Video 1.1
Jianbo Shi

Kodak moments

Capturing Moment

"Rituals Enhance Consumption," Kathleen Vohs, Psychological Science 2013

Moments: selfie

Reid Wiseman and Alexander Gerst with a Nikon D2X and a Nikkor 10.5mm fisheye lens,

DATE:1920

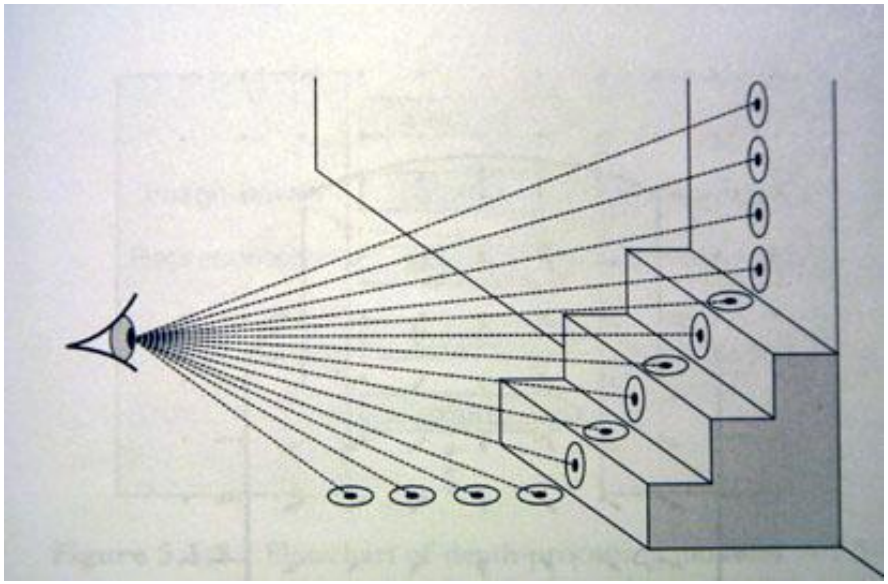
Side view of photographers posing together for a photograph on the roof of Marceau's Studio, while Joseph Byron holds one side of the camera with his right hand and Ben Falk holds the other side with his left hand.

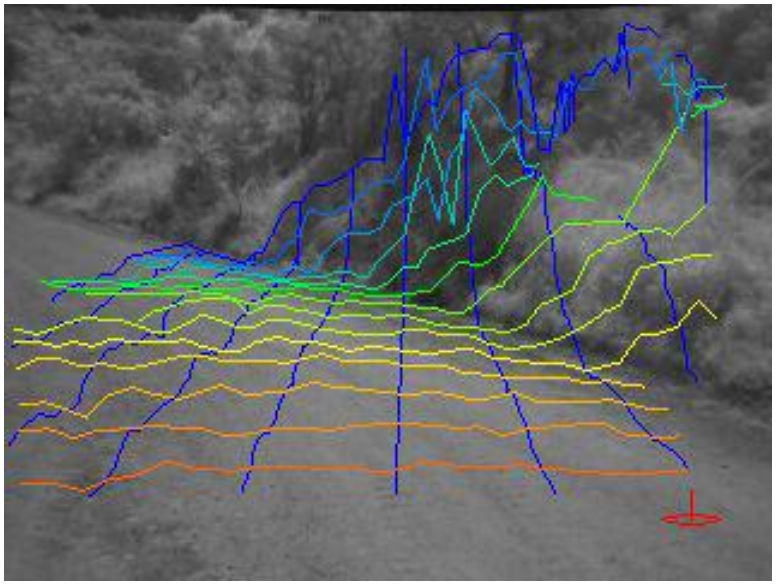
stereoscope was invented by Sir Charles Wheatstone in 1838.

3D Shape perception

1) **Depth**: *the distance of the surface from the observer*

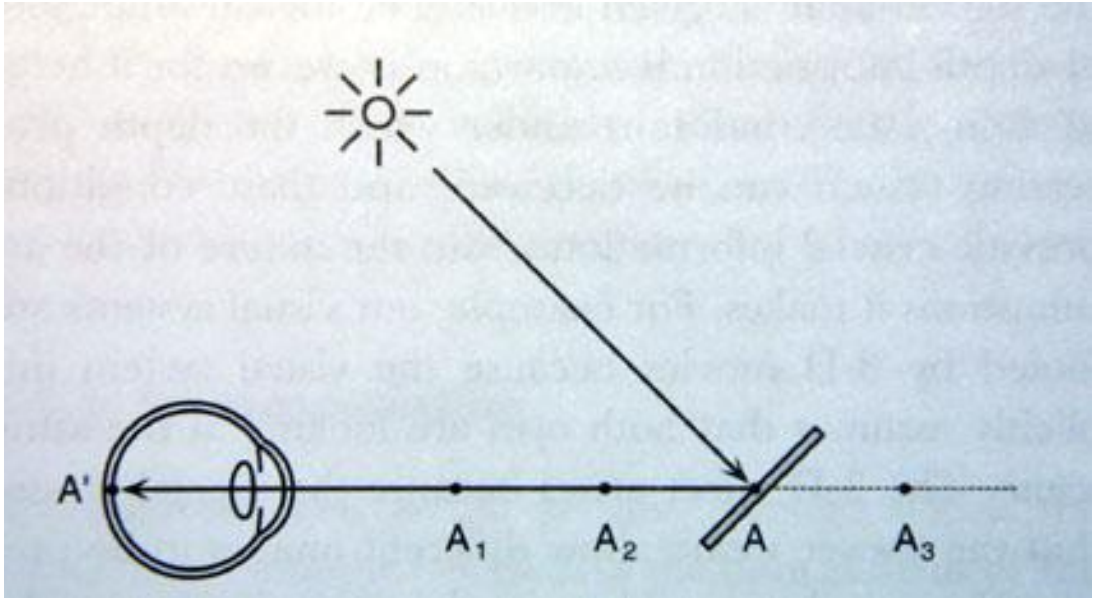
2) **Surface orientation**: *the slant and tilt of the surface with respect to observers' sight*





Depth ambiguity

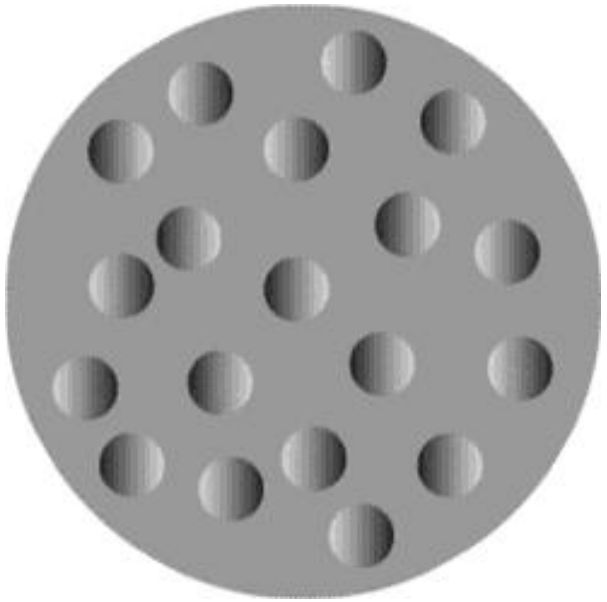
Inverse problem: multiple solution exists



Pictorial cues for 3D shape

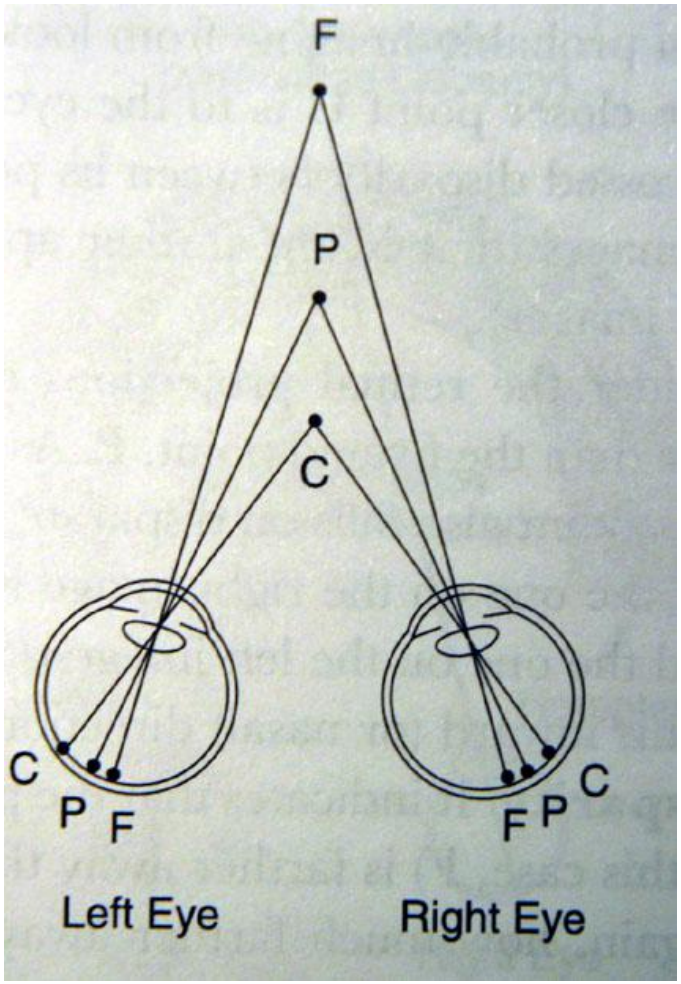
Perspective projection gives us the relative position to horizon, therefore we can deduce its physical size.

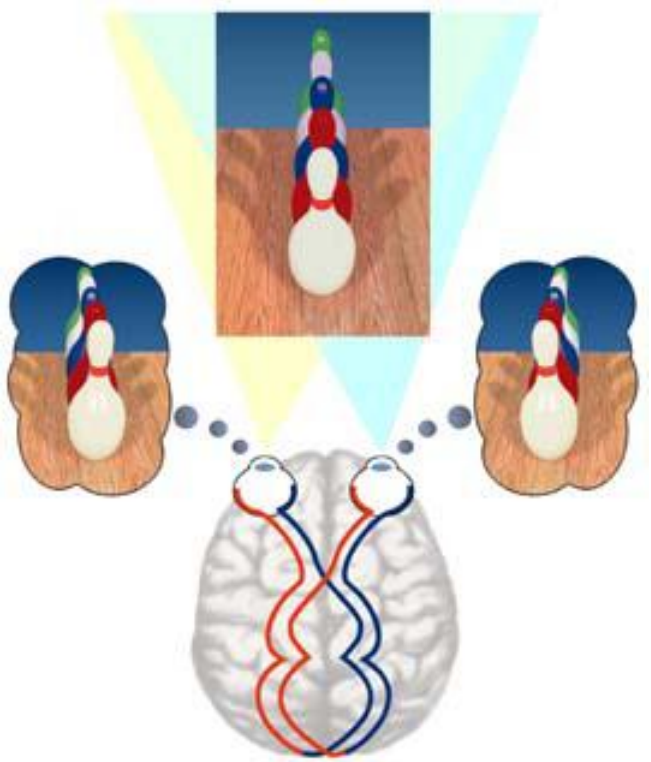
Shading also reveal shape using illumination model

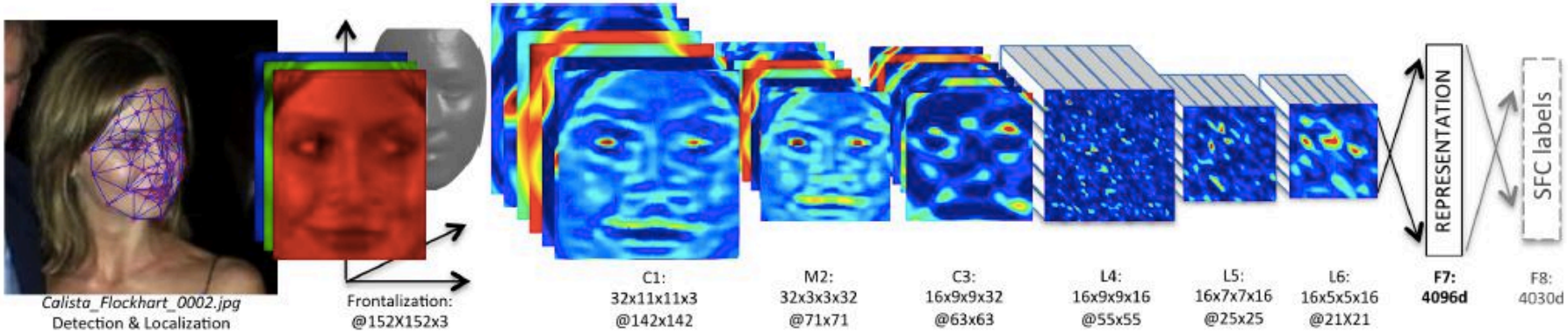


9

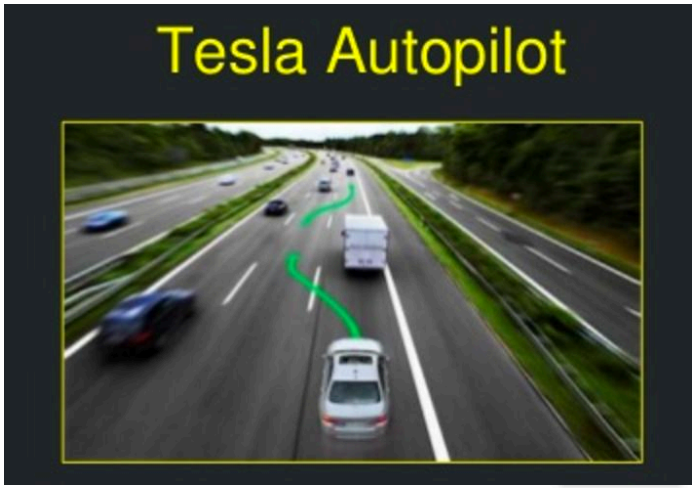
Stereo Vision

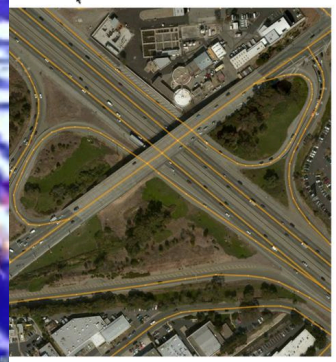





Calista_Flockhart_0002.jpg
Detection & Localization
Frontalization:
@152X152x3
C1:
32x11x11x3
@142x142
M2:
32x3x3x32
@71x71
C3:
16x9x9x32
@63x63
L4:
16x9x9x16
@55x55
L5:
16x7x7x16
@25x25
L6:
16x5x5x16
@21X21
F7:
4096d
F8:
4030d
REPRESENTATION
SFC labels

