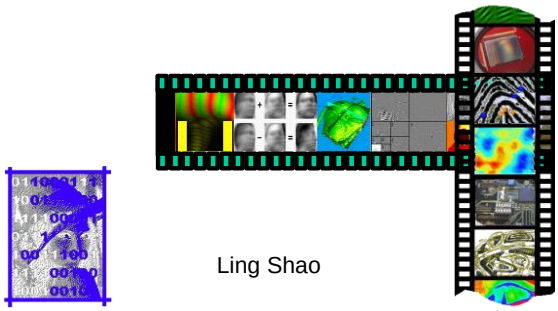
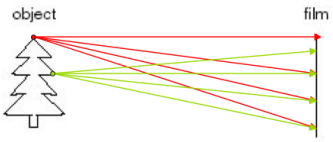
EEE6082 Computational Vision



Ling Shao

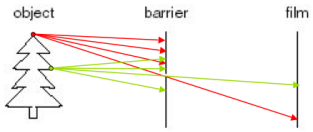
How do we see the world?



- Let's design a camera
  - Idea 1: put a piece of film in front of an object
  - Do we get a reasonable image?

2

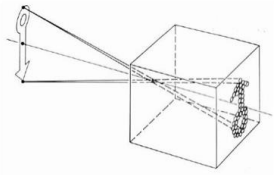
Pinhole camera



- Add a barrier to block off most of the rays
  - This reduces blurring
  - The opening known as the **aperture**
  - How does this transform the image?

3

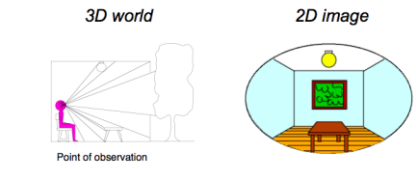
Pinhole camera model



- Pinhole model:
  - Captures **pencil of rays** – all rays through a single point
  - The point is called **Center of Projection (COP)**
  - The image is formed on the **Image Plane**
  - **Effective focal length *f*** is distance from COP to Image Plane

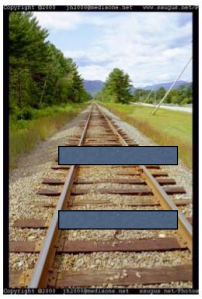
4

Dimensionality Reduction Machine (3D to 2D)

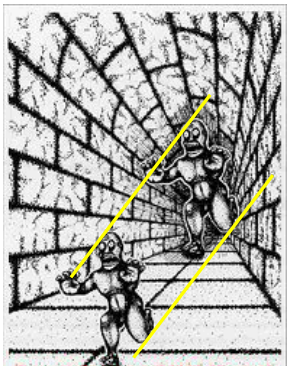


- What have we lost?
  - Angles
  - Distances (lengths)

5

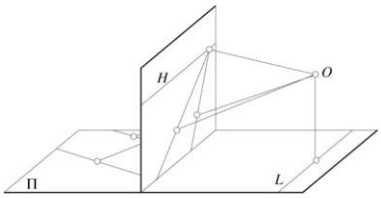


6



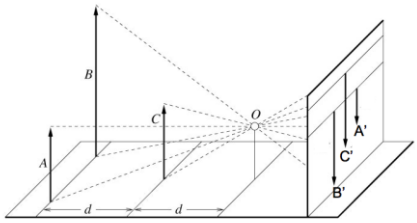
7

Parallel lines aren't…



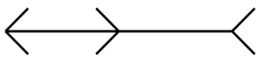
8

Distances can't be trusted...

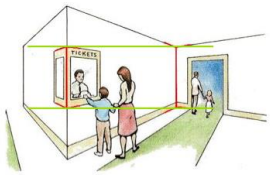


9

We adapt ....

