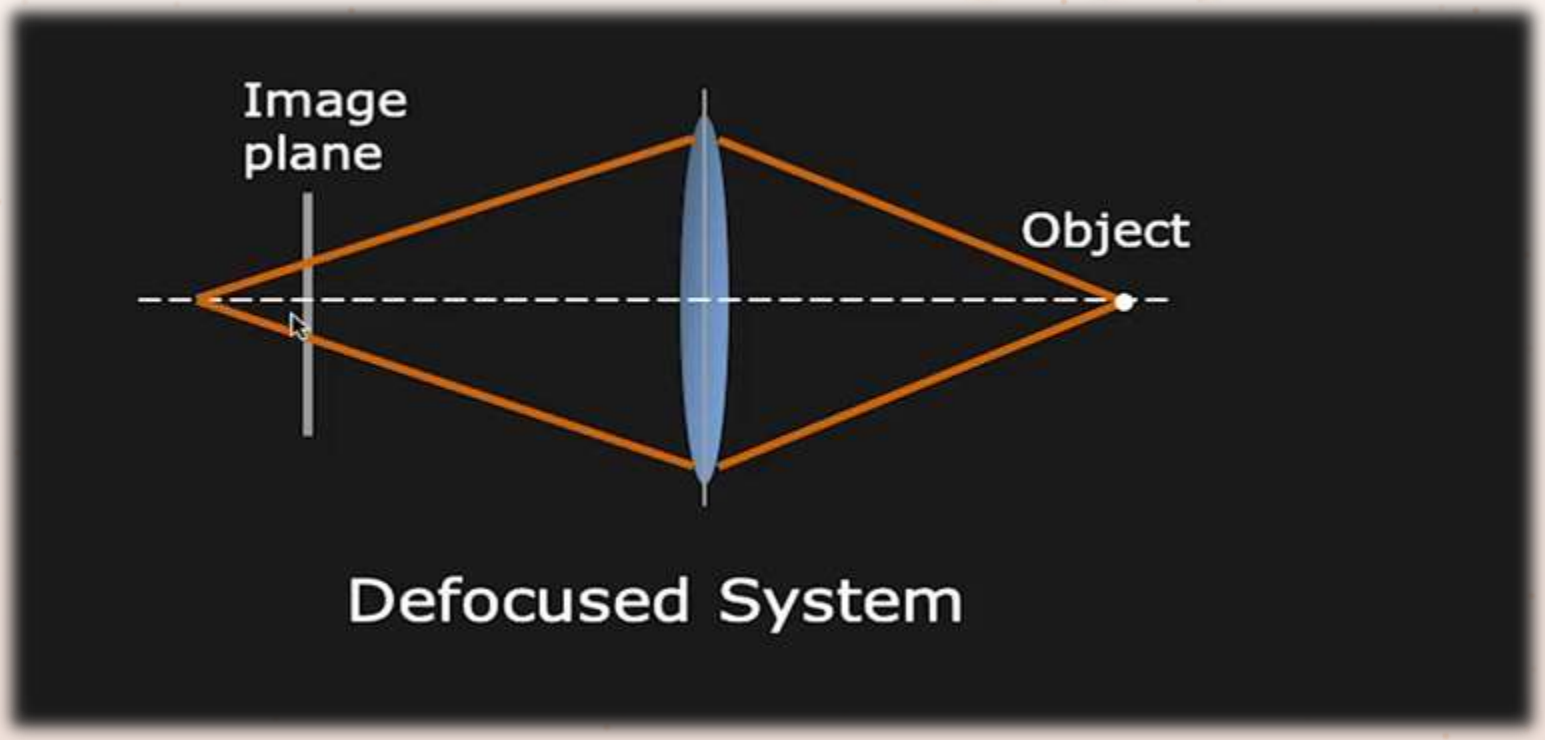
From similar triangles:

$$\frac{b}{D} = \frac{|i' - i|}{i'}$$

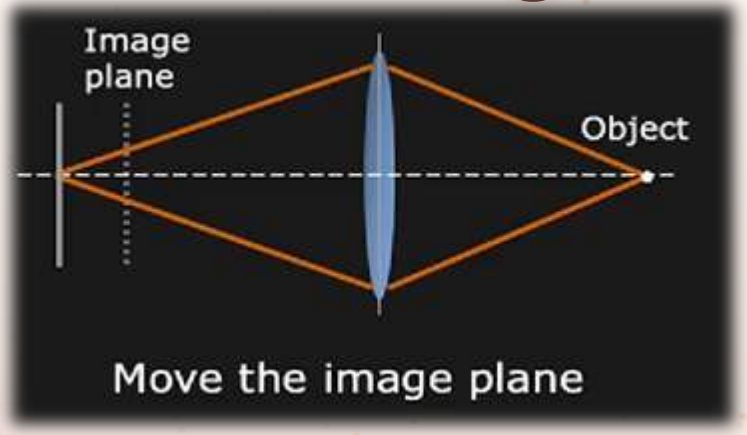
Blur circle diameter:

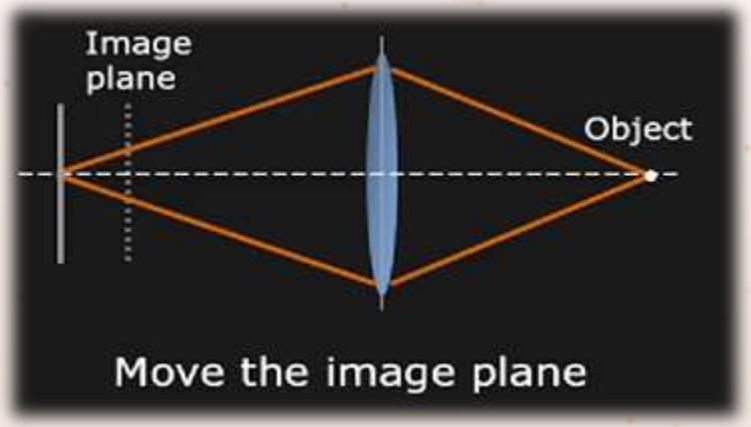
$$b = \frac{D}{i'}|i' - i|$$

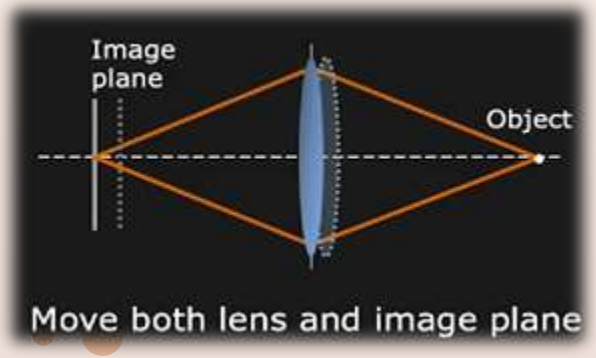
How do we focus on Imaging System?



Fixing a defocussed image



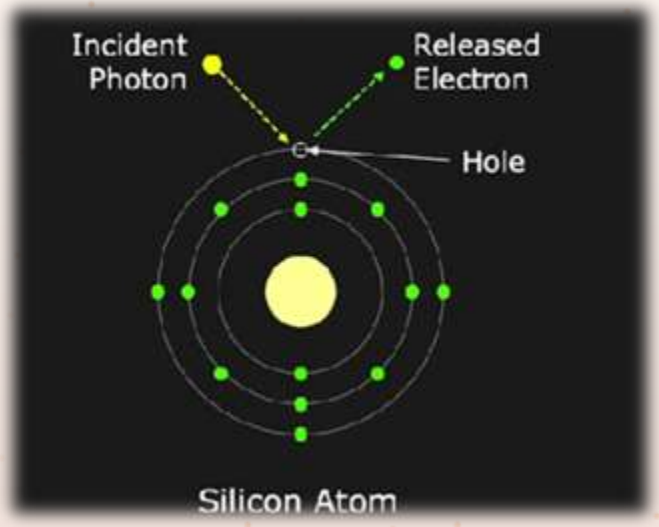




Sensors- Image Sensors

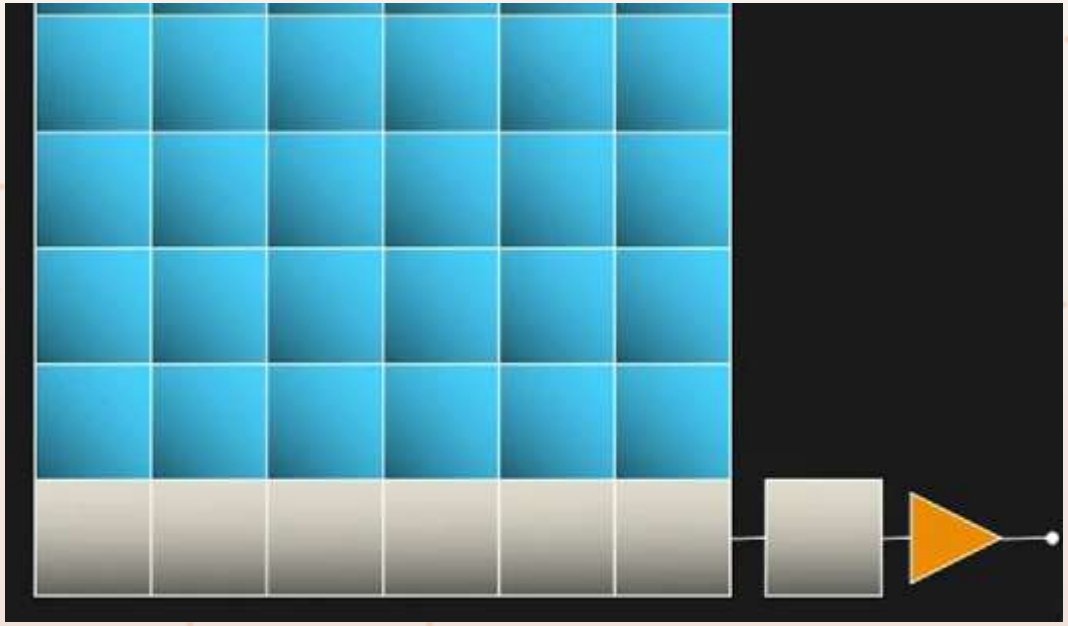
Image Sensor is a device that allows the camera to convert photons to electrical signal that can be interpreted by the device.