04.28 M
CTE: +0.2
Plan +3.6

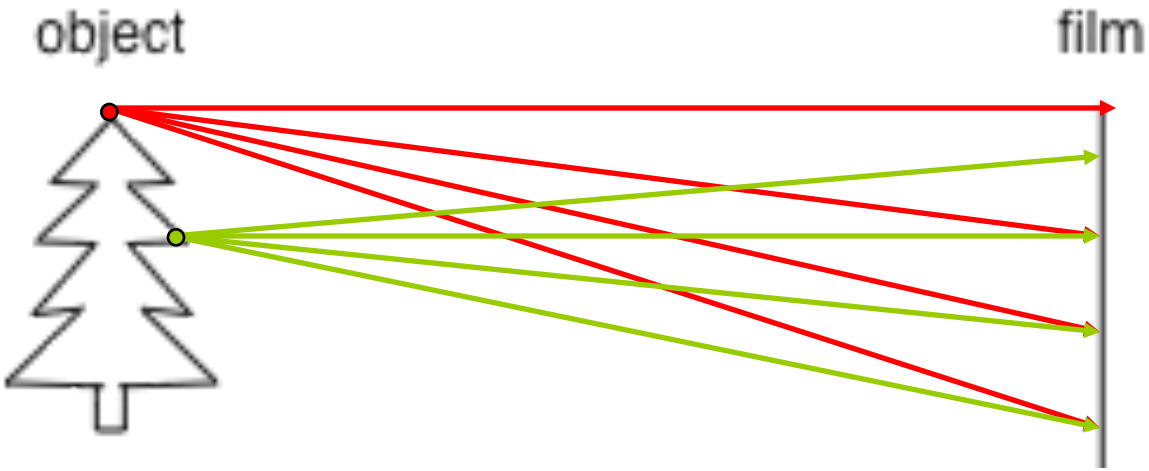

Tesla Autopilot



Camera Design

What is a camera?
Photon collecting machine

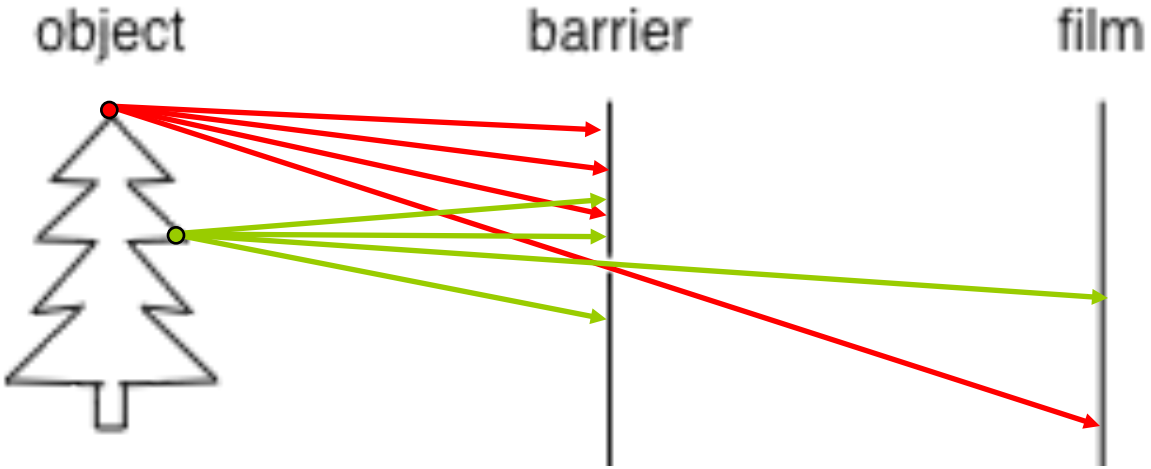
How do we see the world?



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

Slide by Steve Seitz

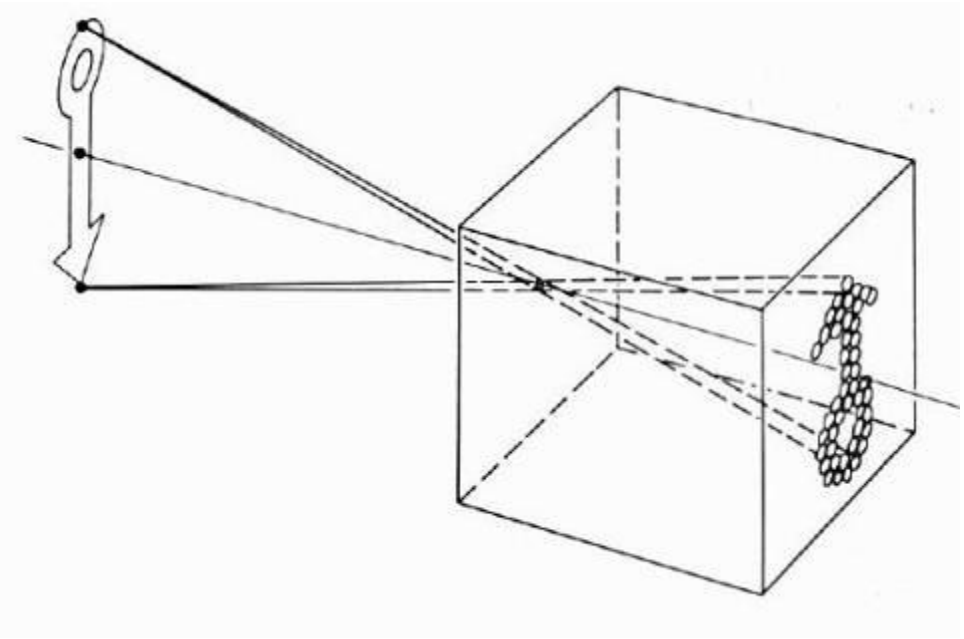
Pinhole camera



- 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?

Slide by Steve Seitz

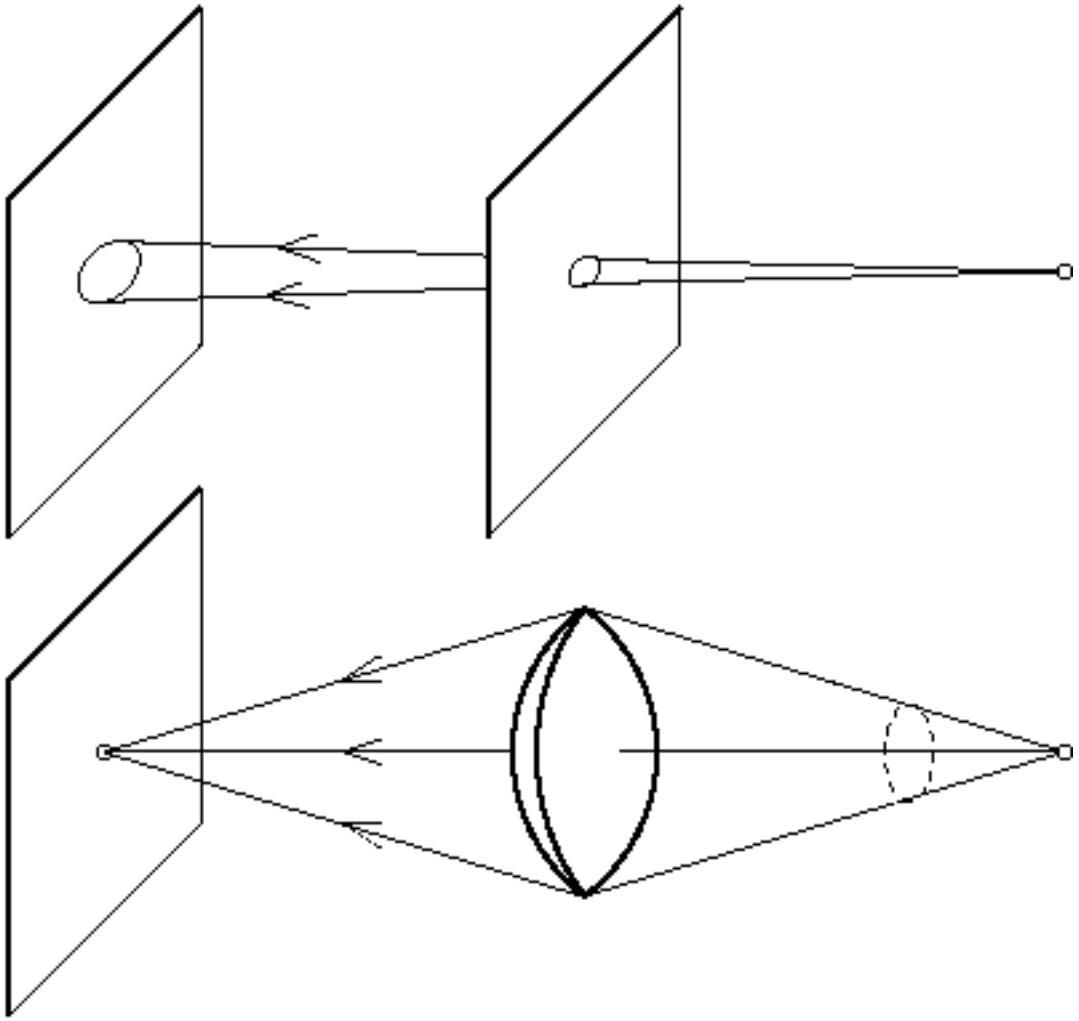
Pinhole camera model



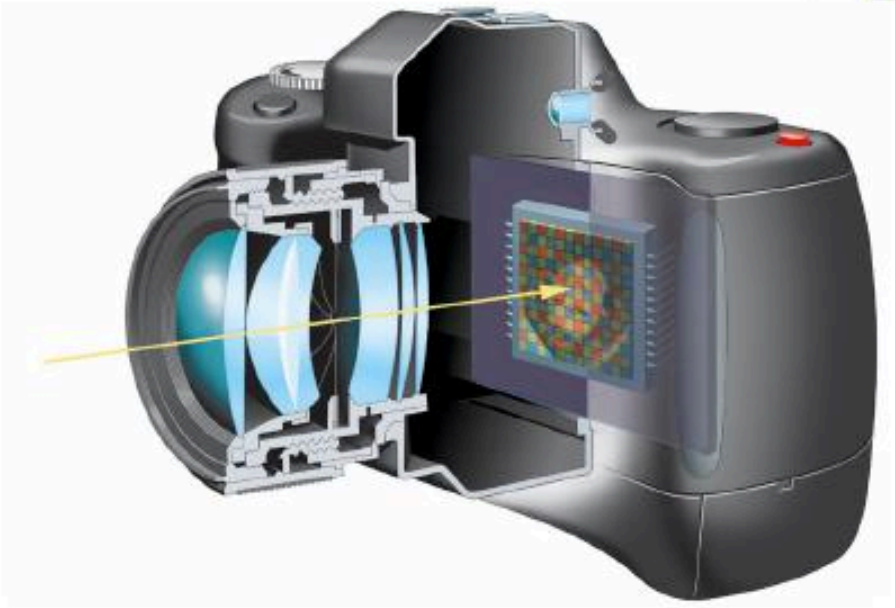
- Pinhole model:
  - Captures **pencil of rays** – all rays through a single point
  - The point is called **Center of Projection (COP)**
  - The image is formed on the **Image Plane**
  - **Effective focal length *f*** is distance from COP to Image Plane

