CS 558: Computer Vision 1st Set of Notes

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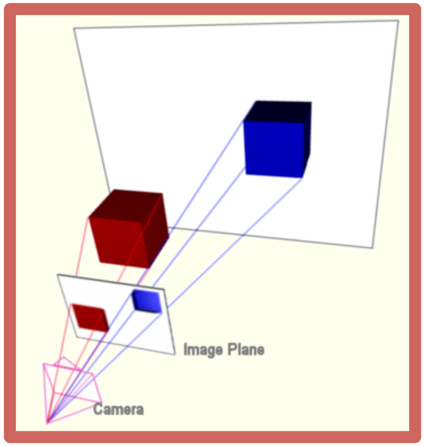
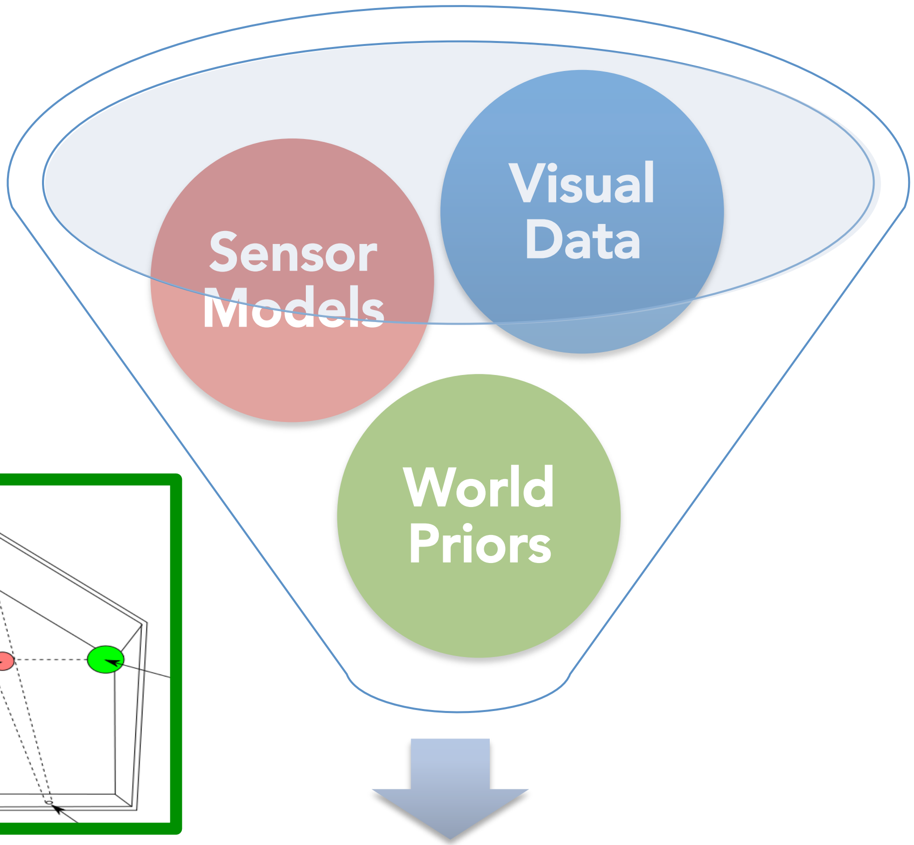
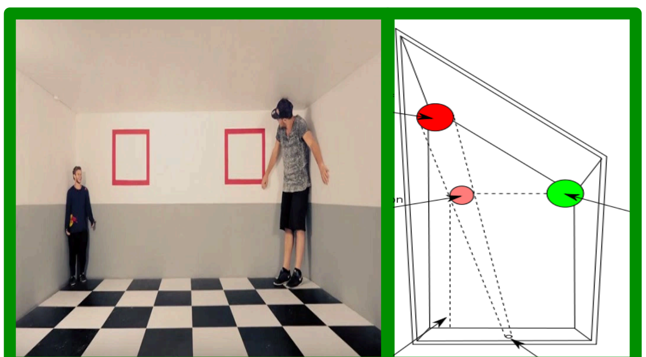
Computer Vision