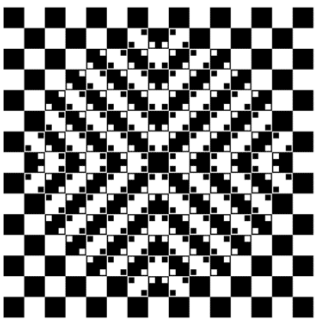


Müller-Lyer Illusion



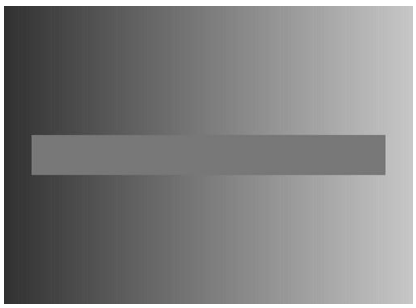
10

More illusions…



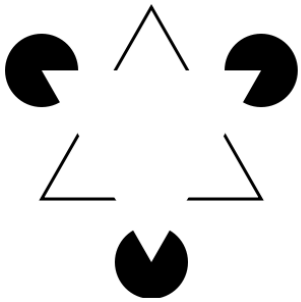
11

More illusions…



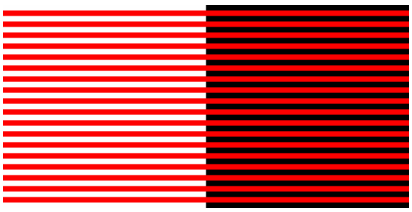
12

More illusions…



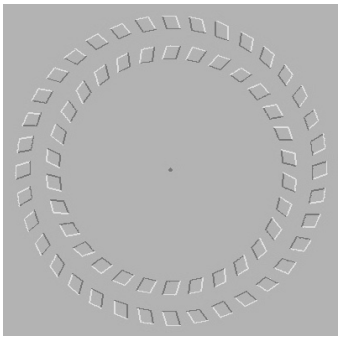
13

More illusions…



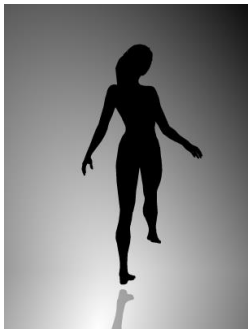
14

More illusions…



15

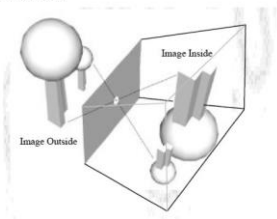
More illusions…



16

Pinhole camera

http://www.pinhole.org/



17

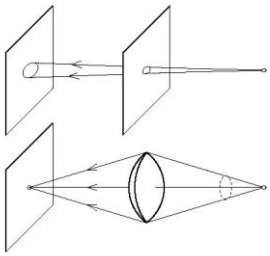
Home-made pinhole camera

Why so blurry?

http://www.debevec.org/Pinhole/

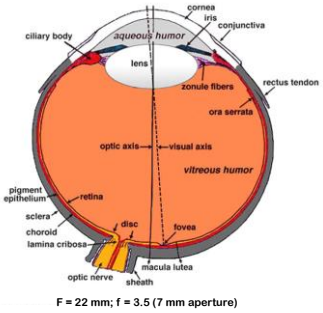
18

Cameras with lenses



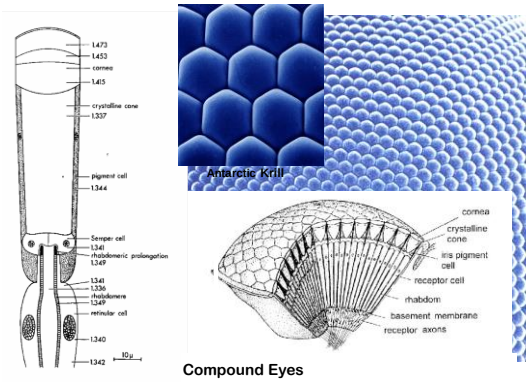
19

Human Eye



F = 22 mm; f = 3.5 (7 mm aperture)