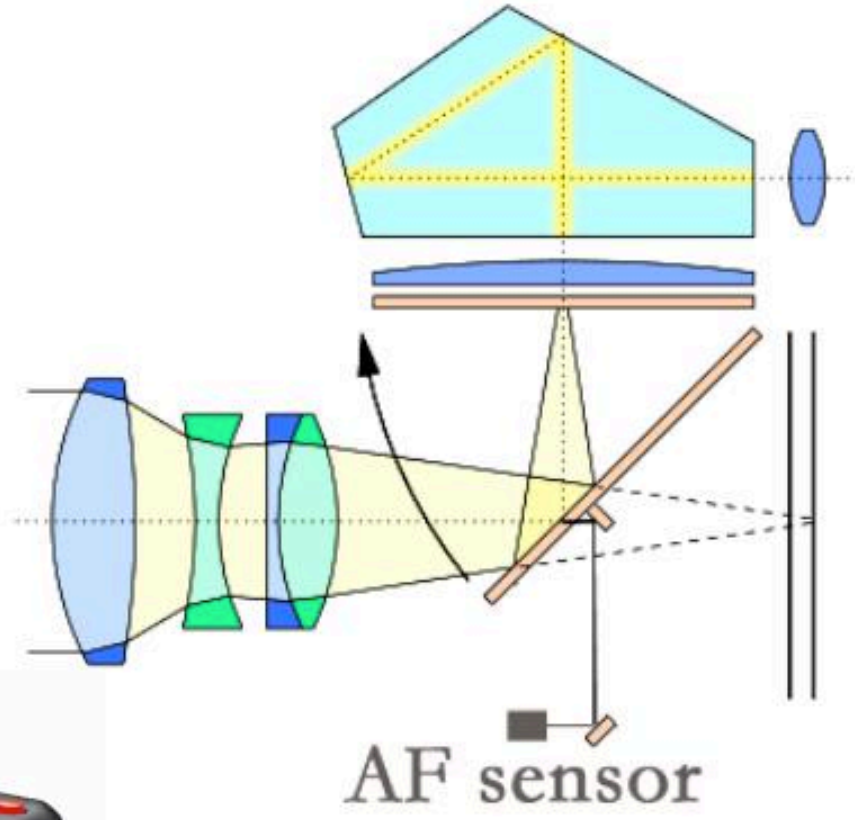
Slide by Steve Seitz

Camera with lense



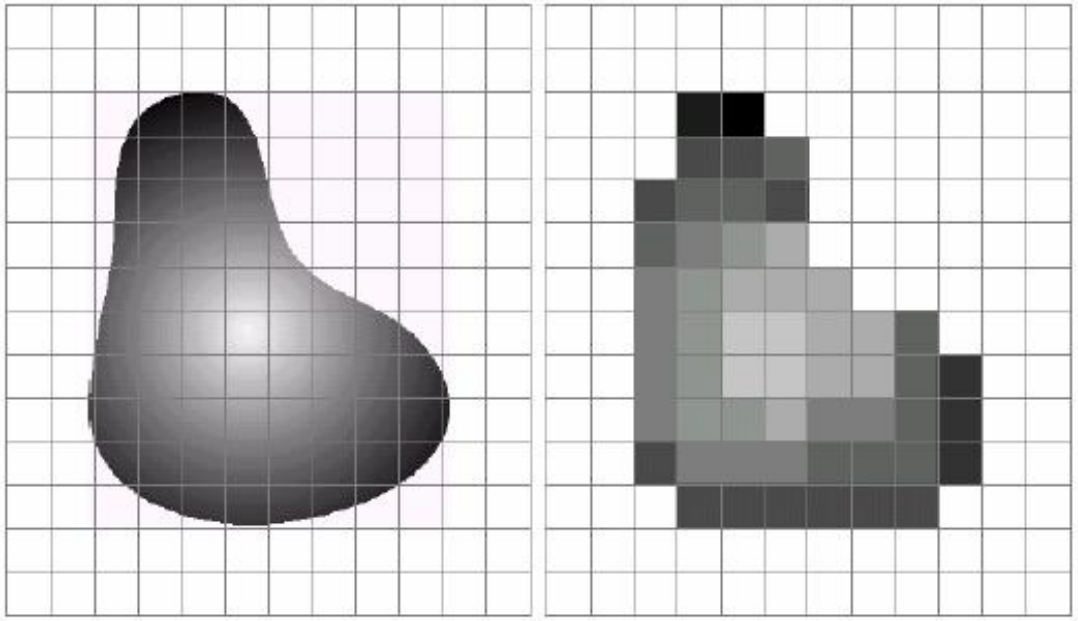
Single-lens reflex with auto-focus





Video 1.2
Jianbo Shi

Sensor Array

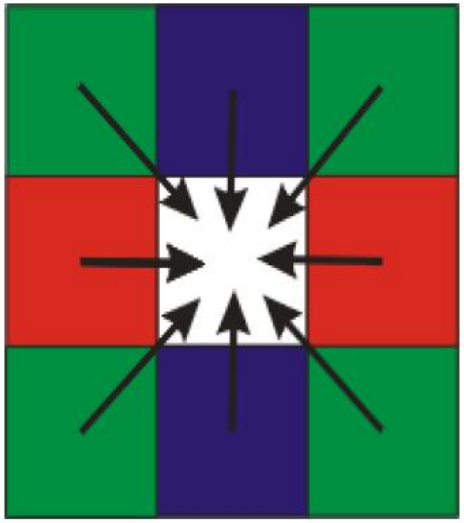


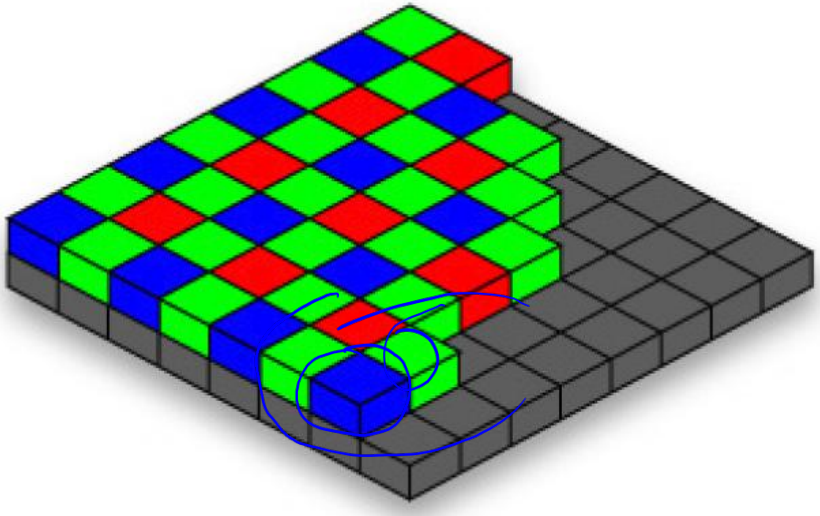
a b

FIGURE 2.17 (a) Continuos image projected onto a sensor array. (b) Result of image sampling and quantization.

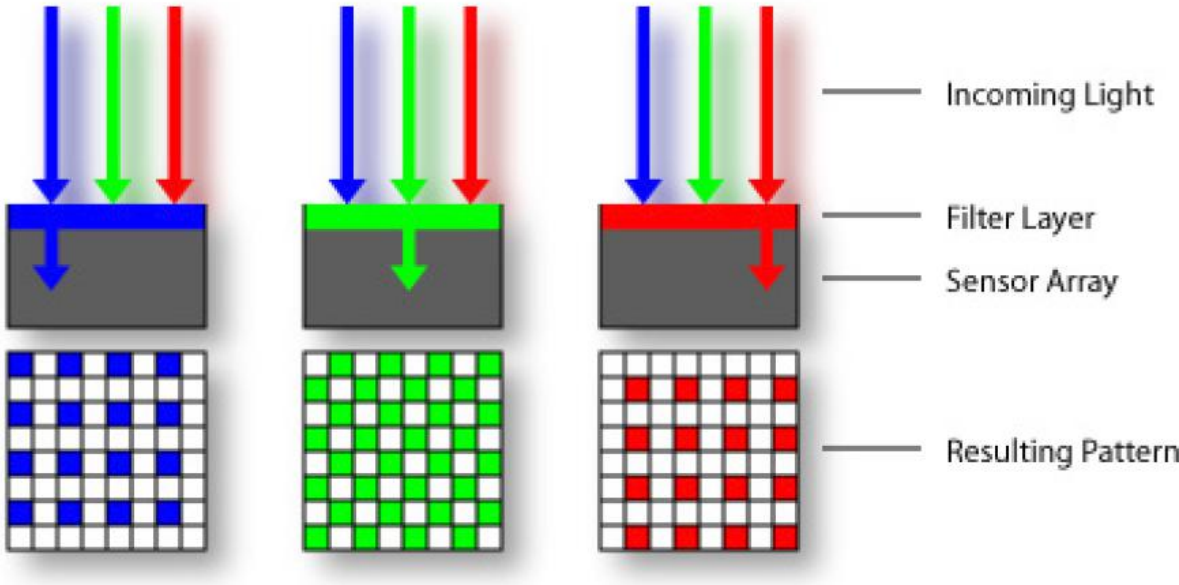
CMOS sensor

Practical Color Sensing: Bayer Grid





Estimate RGB at ‘G’ cels from neighboring values



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

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

j

i

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

I(2,1) = 134
I(3,4) = 136

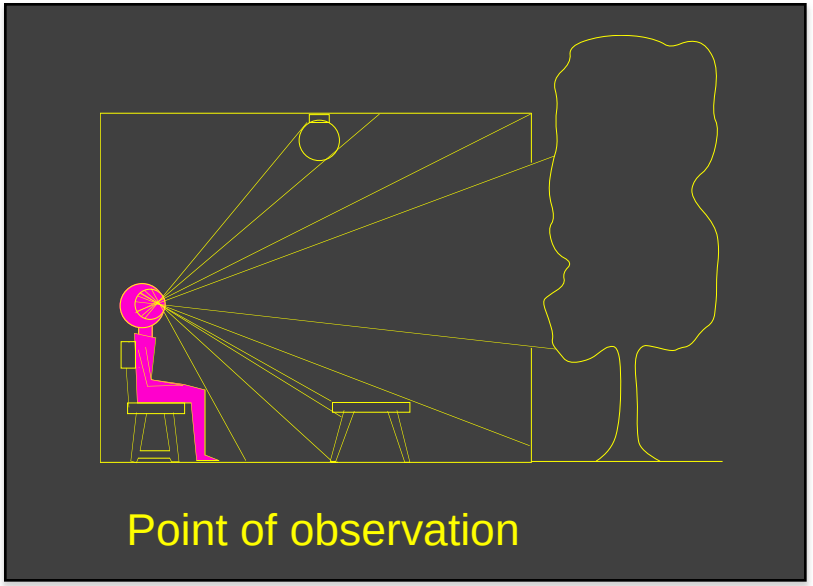
Any 2D matrix can be seen as an image

Camera Design

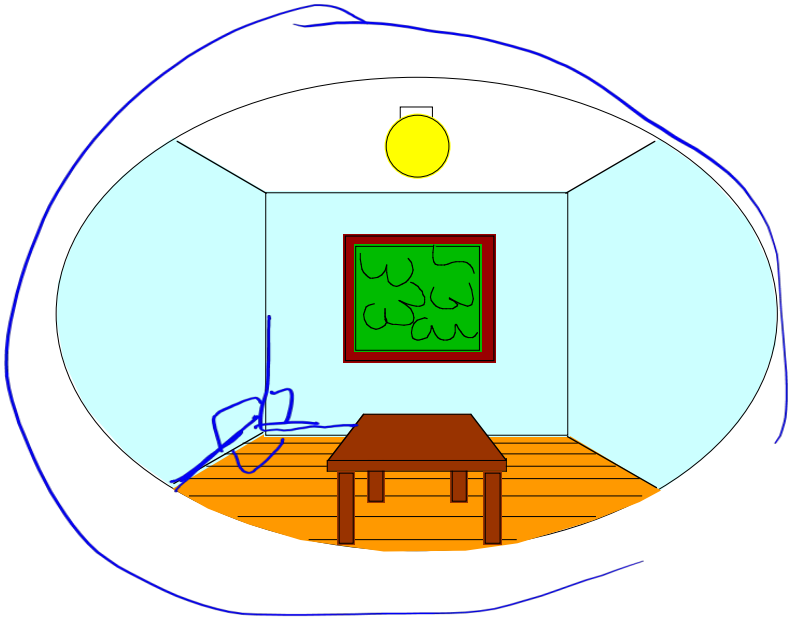
What is a camera?
Dimension Reduction Machine

Dimensionality Reduction Machine (3D to 2D)

3D world

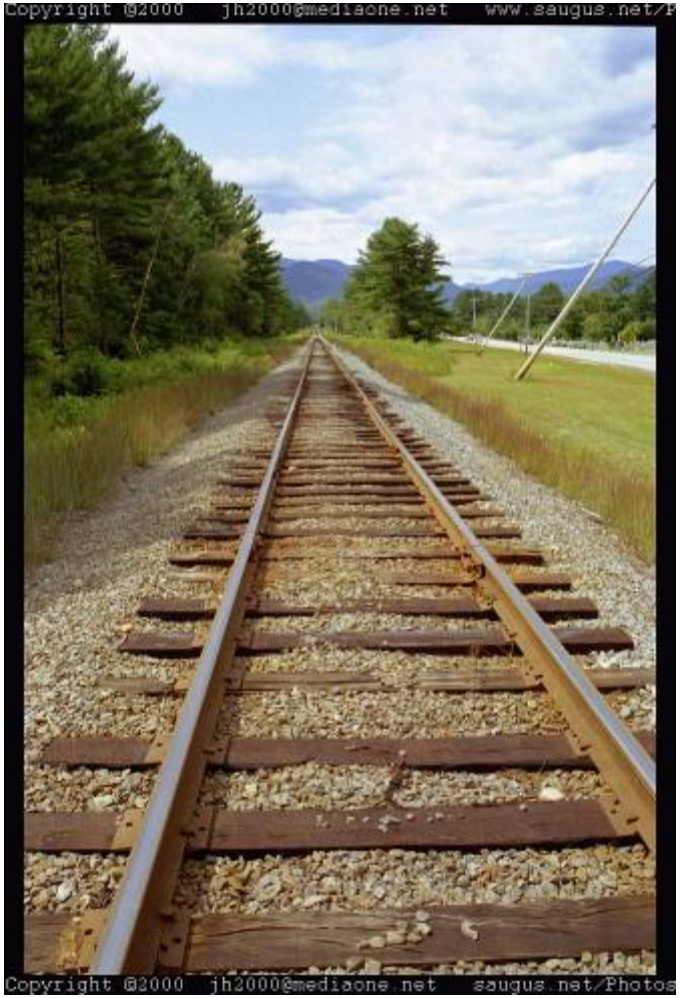


2D image

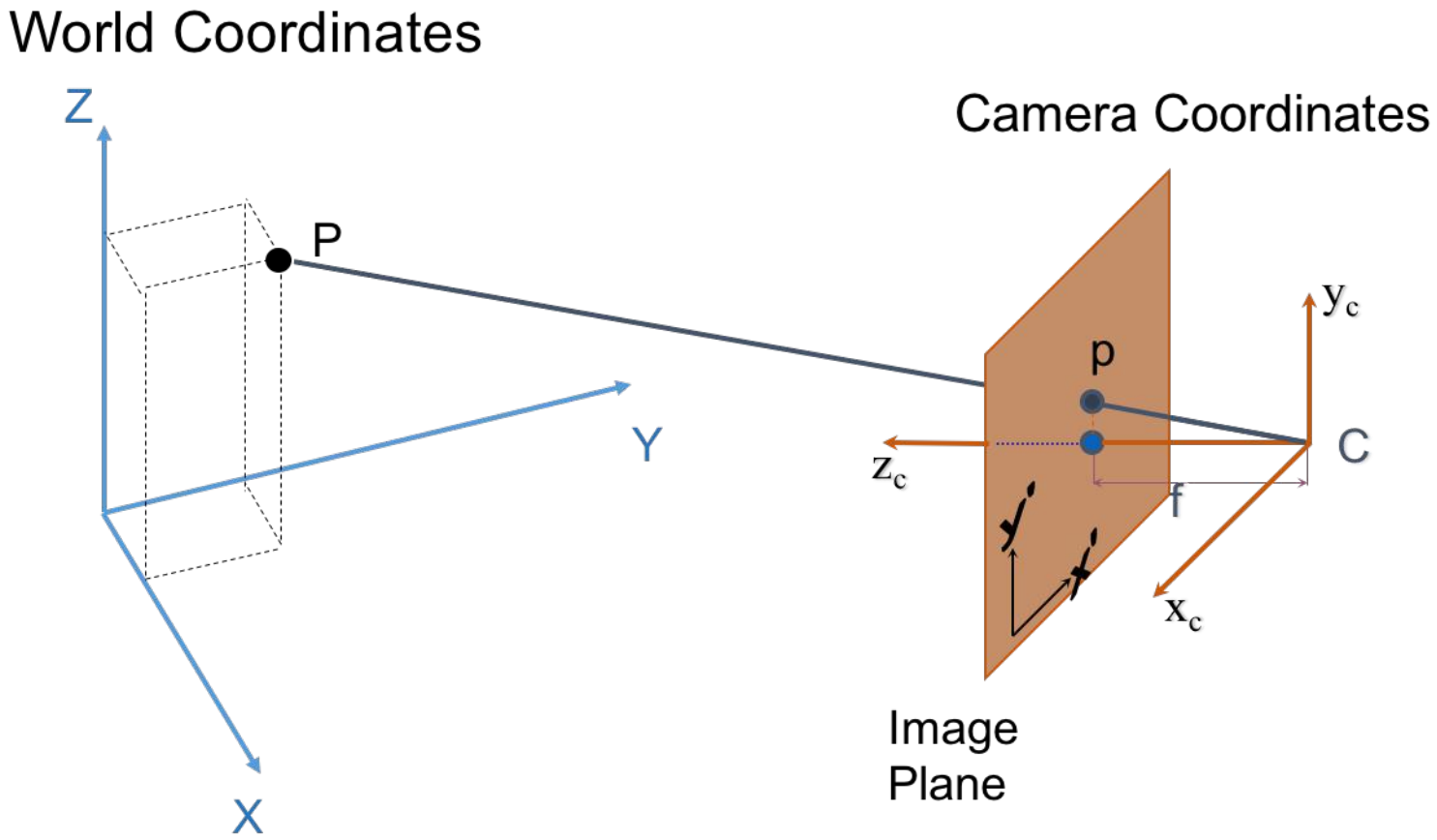


- What have we lost?
  - Angles
  - Distances (lengths)