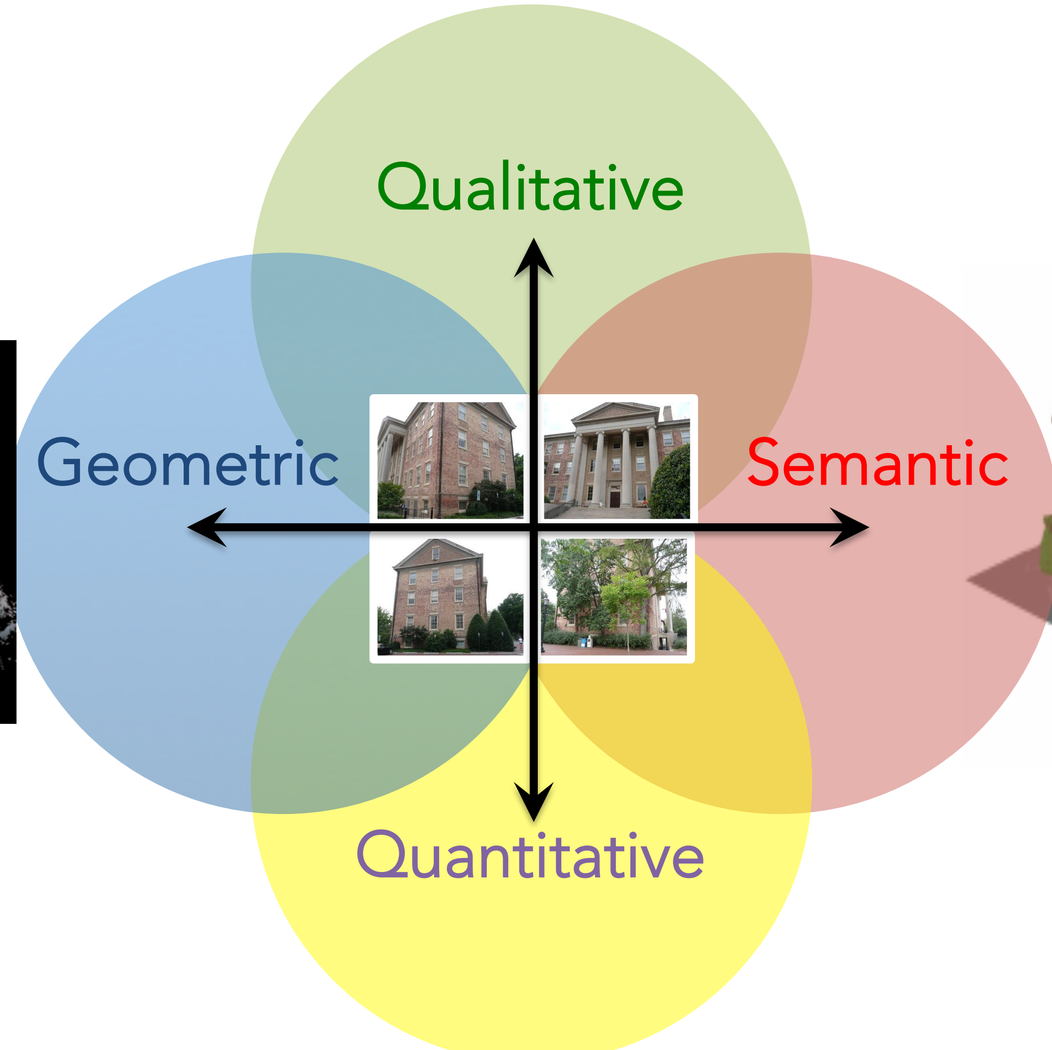


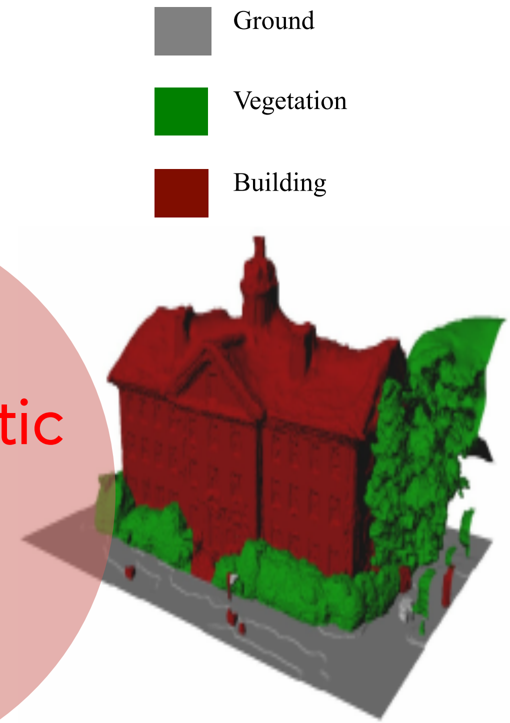


Visual Concepts

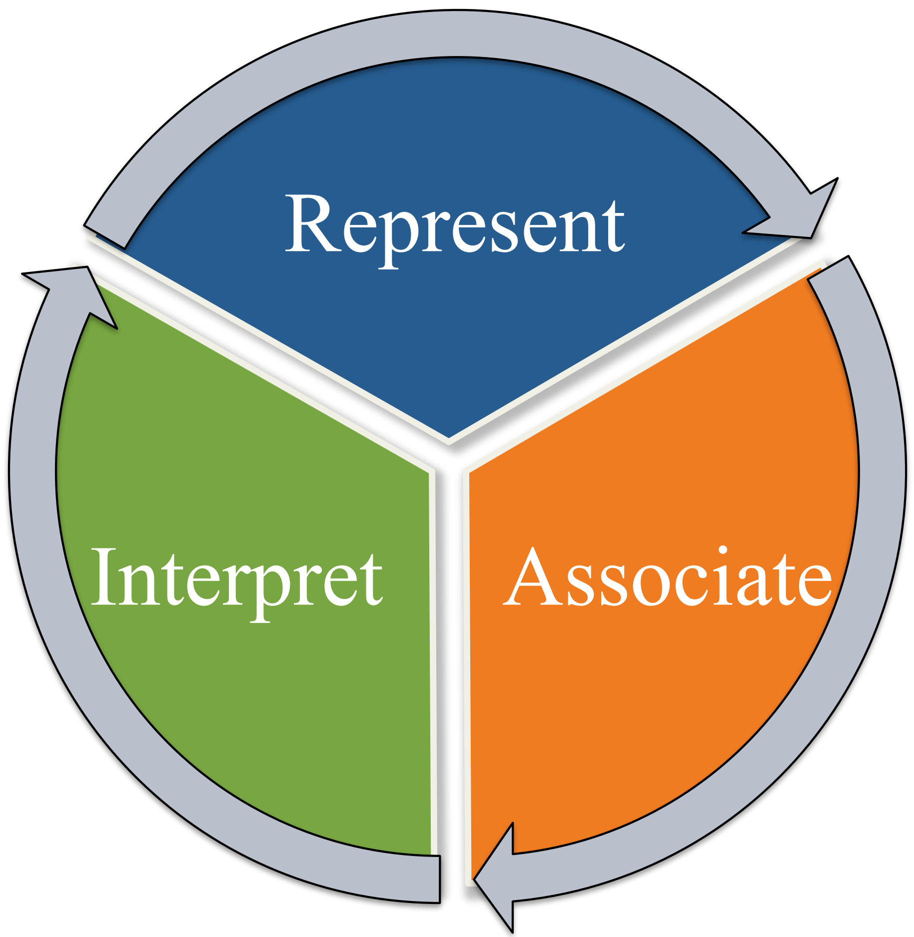
Visual Concepts

3D Content

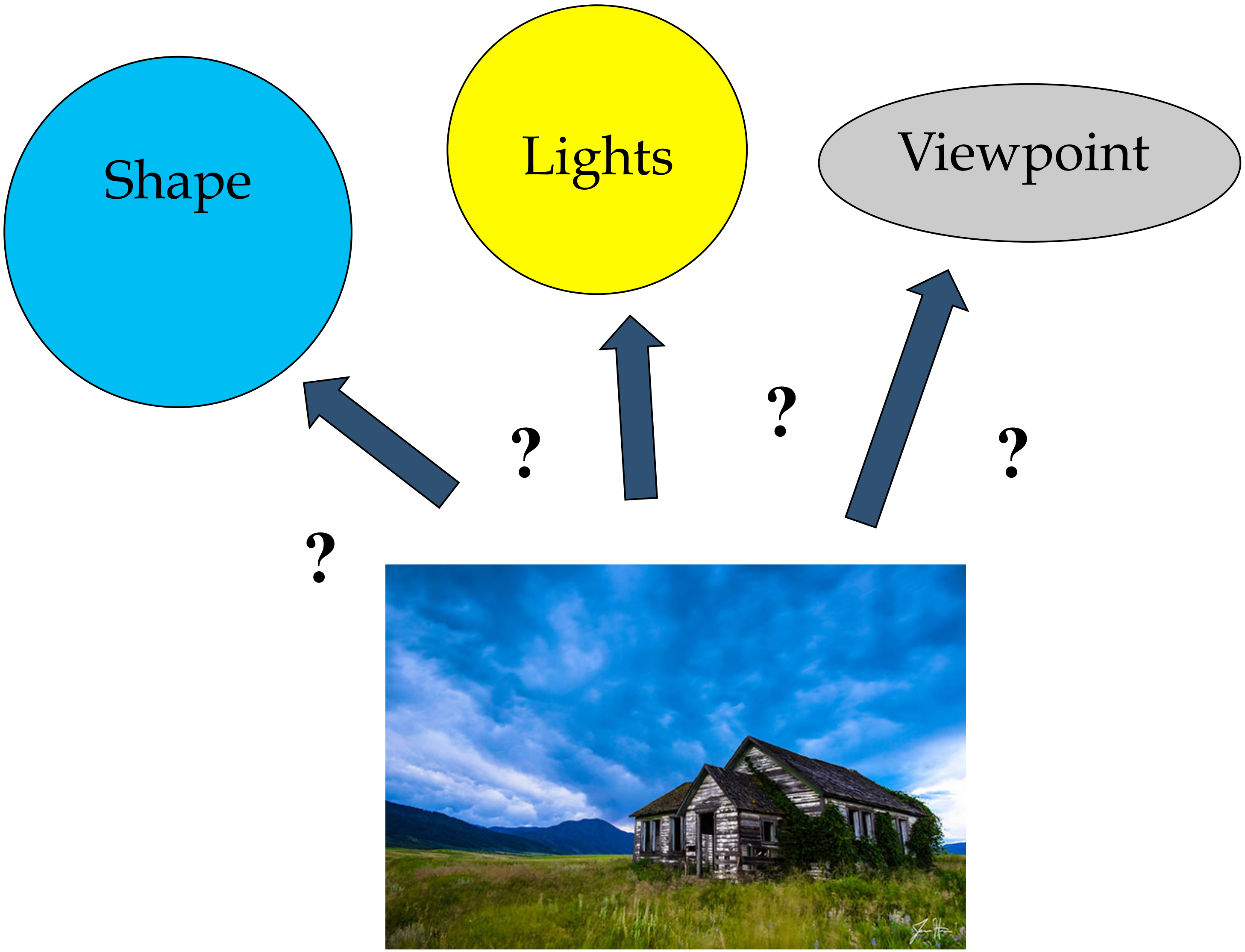




