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3D Vision
BLG 634E

Lecture: Geometric Transforms

Professor: Gozde UNAL

Some slides are from Dr. Angjoo Kanazawa (CS294-173)

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Fundamentals you should know

- Pinhole camera
- Homogenous coordinates
- Orthographic/ Perspective projection
- Extrinsic & Intrinsic Parameters
- Coordinate frames, canonical frames
- SO(3) representations

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What do these things mean + how do they play with each other

- Stereo
- Shape from Shading
- Photometric Stereo
- Epipolar Geometry
- Multi-view Stereo
- Structure-from-motion
- Visual-SLAM
- Bundle-adjustment

ALL assumes rigid geometry, meaning structure is constant in all images

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Recap Image Formation Geometry

Fundamentals

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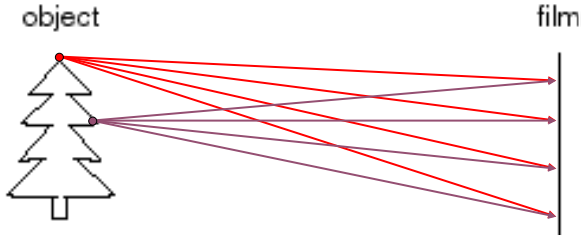
Image formation



Let's design a camera

- Idea 1: put a piece of film in front of an object
- Do we get a reasonable image?
- No. This is a bad camera.

Slide credit: Noah Snavely/Steve Seitz

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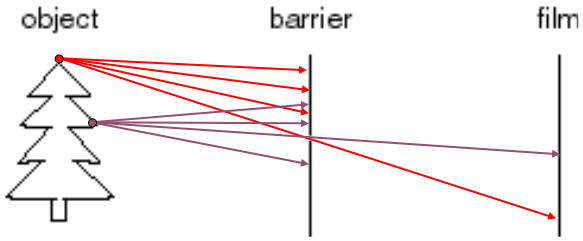
Pinhole camera



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 credit: Noah Snavely

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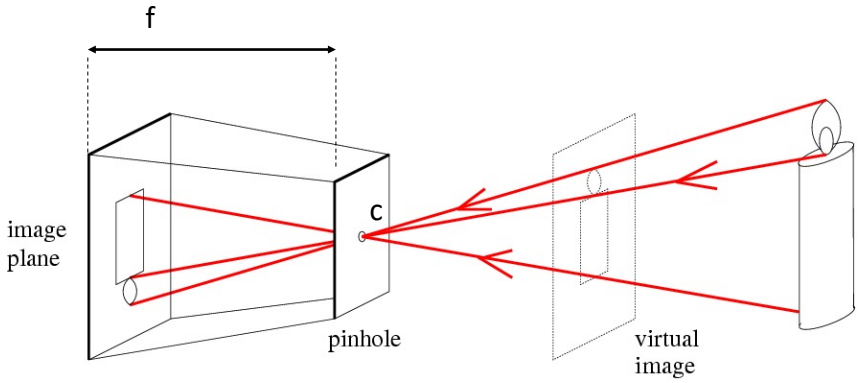
Pinhole camera



f = focal length
c = center of the camera

Figure from Forsyth

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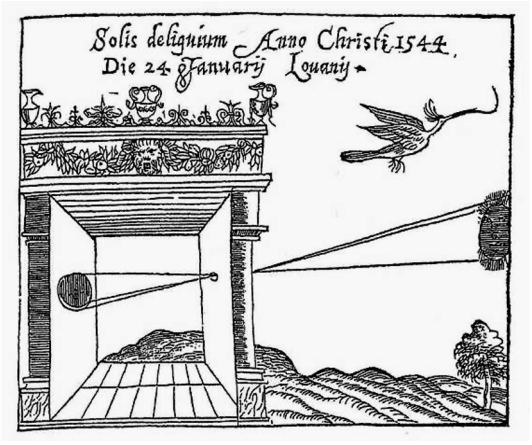
Camera Obscura ("dark chamber")



Gemma Frisius, 1558

- Basic principle known in classical period of China and Greece: Mozi (470-390 BC), Aristotle (384-322 BC)
- Drawing aid for artists: described by Leonardo da Vinci (1452-1519)