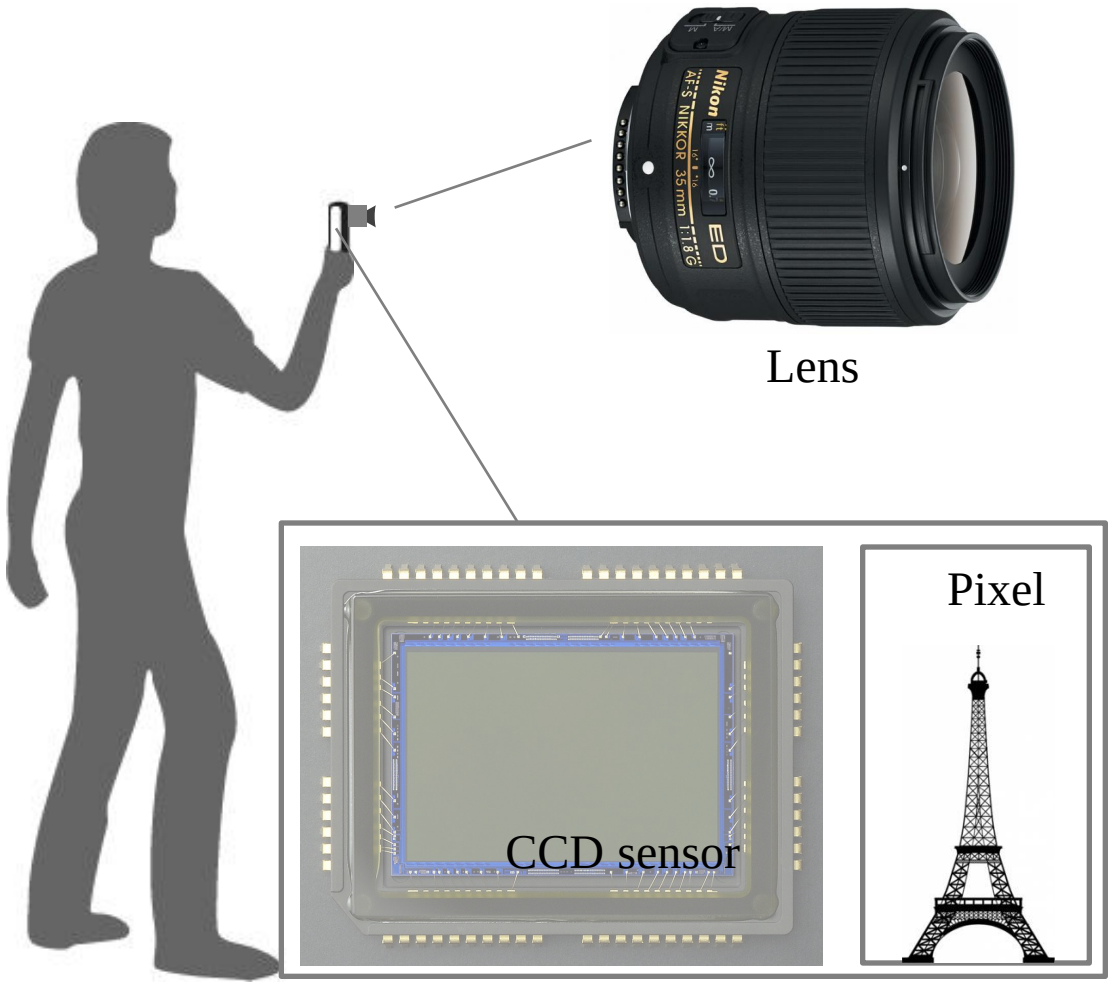
Funny things happen…



3D to 2D mapping

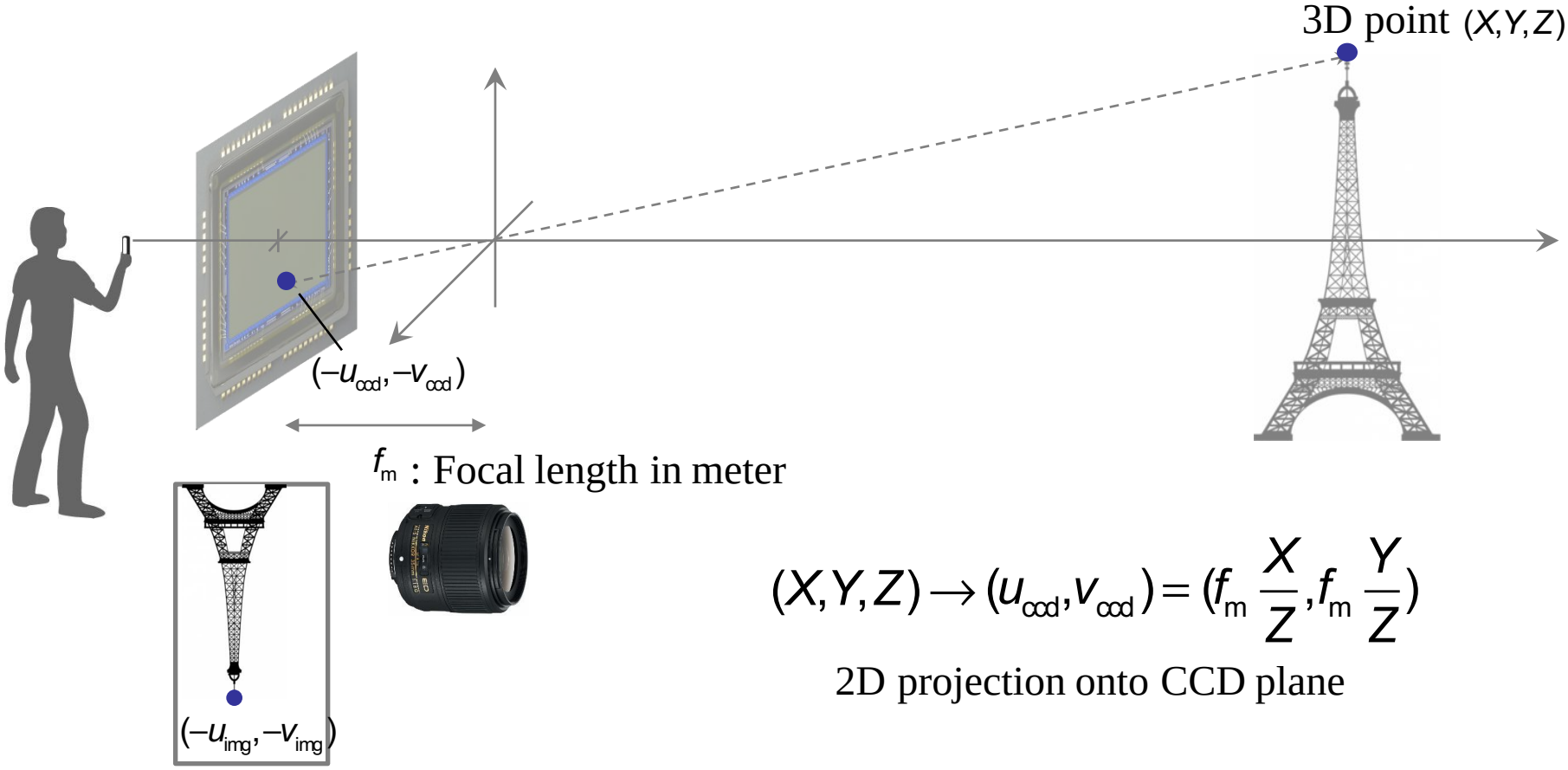


J. Barozzi's Perspectograph



3D object

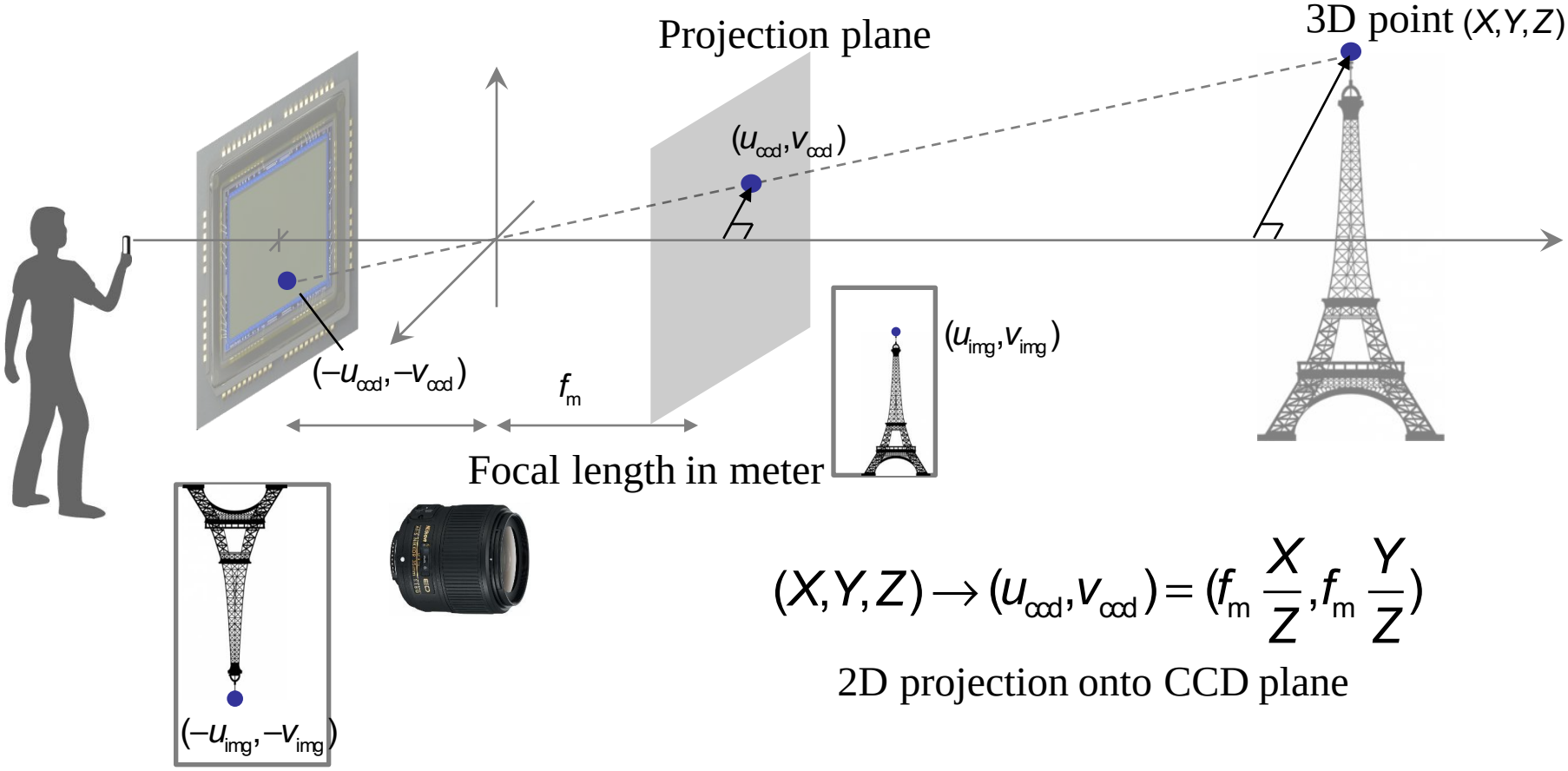
3D Point Projection (Metric Space)



$$(X,Y,Z) \rightarrow (u_{ccd}, v_{ccd}) = (f_m \frac{X}{Z}, f_m \frac{Y}{Z})$$

2D projection onto CCD plane

3D Point Projection (Metric Space)



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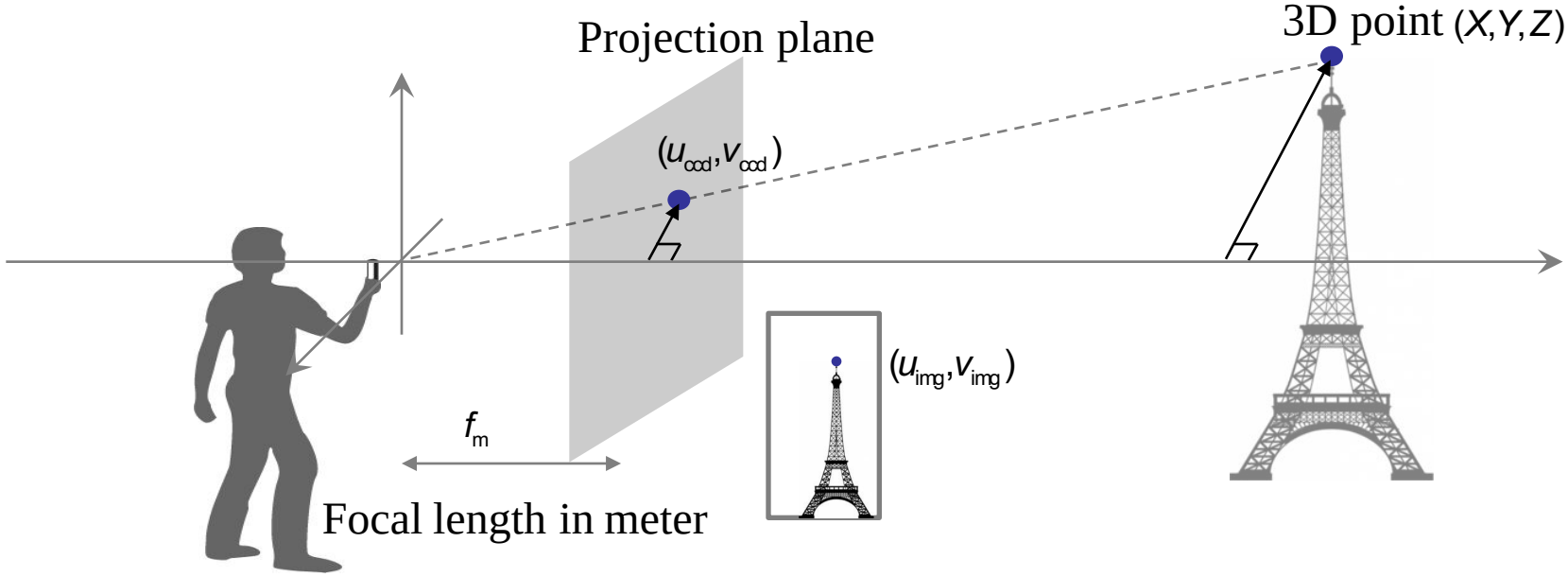
2D projection onto CCD plane

3D Point Projection (Metric Space)