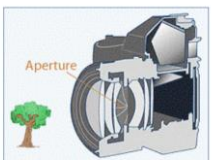
20



Compound Eyes

21

Camera Model



Focal length
Aperture
Exposure time

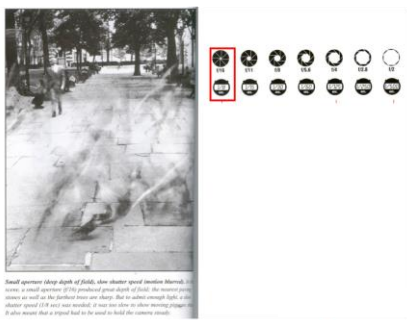
22

Reciprocity

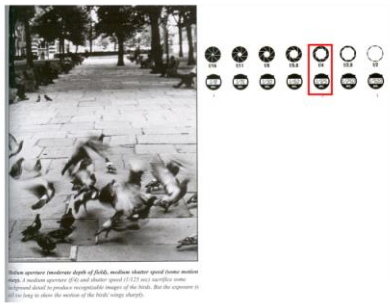
- Assume we know how much light we need
- We have the choice of speed/aperture pairs

- What will guide our choice of a shutter speed?
  - Freeze motion vs. motion blur, camera shake
- What will guide our choice of an aperture?
  - Depth of field, diffraction limit
- Often we must compromise
  - Open more to enable faster speed (but shallow DoF)

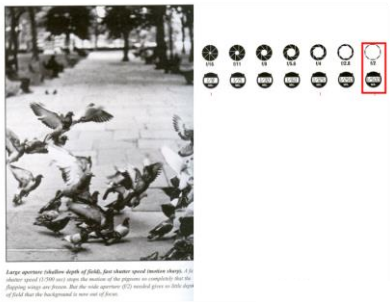
23



24



25



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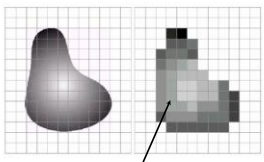
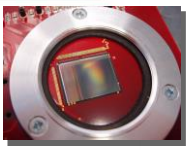
Sensor Array





CMOS Imager

Discrete Pixels (Picture Elements)

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Image Sensors

- Images are formed by the interaction of the incident image irradiance with light sensitive elements on the image plane
- Light sensitive elements
  - Film
  - Charge Coupled Device (CCD)
  - CMOS Imaging element

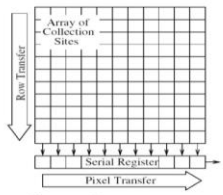

Figure 1.22. A CCD Device.

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Digital Snapshots

- A digital image is an array of numbers indicating the image irradiance at various points on the image plane
- Image intensities are spatially sampled
  - The Image irradiance function across the retinal plane is sampled to obtain the digital image
  - The spacing of the image elements limits the resolution of the image
  - The frequency content of the irradiance function is limited by the effective aperture of the camera
- Intensity values are quantized (8-bits, 10-bits, 12-bits)
- Video Imagery
  - For a video camera, Images are taken sequentially by opening and closing the shutter 30 times per second

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Seeing in Colour

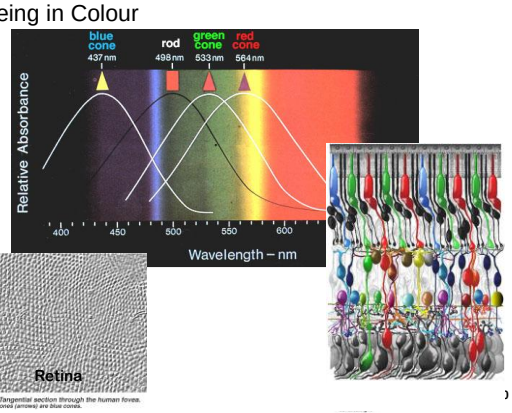
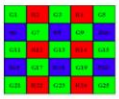


Fig. 13. Tangential section through the human fovea. Larger cones (arrows) are blue cones.