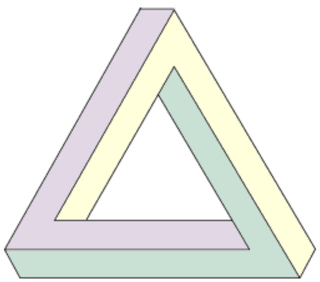
Computer Vision

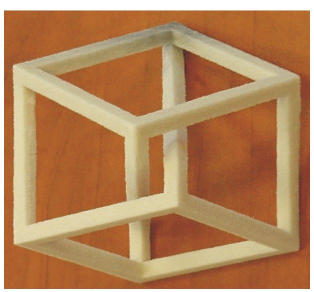


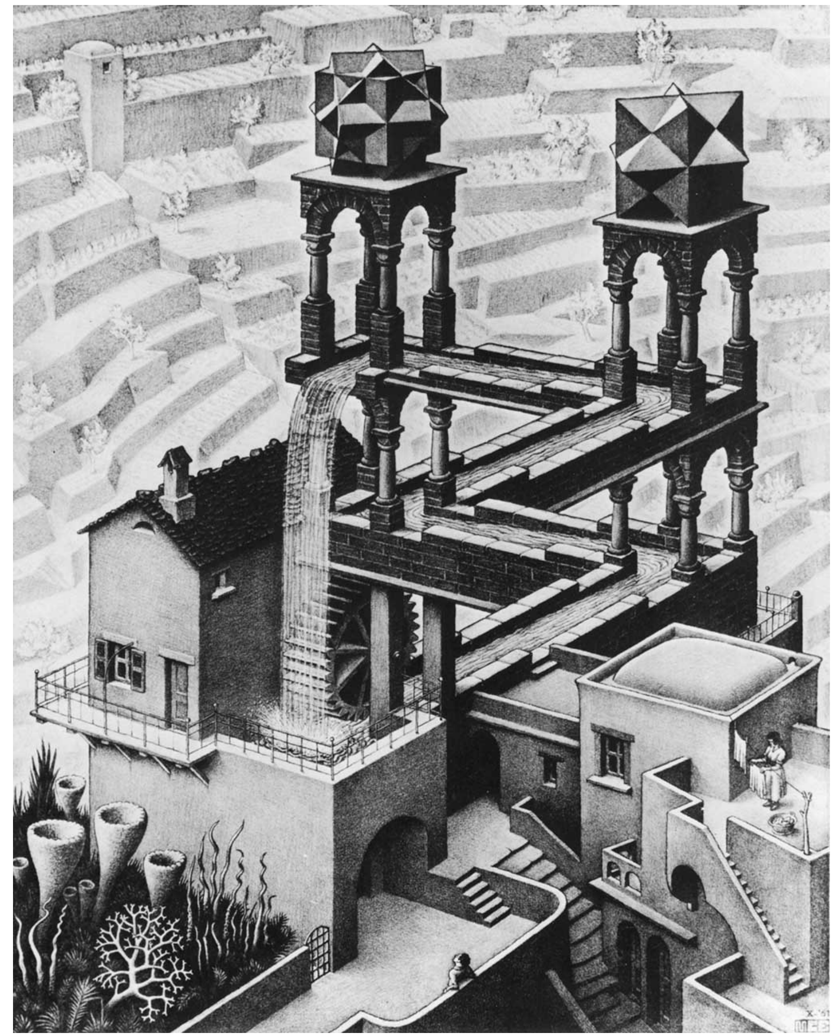
Graphics vs. Vision



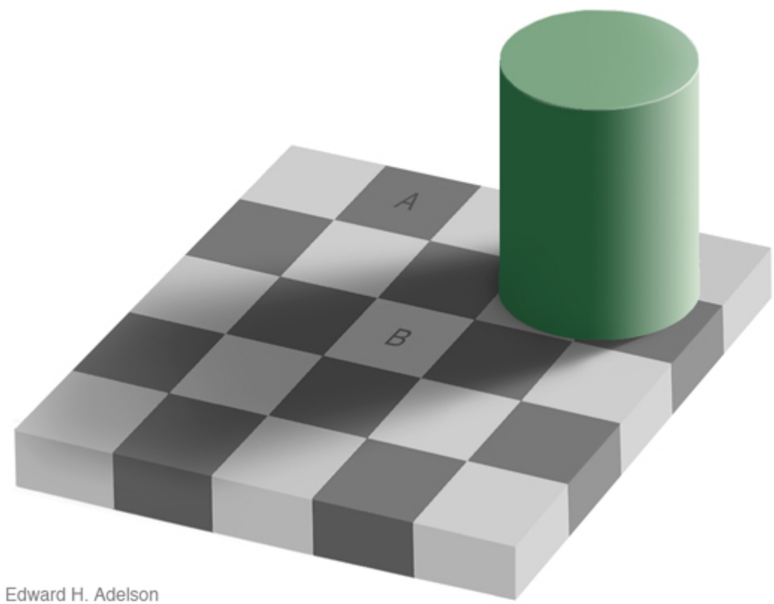