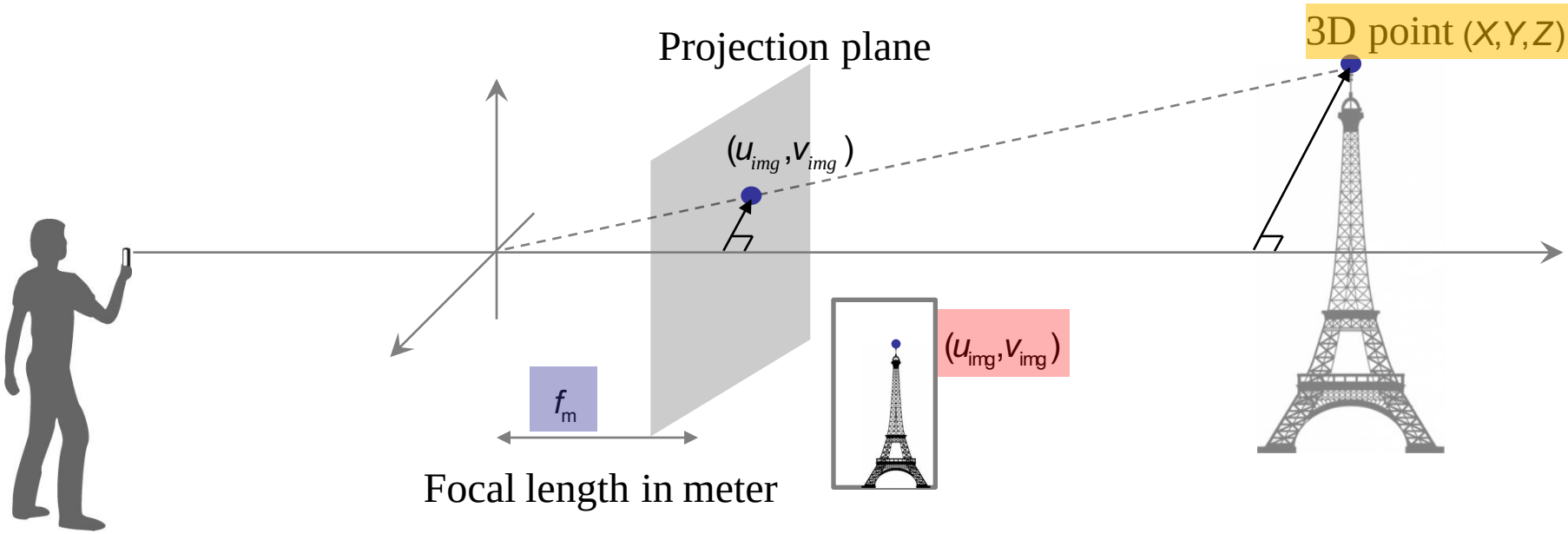


$$(X,Y,Z) \rightarrow (u_{ccd}, v_{ccd}) = (f_m \frac{X}{Z}, f_m \frac{Y}{Z})$$

2D projection onto CCD plane

Video 1.3
Jianbo Shi

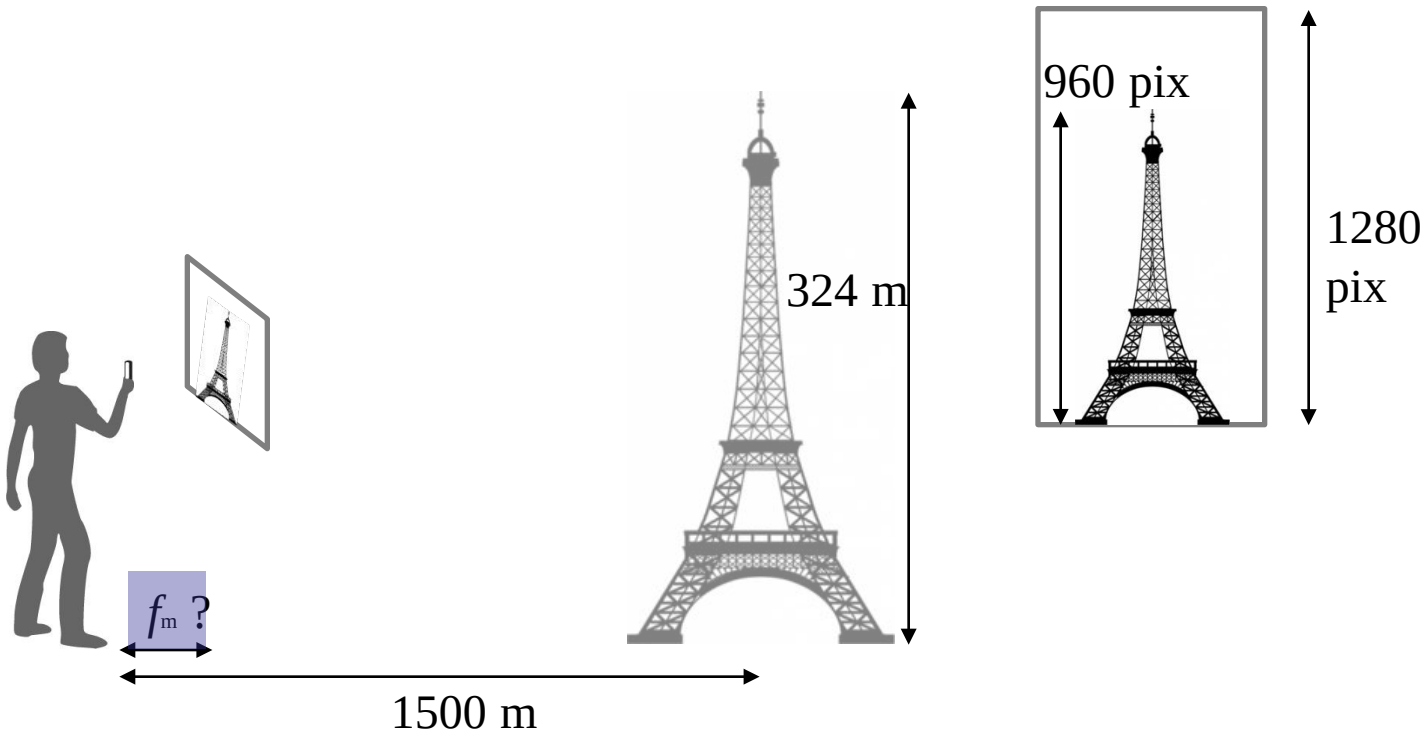
3D Point Projection (Pixel Space)



$$(X,Y,Z) \rightarrow (u_{img}, v_{img}) = (f_m \frac{w_{img}}{w_{ccd}} \frac{X}{Z}, f_m \frac{h_{img}}{h_{ccd}} \frac{Y}{Z})$$

Exercise

What f to make the height of Eifel tower appear 960 pixel distance?



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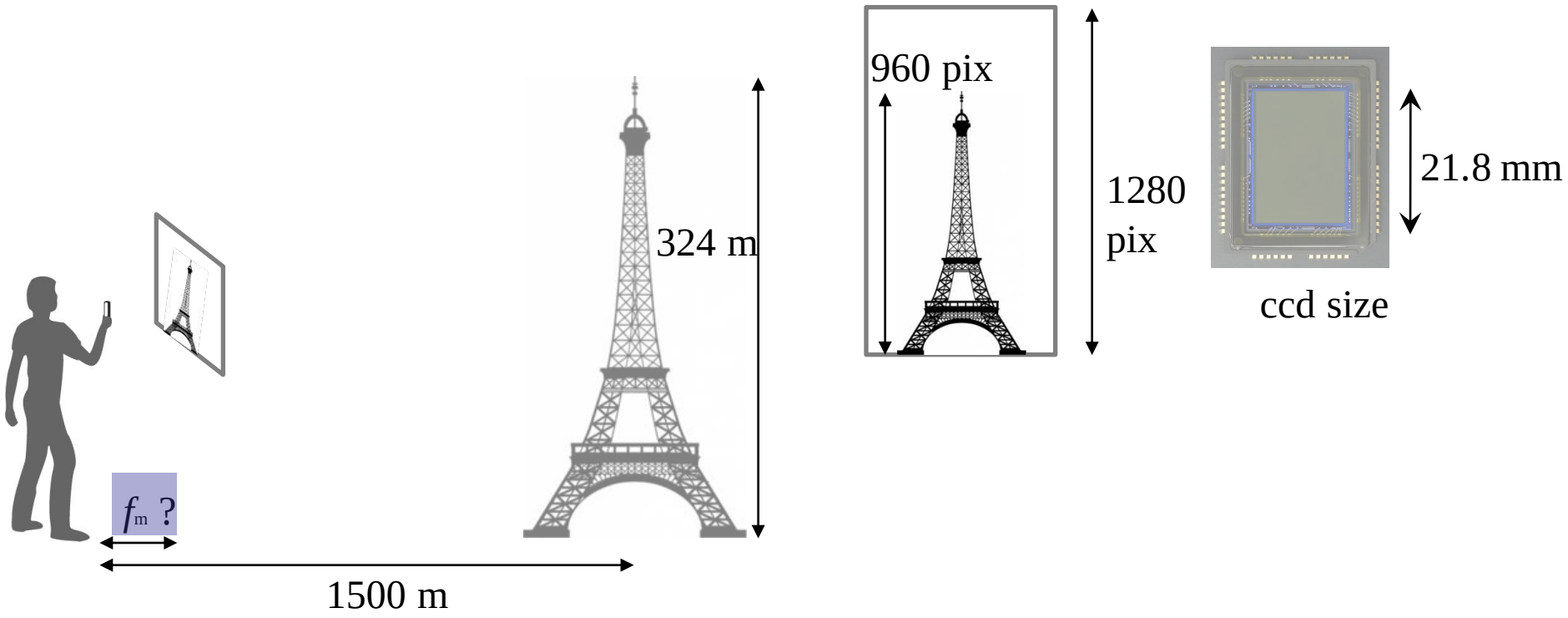

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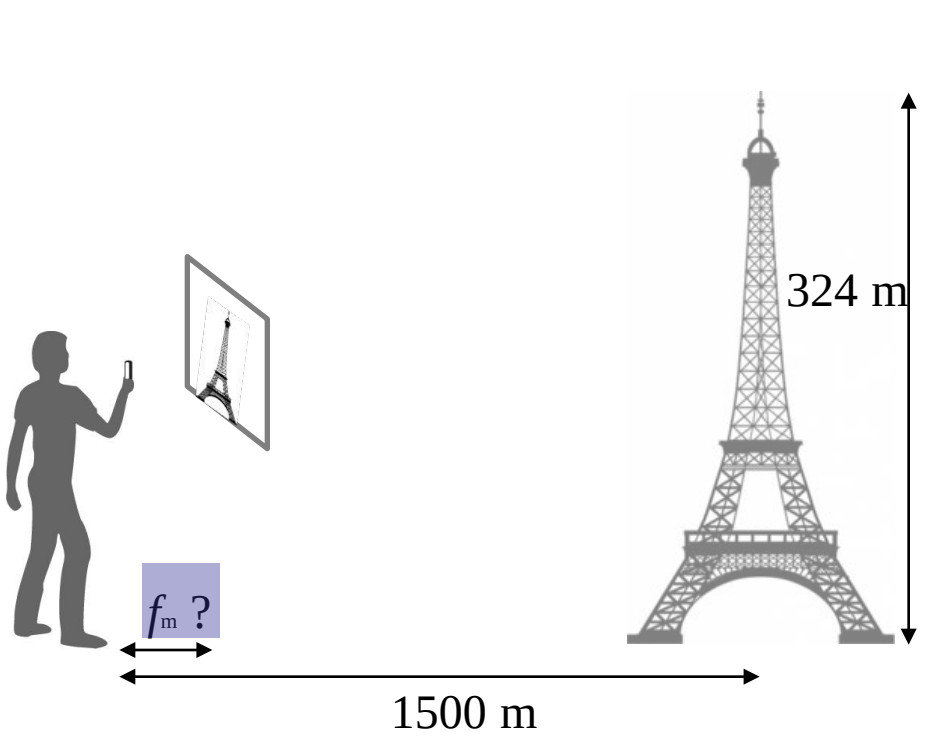
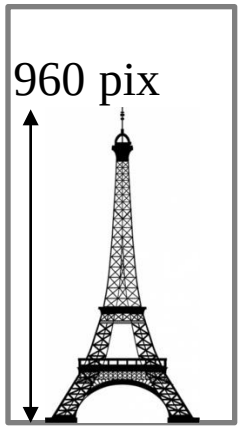
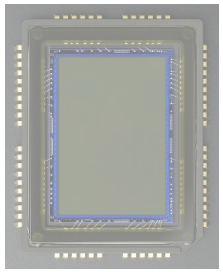


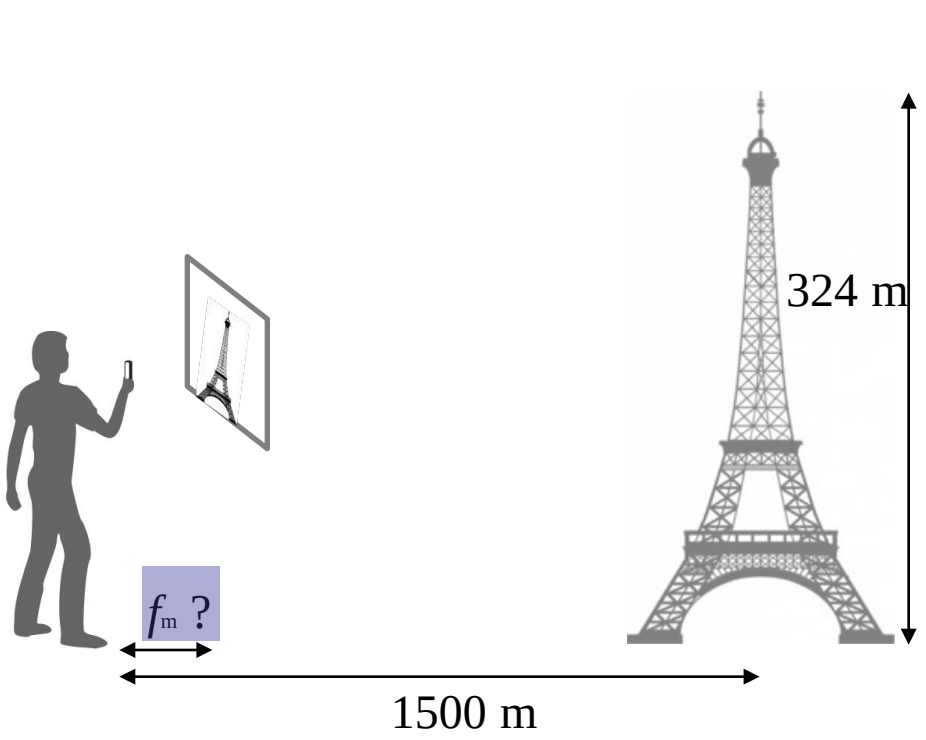


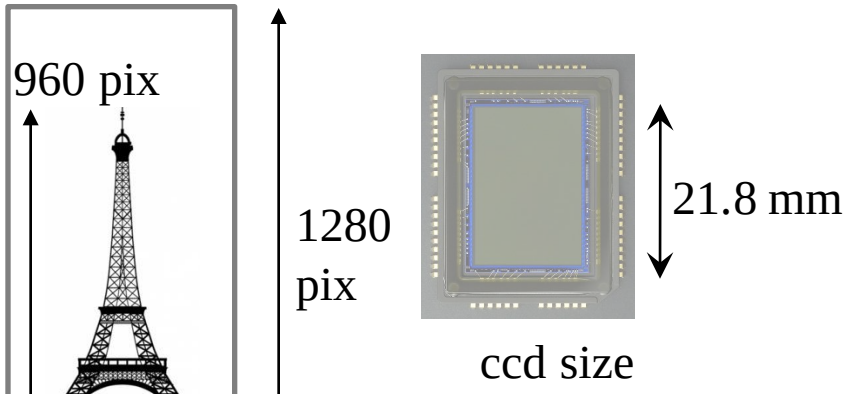


$$y_{\text{img}} = f\frac{Y}{Z} = f_m \frac{h_{\text{img}}}{h_{\text{ccd}}}\frac{Y}{Z}$$

Exercise

What f to make the height of Eifel tower appear 960 pixel distance?