Source: A. Efros

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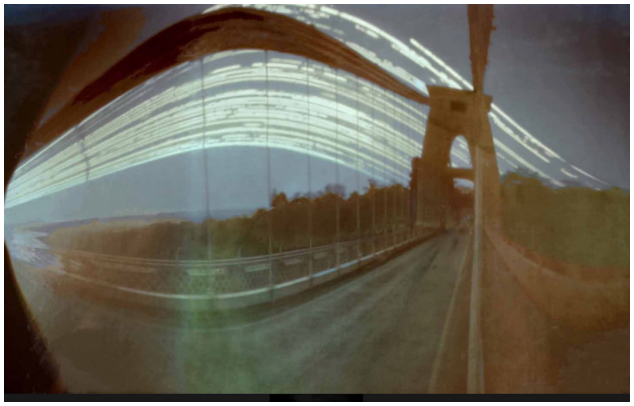
Pinhole Photography

https://www.pinholephotography.org

You thought a 1 minute exposure was long, check out this: 6 month exposure!



Justin Quinnell, The Clifton Suspension Bridge.
December 17th 2007 - June 21st 2008
***6-month* exposure**

Also, see OpenShutter project by artist Michael Wesely: https://casanovaarte.com/en/artista/michael-wesely/

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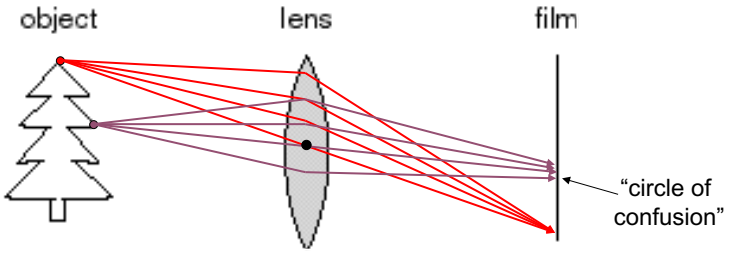
Adding a lens



A lens focuses light onto the film

- There is a specific distance at which objects are "in focus"
  - other points project to a "circle of confusion" in the image
- Changing the shape of the lens changes this distance

Slide credit: Noah Snavely/Steve Seitz

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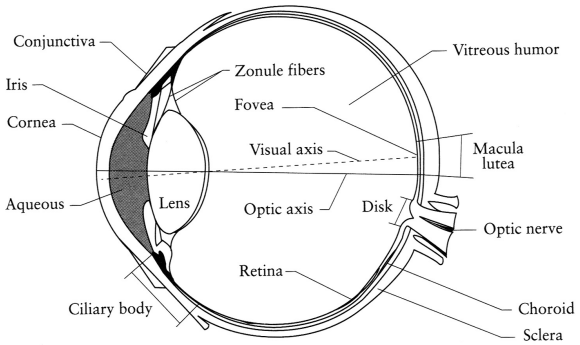
The eye



The human eye is a camera

- **Iris** - colored annulus with radial muscles
- **Pupil** - the hole (aperture) whose size is controlled by the iris
- What's the "film"?
  - photoreceptor cells (rods and cones) in the **retina**

Slide credit: Noah Snavely

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Can Lengths be trusted ?