Sensors and its Types

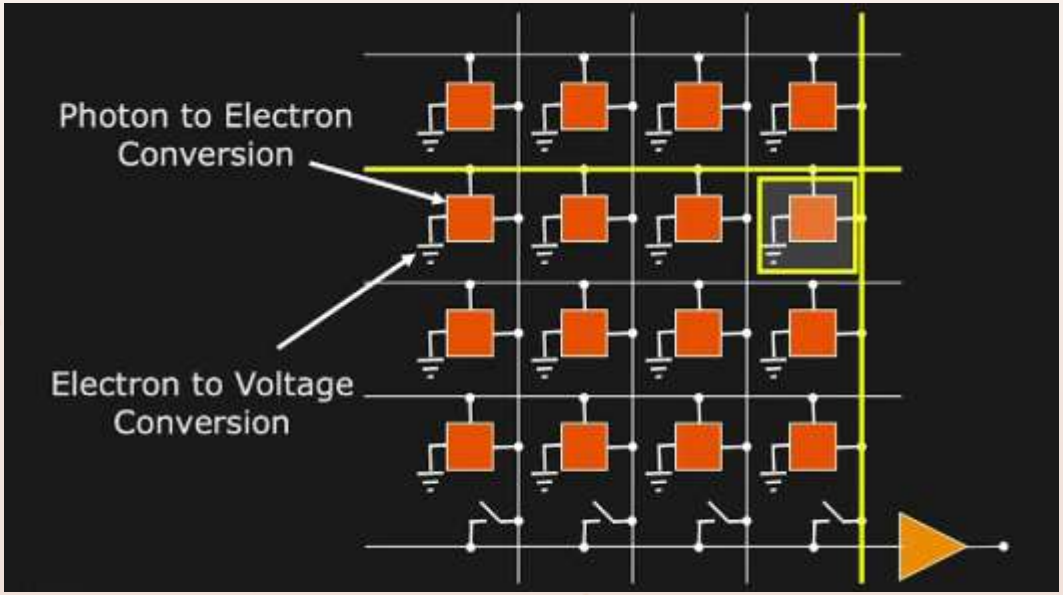


1) CCD (Charge coupled Device)
2) C-MOS (Complimentary Metal Oxide Semi Conductor)

Charge Coupled Device(CCD)



Complimentary Metal Oxide Semi-Conductor(C-MOS)



Next Lecture:

- Radiometry
  - Light
  - Measuring Light
- Surface Representation
  - Color spaces
  - Camera model
  - Camera Calibration
- Binocular Imaging System
  - Sources
  - Shadows and Shading
- Numerical
  - Pinhole Camera
  - Lens
  - Aperture
  - Sensors
  - Camera Calibration

Quick Recap

- Cameras
  - Pinhole Camera
  - Lens
  - Aperture
  - Sensors
- Types of Projection by the camera
- Advantages and Disadvantages

Radiometry- Light and Measuring Light

Image Intensity Understanding:

What is it?

What are the factors that affect the intensity of a point?

Color Spaces in Computer Vision

What are the different color spaces available?
Explain each of them using a diagram.

Camera Model and Camera Callibration

How would you model a camera? What are the standard methods for modelling a camera? Give its mathematical explanation with appropriate diagram.

Shadows and Shading

Any doubts, we will discuss every Tuesday and Friday in classroom between 2-4pm. Only interested people are welcomed.
Tuesday Classroom(opp to Samsung Lab, Dept of Computer Science, 3rd Floor)
Friday Classroom(LW3-SF4, Dept of Computer Science, 2nd Floor, behind Software Testing Lab)

We will complete 3 chapters before mid term examination.

Thanks!