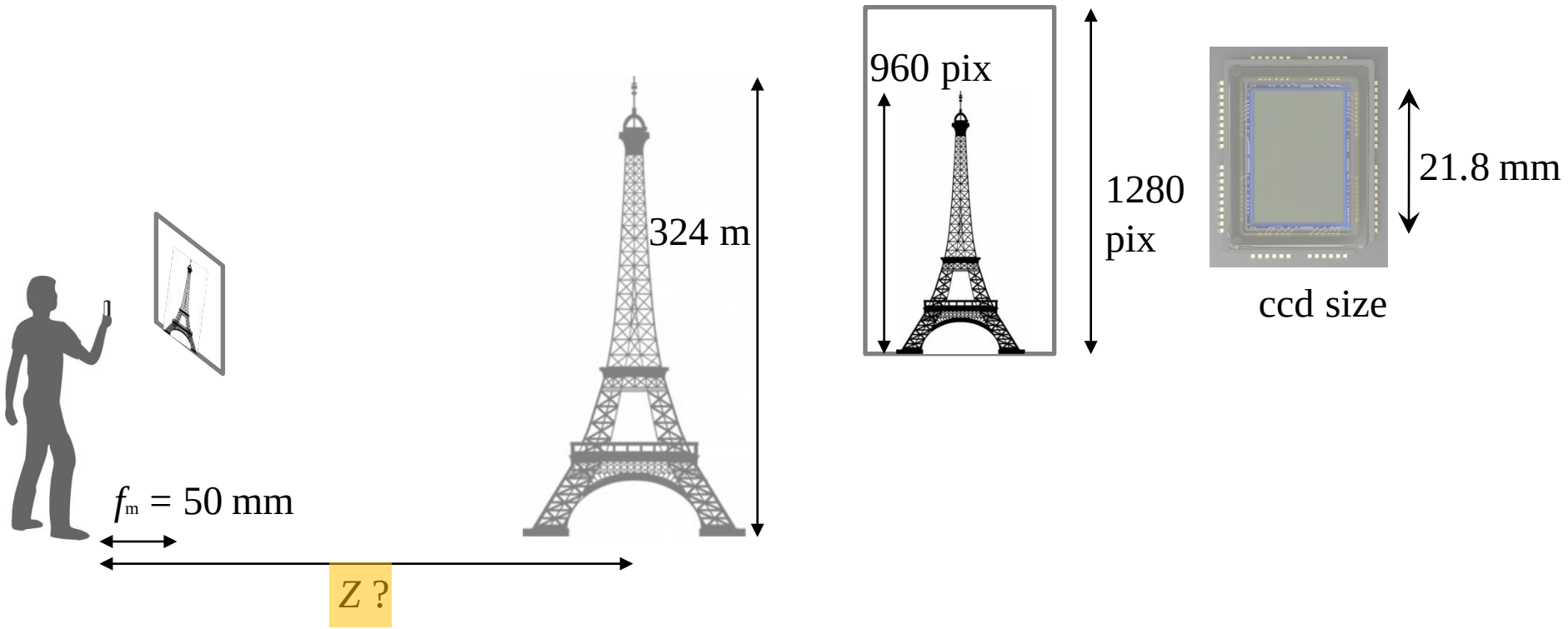


$$y_{\text{img}} = f\frac{Y}{Z} = f_m \frac{h_{\text{img}}}{h_{\text{ccd}}}\frac{Y}{Z}$$

$$960 = f_m \frac{1280}{0.0218}\frac{324}{1500} \rightarrow f_m = 0.0757m$$

Exercise

What f to make the height of Eifel tower appear 960 pixel distance?



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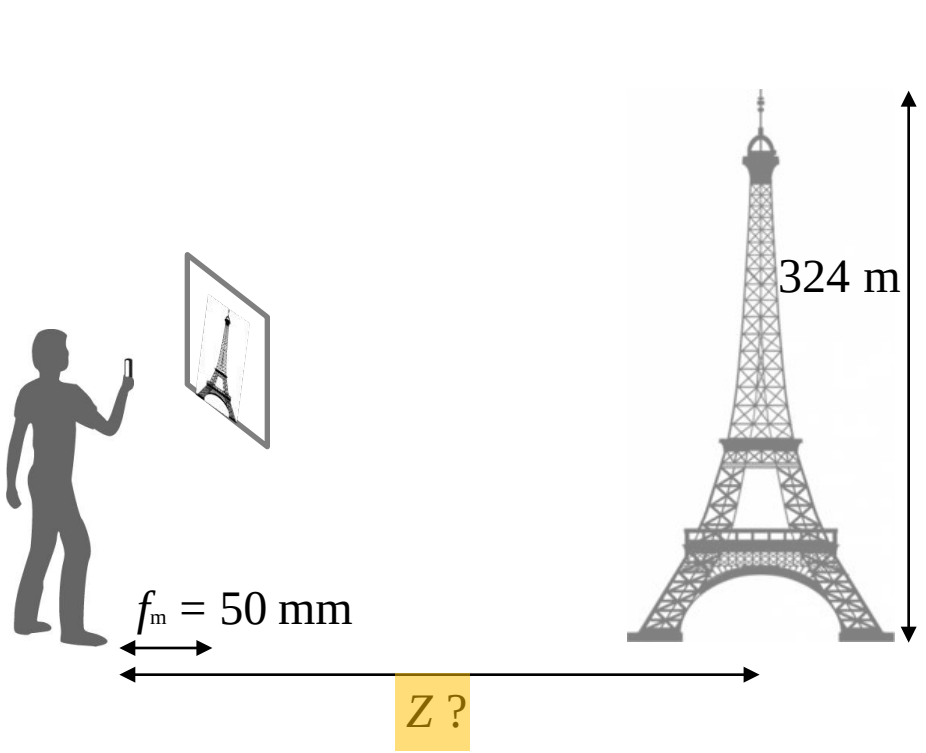
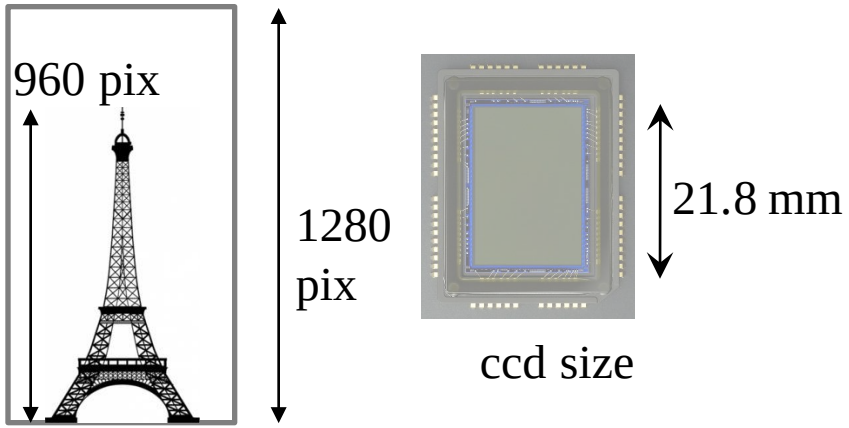
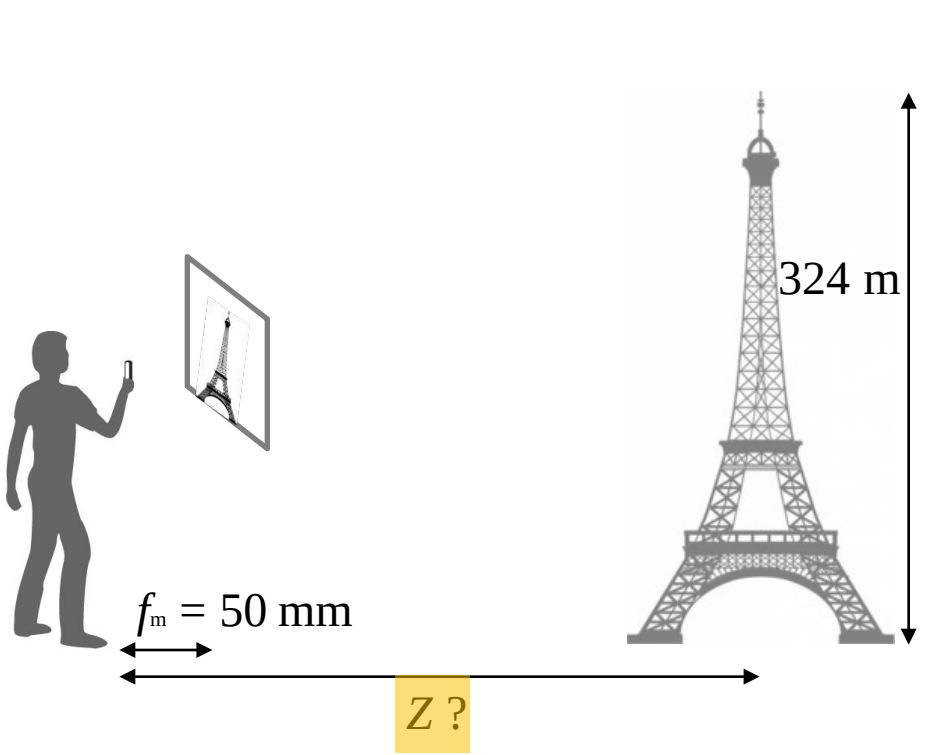




$$y_{img} = f\frac{Y}{Z} = f_m \frac{h_{img}}{h_{ccd}}\frac{Y}{Z}$$

Exercise

What f to make the height of Eifel tower appear 960 pixel distance?

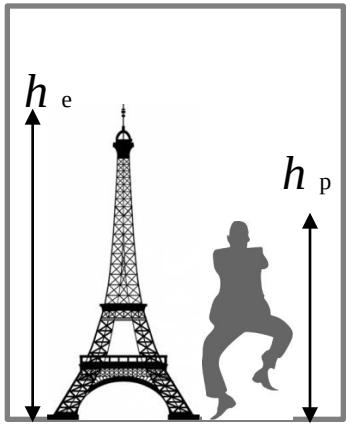


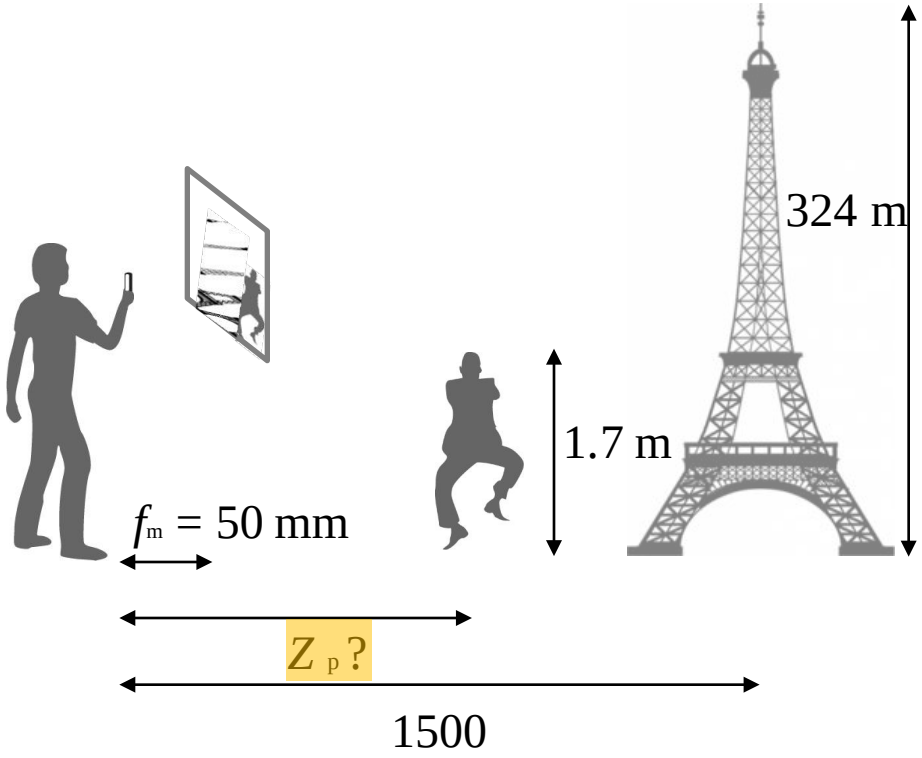
$$y_{\text{img}} = f\frac{Y}{Z} = f_m\frac{h_{\text{img}}}{h_{\text{ccd}}}\frac{Y}{Z}$$

$$960 = 0.05\frac{1280}{0.0218}\frac{324}{Z} \rightarrow Z = 990.826\text{m}$$

Exercise

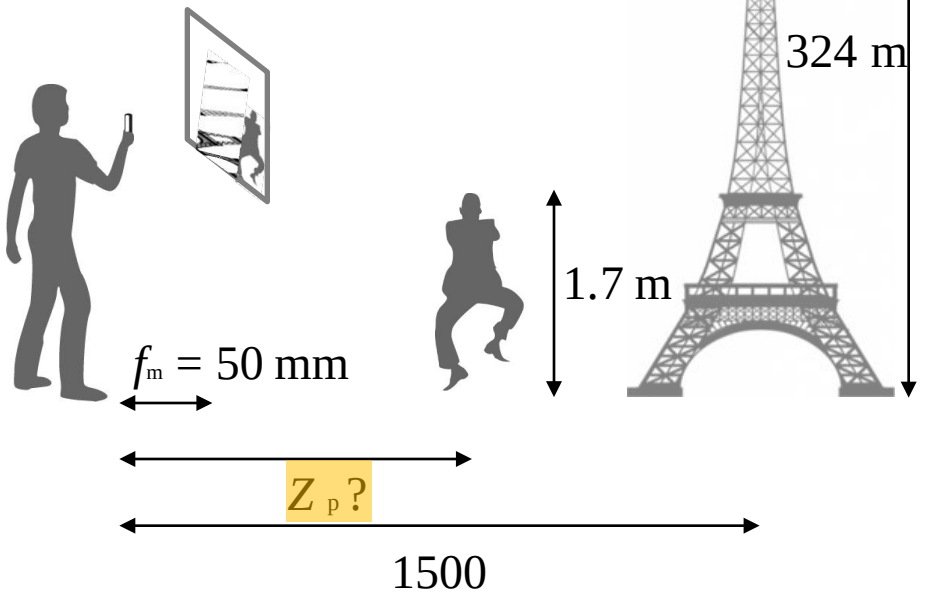
What Z_p to make the height of Eifel tower appear twice of the person?