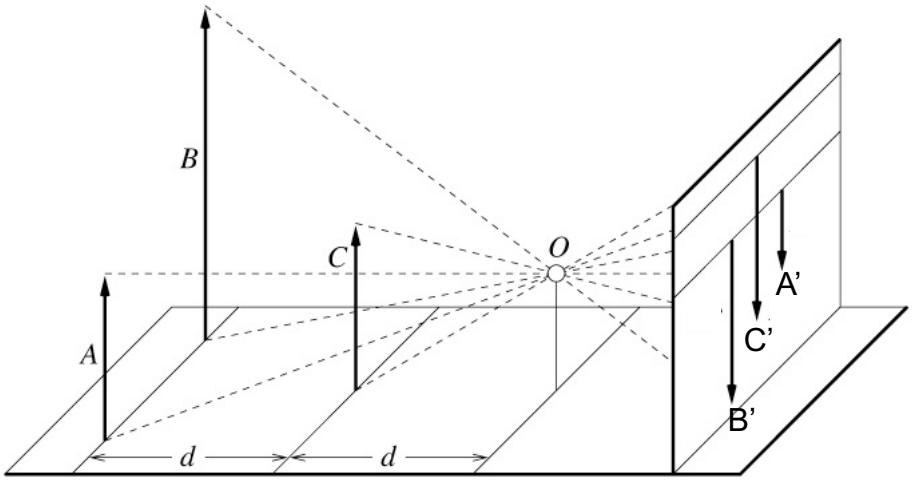

Figure by David Forsyth

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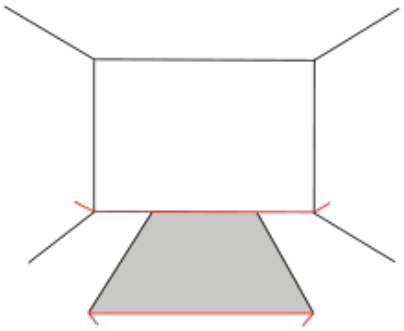
Lengths can't be trusted...



E.g. compare the length of the bottom border of the wall and the front line of the rug in a room:

Our brains would perceive this as: rug has a shorter length than the wall

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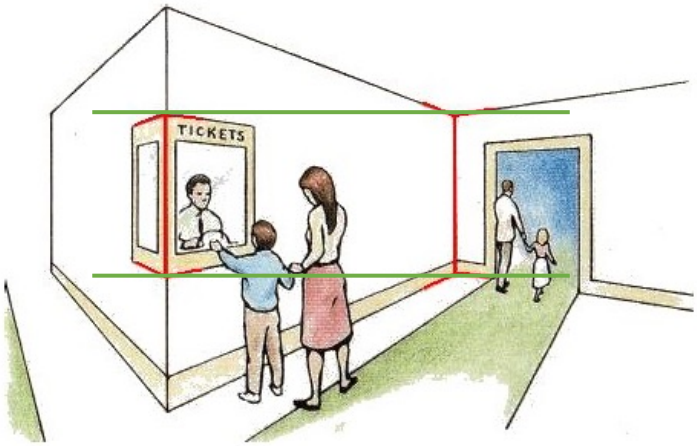
We adopt: Müller-Lyer Illusion



We don't make measurements in the image plane

https://en.wikipedia.org/wiki/Müller-Lyer_illusion

Slide credit: Efros

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Other Camera Models

- Fisheye
- 360 degree camera
- Panorama
- Tilt-Shift Lens
- Biological Eyes

http://www.popgadget.net/2006/07/fisheye_camera.php

http://www.0-360.com/

Canon TS-E 24mm f/3.5L II

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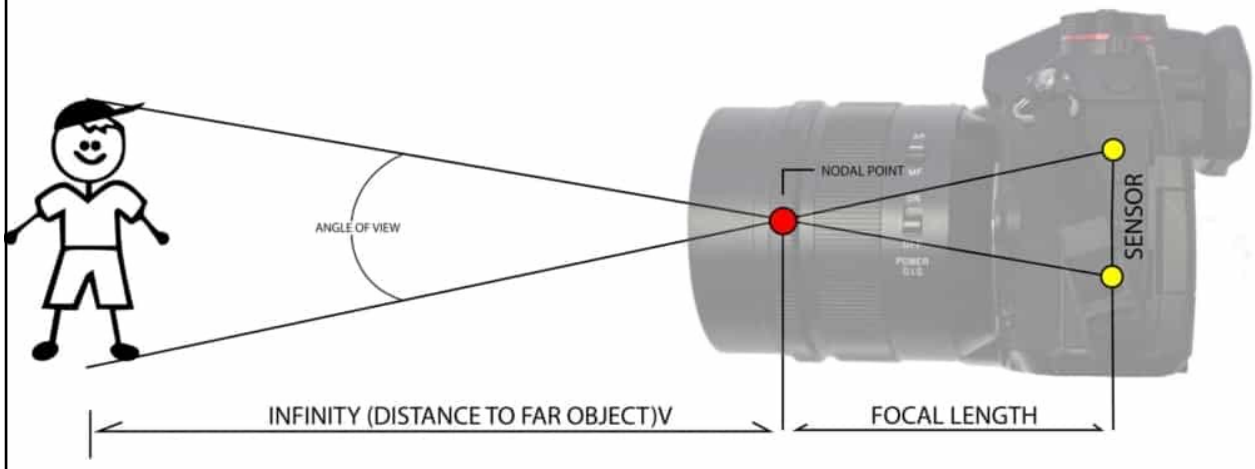
Focal length