Vision is Hard

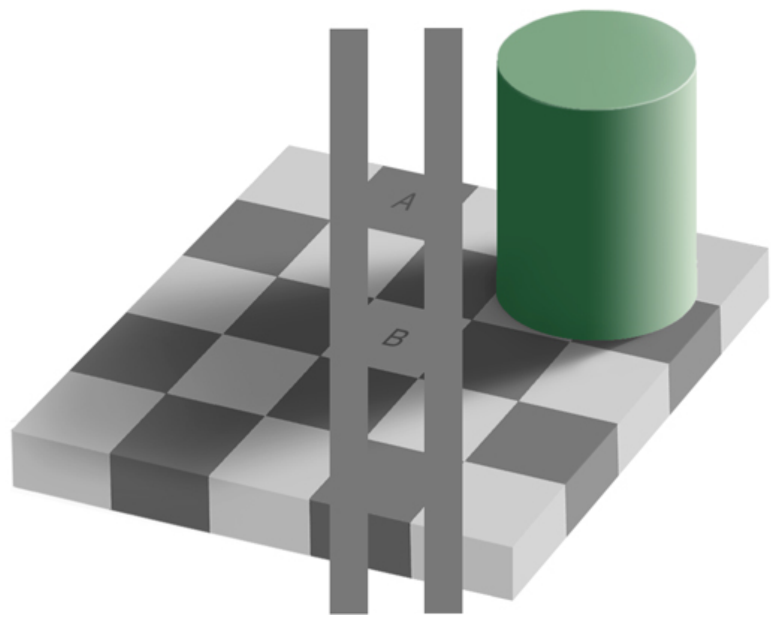






Vision is Hard

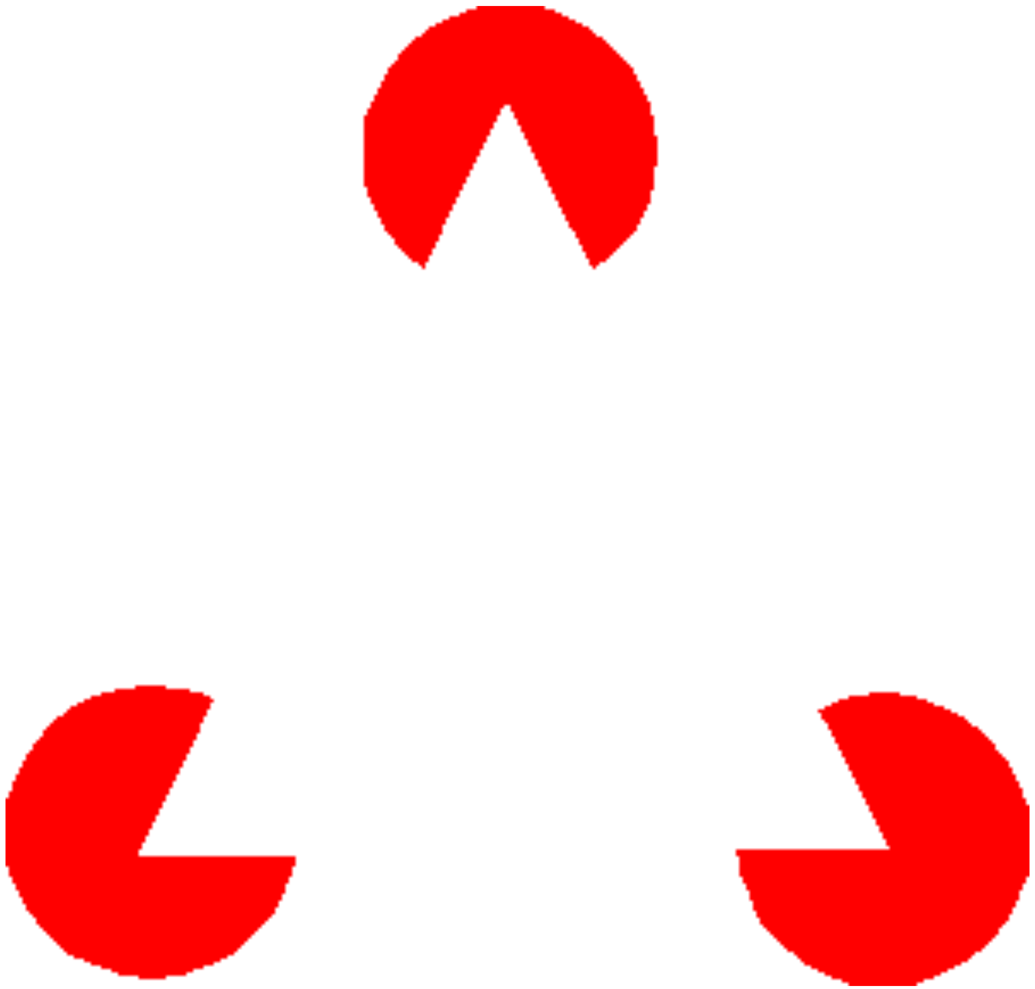




Vision is Hard

- A 2D picture may be produced by many different 3D scenes

Vision is Inferential



Vision is Fascinating

Why is Vision Hard?

- Loss of information due to projection from 3D to 2D
  - Infinite scenes could have generated a given image
- Image colors depend on surface properties, illumination, camera response function and interactions such as shadows
- Noise
  - sensor noise and nonlinearities, quantization
- Lots of data
- Conflicts among local and global cues
  - Illusions

The Horizon

- Not all hard to explain phenomena are unusual…

Vanishing Points

How Vision is Used Now

- Examples of state-of-the-art

Some of the following slides by Steve Seitz and Derek Hoiem

Earth Viewers (3D modeling)