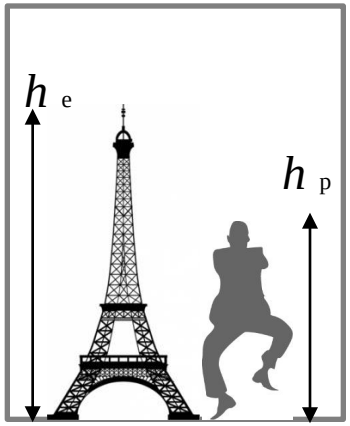




Exercise

What Z_p to make the height of Eifel tower appear twice of the person?





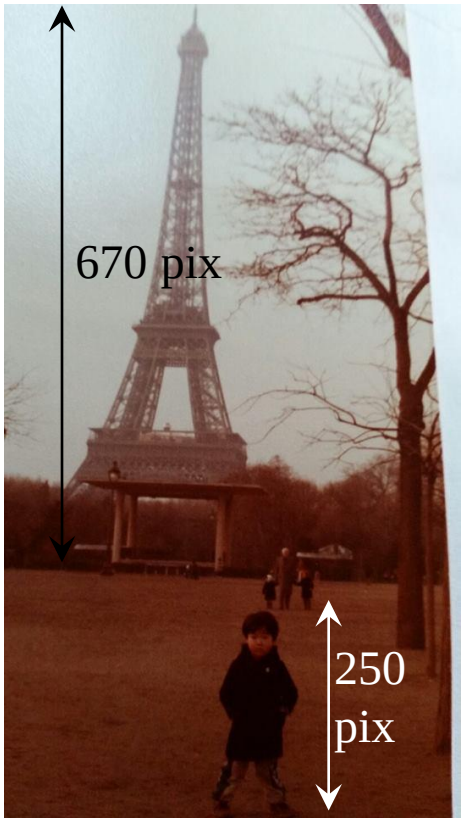
s.t.

$$h_e = f\frac{Y_e}{Z_e} \quad h_p = f\frac{Y_p}{Z_p} \quad h_p = \frac{h_e}{2}$$

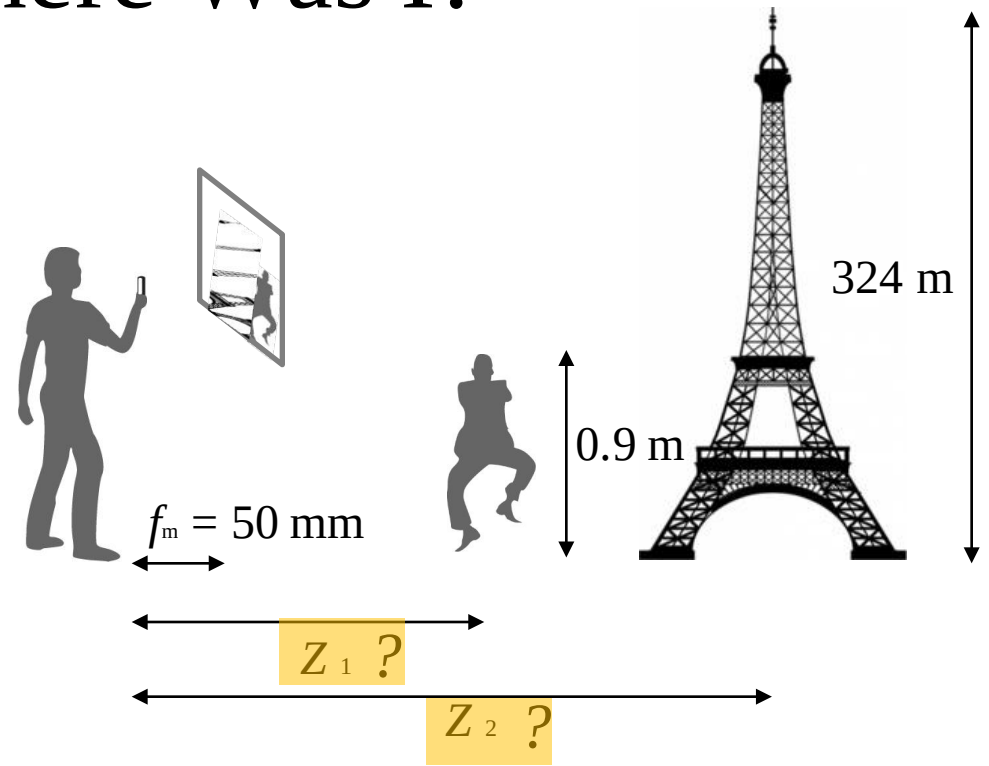
$$f\frac{Y_p}{Z_p} = f\frac{Y_e}{2Z_e} \rightarrow$$

$$Z_p = 2 \cdot 1500\frac{1.7}{234} = 15.741m$$

Where Was I?

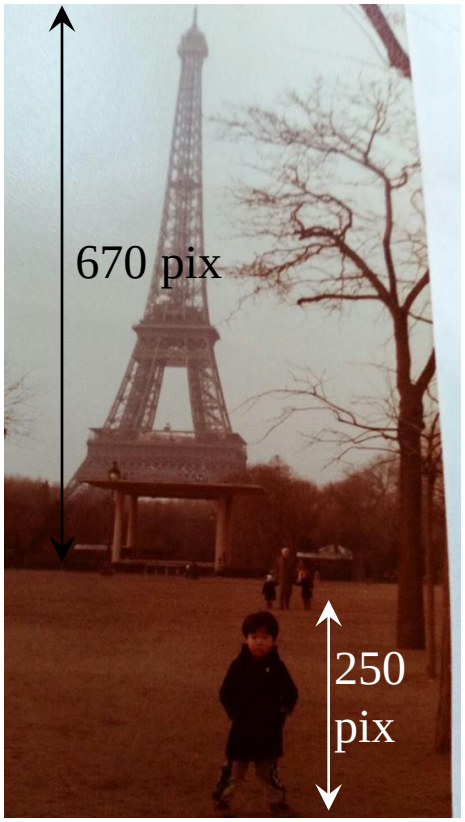


Circa 1984

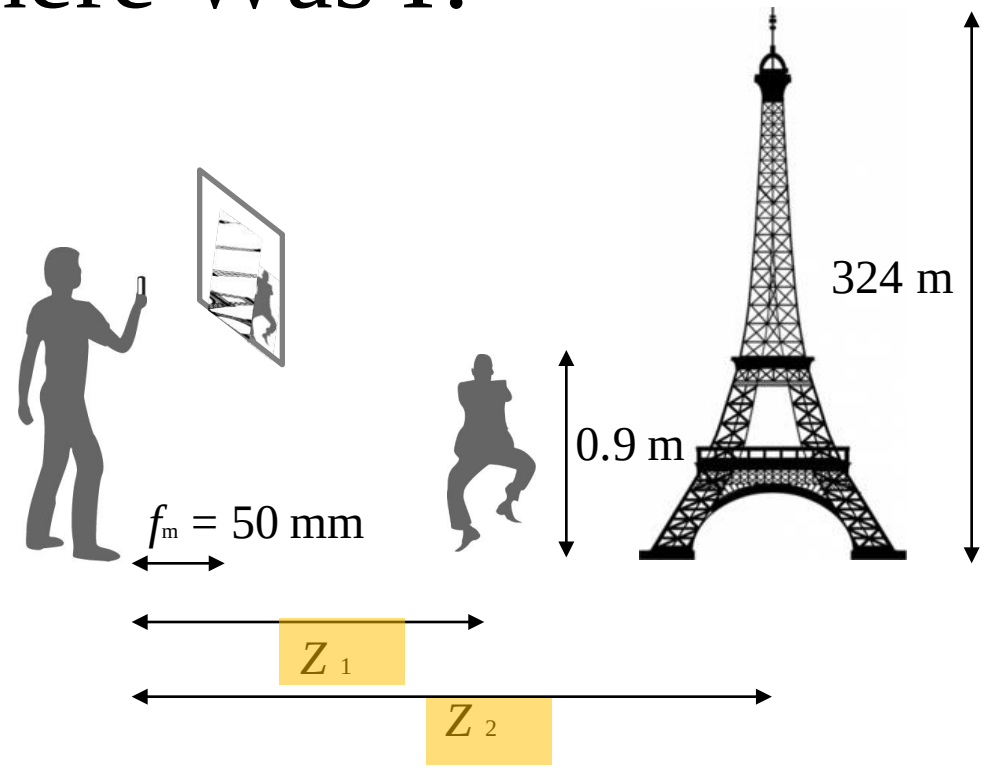


$$y_1 = f\frac{Y}{Z} = f_m \frac{h_{img}}{h_{ccd}}\frac{Y_1}{Z_1} \rightarrow Z_1 = f_m \frac{h_{img}}{h_{ccd}}\frac{Y_1}{y_1} = 0.05\frac{1280}{0.0218}\frac{0.9}{250} = 8.03\text{m}$$

Where Was I?



Circa 1984

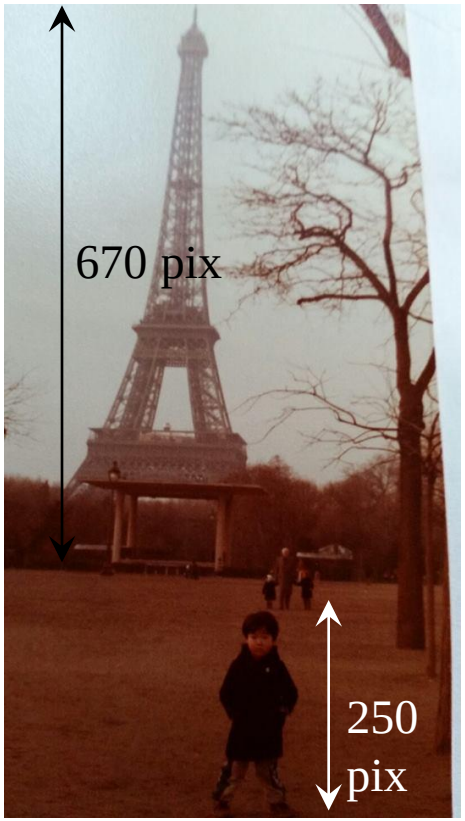


$$y_1 = f\frac{Y}{Z} = f_m\frac{h_{img}}{h_{ccd}}\frac{Y_1}{Z_1} \rightarrow Z_1 = f_m\frac{h_{img}}{h_{ccd}}\frac{Y_1}{y_1} = 0.05\frac{1280}{0.0218}\frac{0.9}{250} = 8.03\text{m}$$

$$y_2 = f\frac{Y_2}{Z_2} = f_m\frac{h_{img}}{h_{ccd}}\frac{Y_2}{Z_2} \rightarrow Z_2 = f_m\frac{h_{img}}{h_{ccd}}\frac{Y_2}{y_2} = 0.05\frac{1280}{0.0218}\frac{324}{670} = 1079\text{m}$$

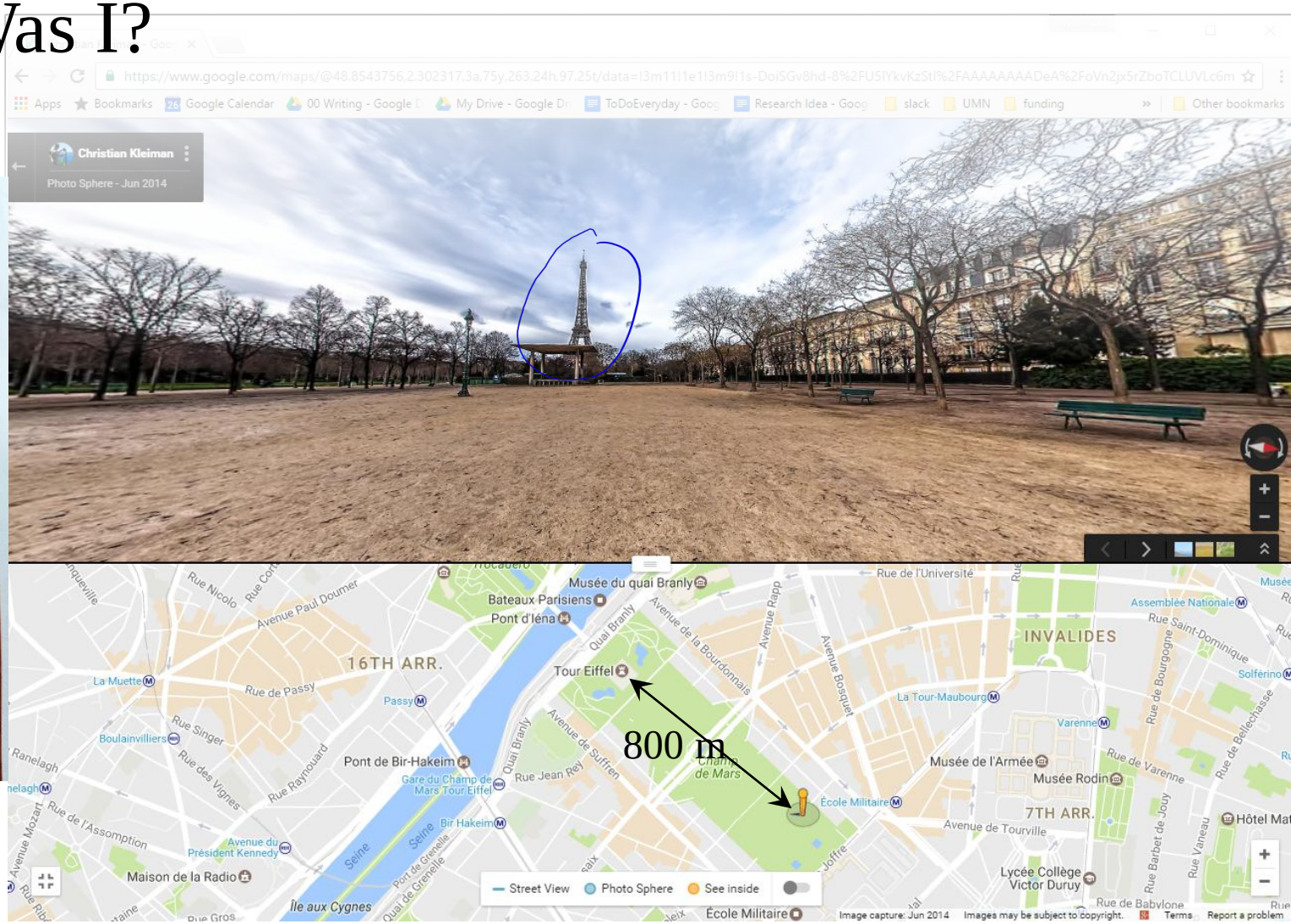
Where Was I?

$$y_2 = f\frac{Y_2}{Z_2} = f_m\frac{h_{img}}{h_{ccd}}\frac{Y_2}{Z_2} \rightarrow Z_2 = f_m\frac{h_{img}}{h_{ccd}}\frac{Y_2}{y_2} = 0.05\frac{1280}{0.0218}\frac{324}{670} = 1079\text{m}$$



Circa 1984

Where Was I?