Nodal point is the optical center

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Focal length

- Can think of as "zoom"

24mm

50mm

200mm

800mm

- Also related to *field of view*

Slide credit: Noah Snavely

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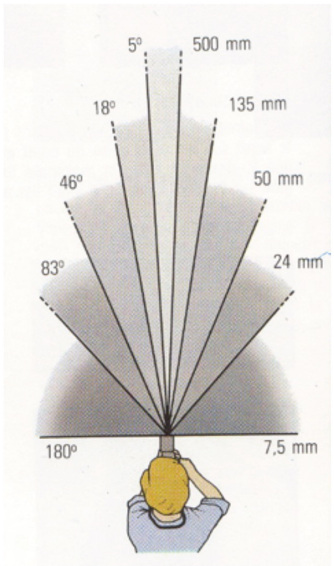
Focal length in practice



24mm

50mm

135mm

Fredo Durand

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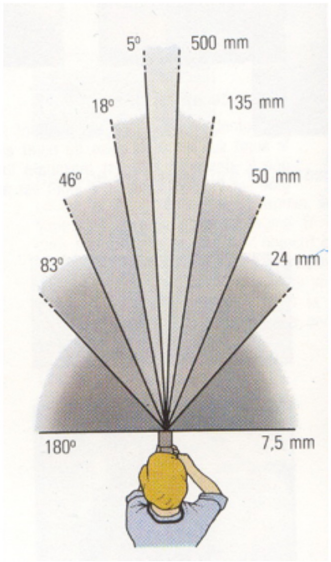
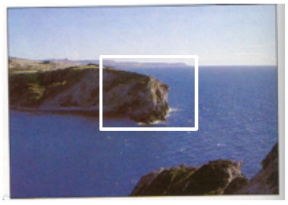
Focal length = cropping



24mm

50mm



135mm

Fredo Durand

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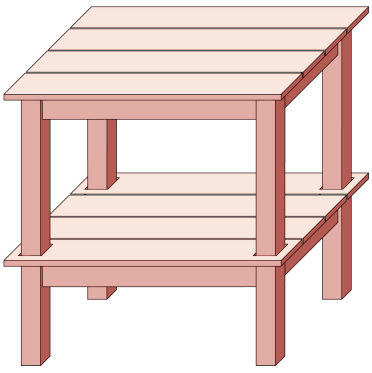
Orthographic projection



Slide credit: Noah Snavely

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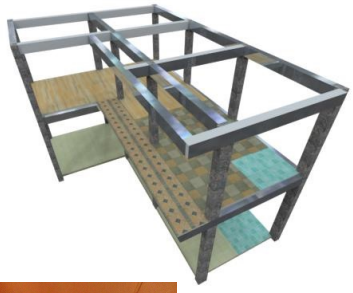
Perspective projection



Slide credit: Noah Snavely

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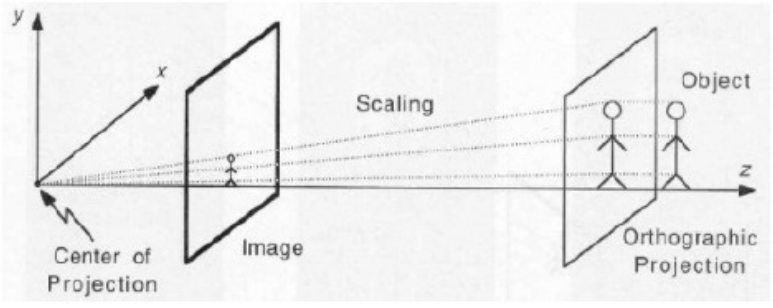
Scaled orthographic projection

Also called “weak perspective”. If a model uses orthographic projection, it’s most likely weak perspective.