Sensing Color

- In a 3 CCD video camera the light path is split into three components which are passed through colored light filters and then imaged
- As a result - a color image contains three channels of information; red, green and blue image intensities
- In a 1-CCD color camera color information is obtained by covering the individual elements with a spatially varying pattern of filters, RGB

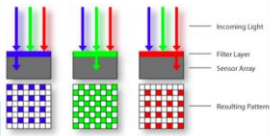


Bayer pattern used to capture color images on a single imaging surface

31

Practical Color Sensing: Bayer Grid

Estimate RGB at 'G' cels from neighboring values



http://www.cooldictionary.com/words/Bayer-filter.wikipedia

32

In a computer…
an image is a 2 dimensional table of numbers, a 2D matrix

121	121	118	111	…	21
134	136	137	132	…	23
133	131	136	136	…	25
136	145	148	151	…	34
137	140	147	149	…	54
…	…	…	…	…	…
231	233	243	244	…	179

i

j

I(i,j) is the sensor value at location x = i, y = j

I(2,1) = 133
I(3,4) = 136

Any 2D matrix can be seen as an image

33

(r,g,b) = (255,255,251) (222,15,7) (0,0,0) (89,120,1)

(246,99,0

(19,37,87) (255,255,115)

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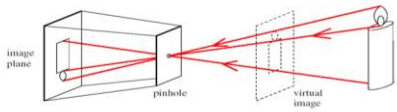
The Pinhole Camera

– Light enters a darkened chamber through a pinhole opening and forms an image on the further surface



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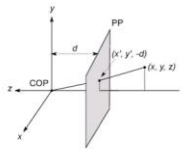
Modeling (pinhole) projection



- The coordinate system
  - We will use the pin-hole model as an approximation
  - Put the optical center (**C**enter **O**f **P**rojection) at the origin
  - Put the image plane (**P**rojection **P**lane) *in front* of the COP
    - Why?
  - The camera looks down the *negative* z axis
    - we need this if we want right-handed-coordinates

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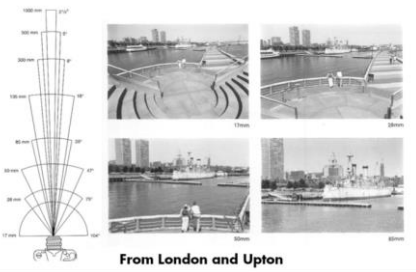
Field of View (Zoom)



From London and Upton

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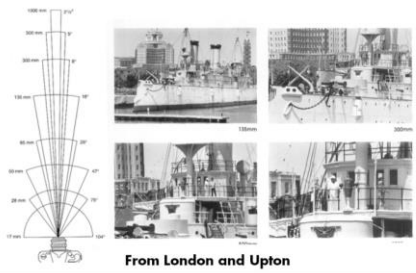
Field of View (Zoom)



From London and Upton

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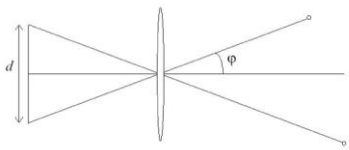
FOV depends of Focal Length



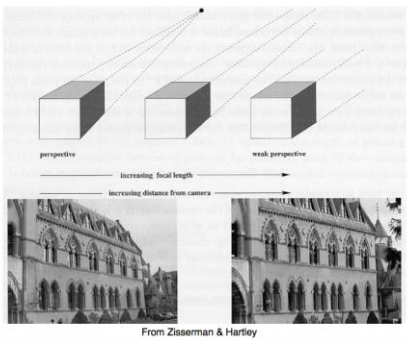
Size of field of view governed by size of the camera retina:

$$\varphi = \tan^{-1}\left(\frac{d}{2f}\right)$$

Smaller FOV = larger Focal Length

40

Perspective



From Zisserman & Hartley

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Field of View / Focal Length

Large FOV, small f
Camera close to car

Small FOV, large f
Camera far from the car

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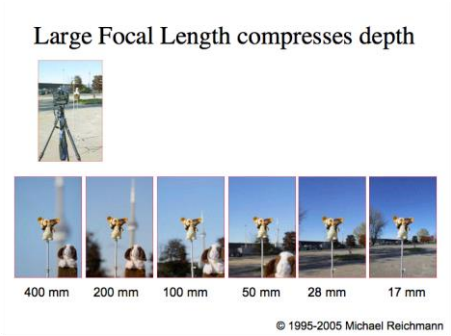
Large Focal Length compresses depth
400 mm
200 mm
100 mm
50 mm
28 mm
17 mm
© 1995-2005 Michael Reichmann

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