Christian Kleiman
Photo Sphere - Jun 2014
Musée du quai Branly
Bateaux Parisiens
Pont d'Iéna
Tour Eiffel
800 m
16TH ARR.
INVALIDES
Pont de Bir-Hakeim
Maison de la Radio
Île aux Cygnes
École Militaire
Musée de l'Armée
Musée Rodin
7TH ARR.
Lycée Collège Victor Duruy
Street View
Photo Sphere
See inside
Image capture: Jun 2014
Images may be subject to copyright.
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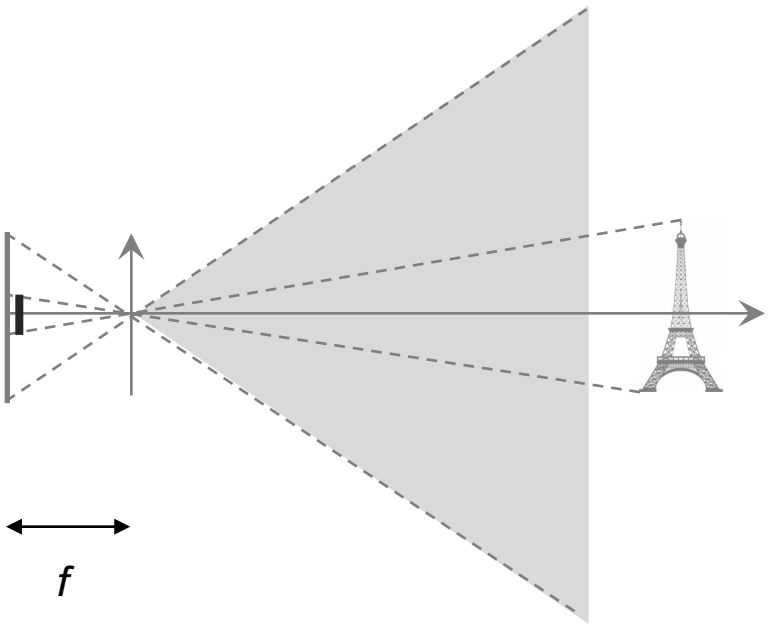
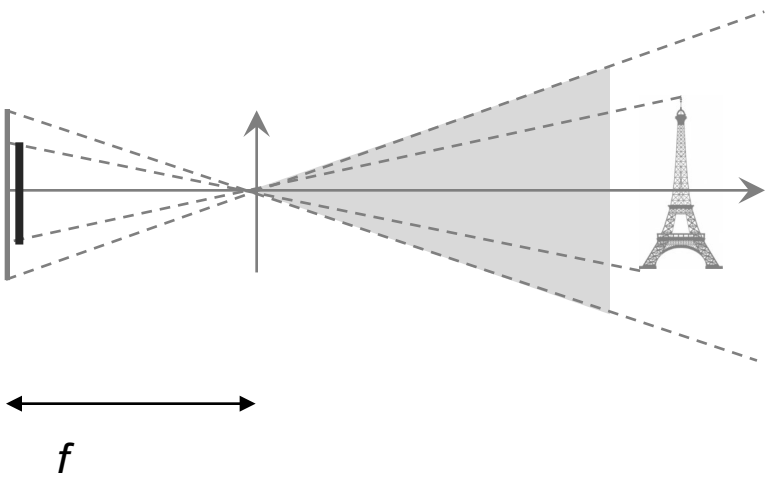
Focal Length

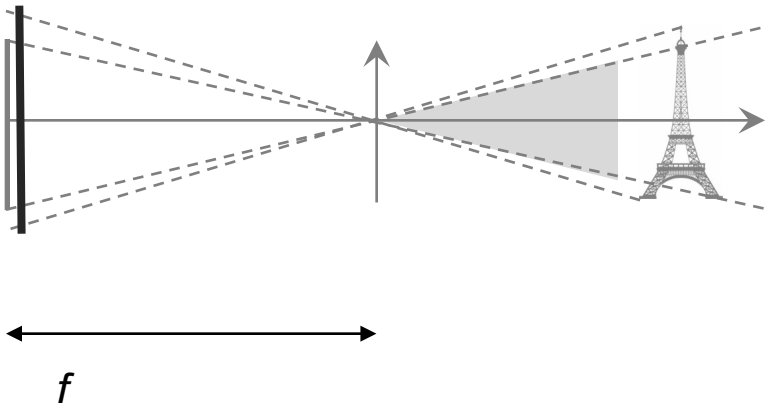


Shorter focal length, larger field of view!

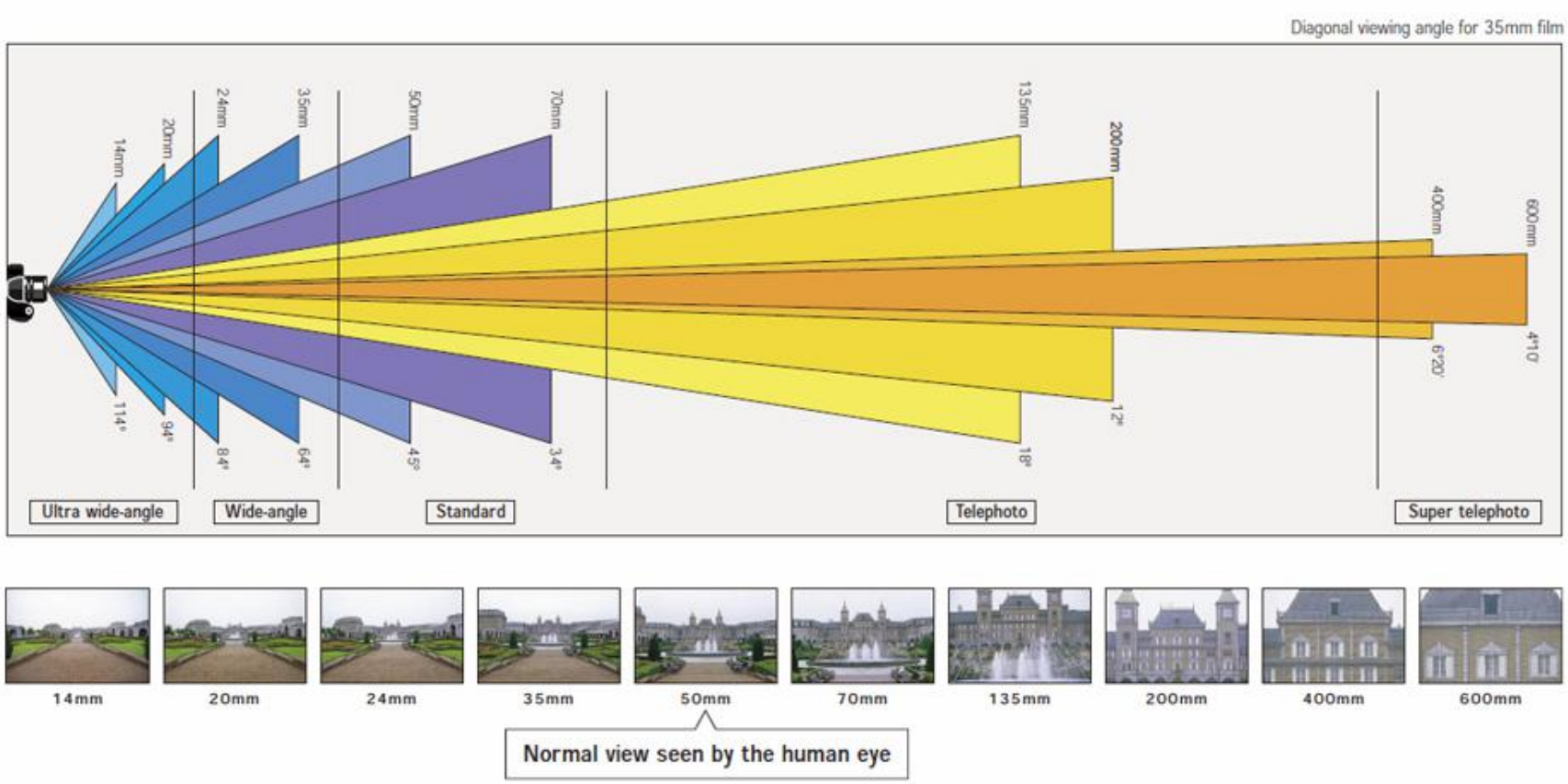
Focal Length



Focal Length

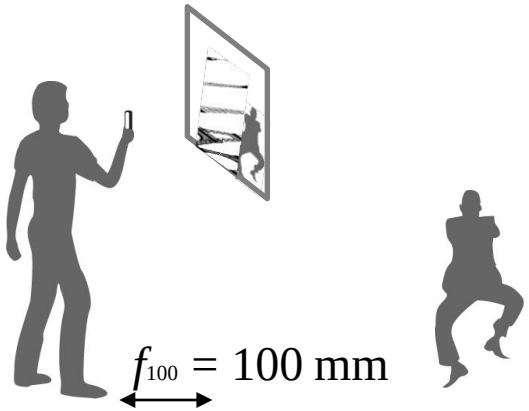


Focal Length



Dolly Zoom

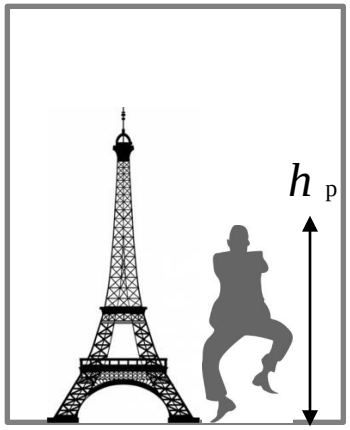
Given focal length (f_m=100mm),
what Z_{100} to make the height of the person remain the same as f_m=50mm?

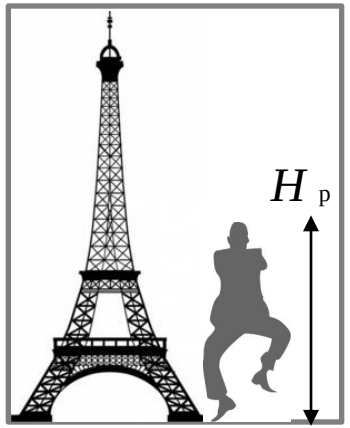


f_{100} = 100 mm

Z_{100} ?

Z_{50} =157.41m





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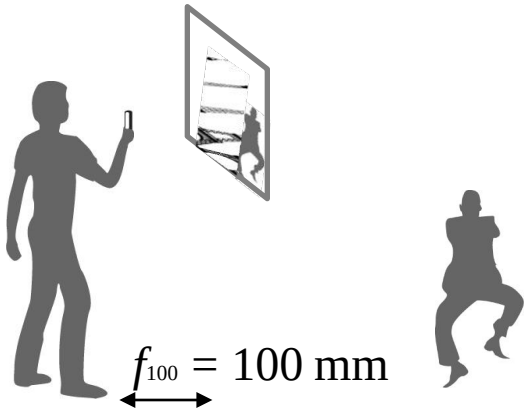
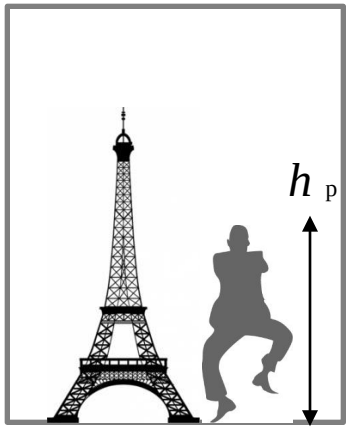


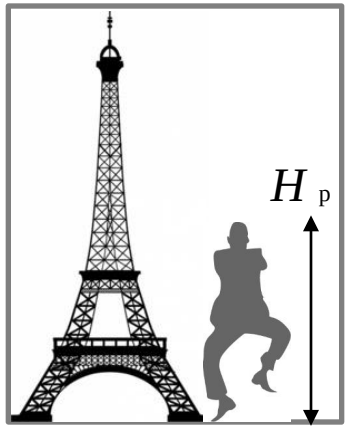
f_{100} = 100 mm

Z_{100} ?

Z_{50} =157.41m



$$h_{50} = f_{50}\frac{Y}{Z_{50}}$$



$$h_{100} = f_{100}\frac{Y}{Z_{100}}$$

s.t. $h_{100} = h_{50}$

Dolly Zoom

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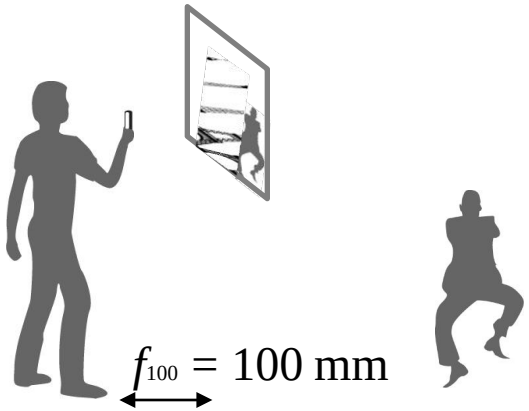
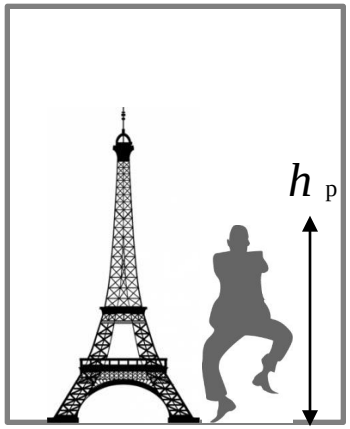
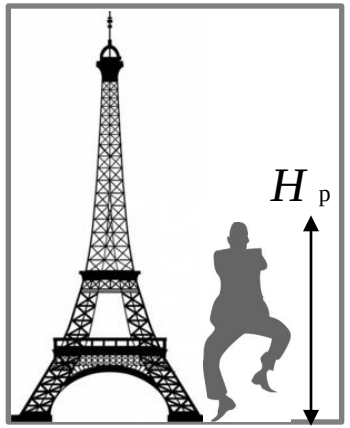




$$h_{50} = f_{50}\frac{Y}{Z_{50}}$$



$$h_{100} = f_{100}\frac{Y}{Z_{100}}$$

s.t. $h_{100} = h_{50}$

$$Z_{100} = \frac{f_{100}}{f_{50}} Z_{50} \qquad Z_{100} = \frac{100}{50} 157.41 = 314.8\text{m}$$