- Simply projection is a scaled value: (X, Y, Z) → (dx, dy)
- This scale factor, d, approximates, f/z
- But it’s like same z everywhere (bc one scale for everything)

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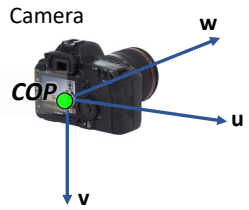
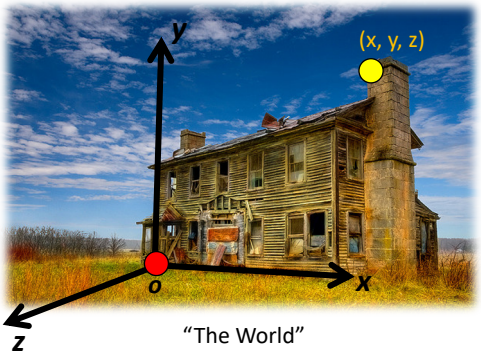
Camera parameters

- How can we model the geometry of a camera?





"The World"

Three important coordinate systems:
1. *World* coordinates
2. *Camera* coordinates
3. *Image* coordinates

How do we project a given world point (x, y, z) to an image point?

Slide credit: Noah Snavely

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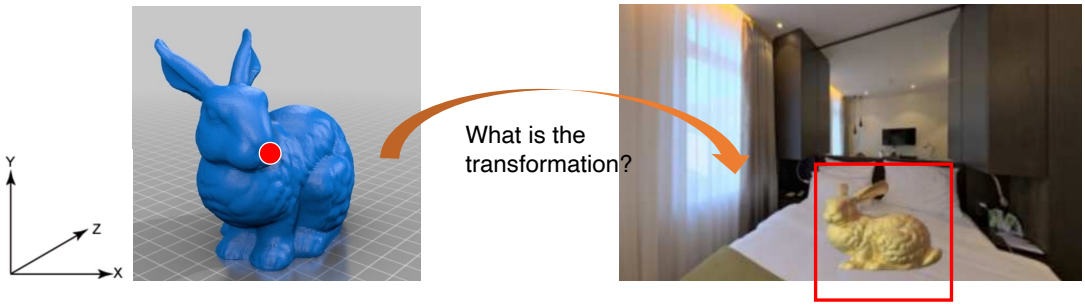
World to Camera Frame



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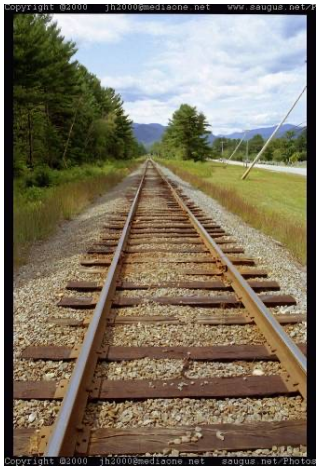
Why do we need Projective Geometry? Camera to Image Projection

- Parallel lines converge at a vanishing point
- Euclidean Geometry does not model this behavior
- Projective Geometry does!



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Geometric Image Formation (coordinate frames)

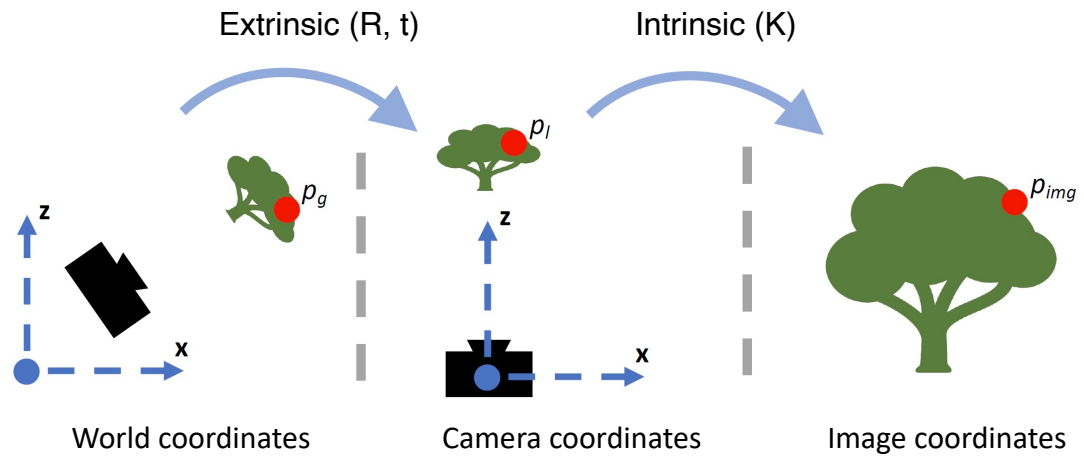

Figure credit: Peter Hedman

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