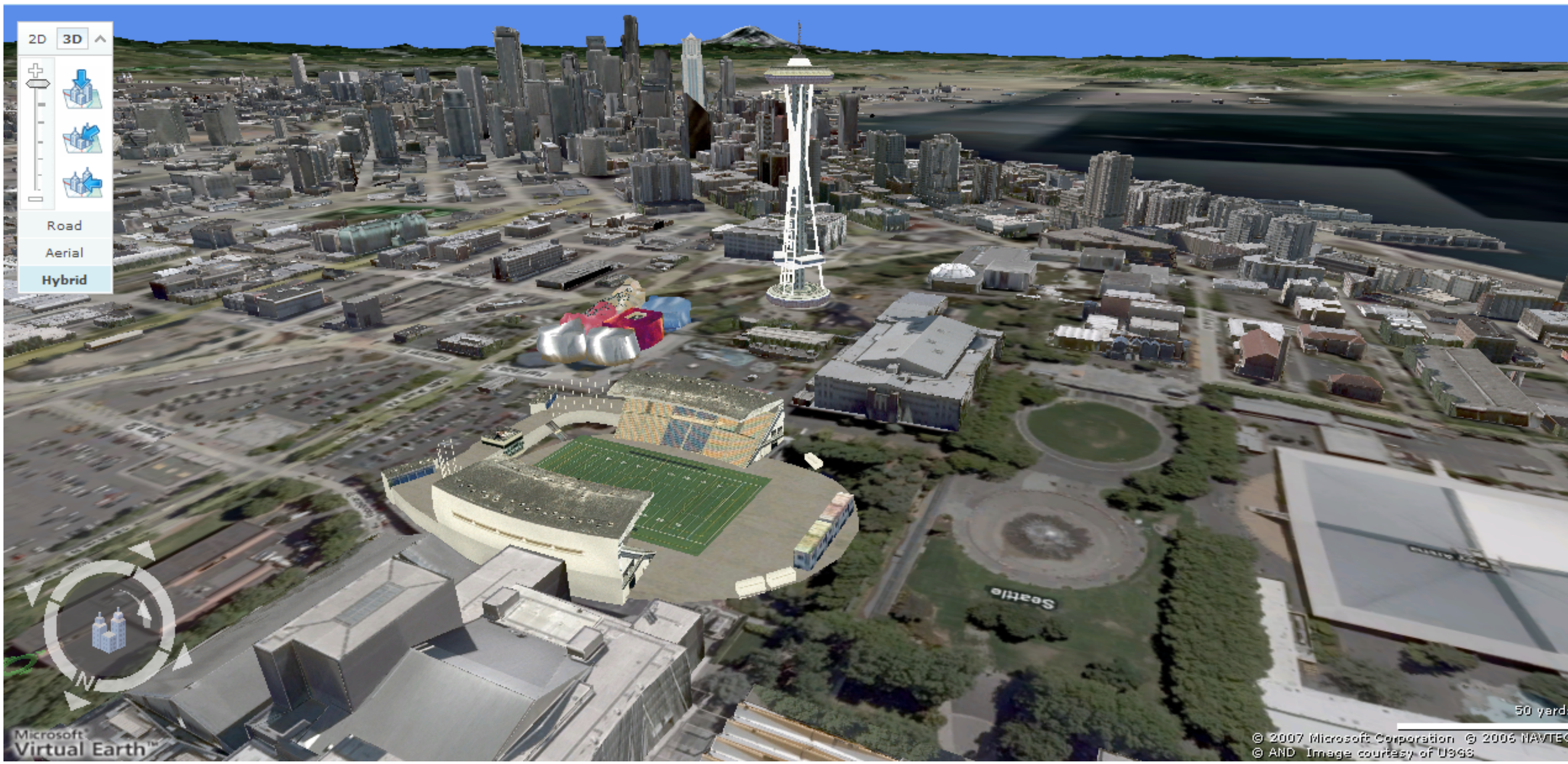
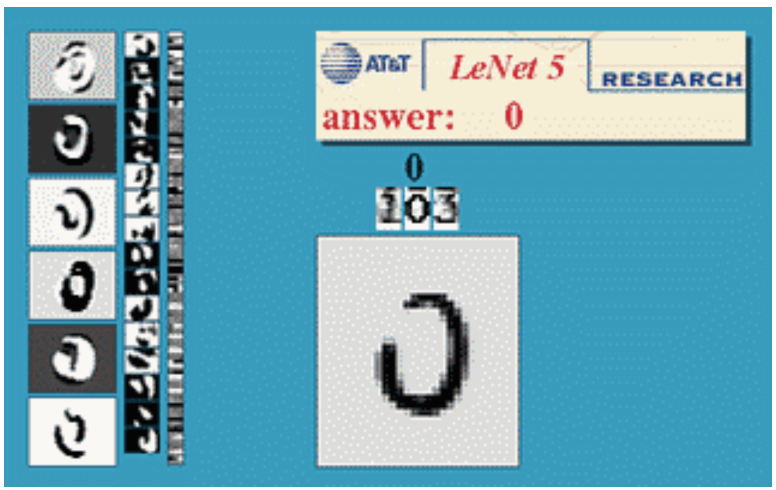


Image from Microsoft's [Virtual Earth](#)
(see also: [Google Earth](#))

Optical Character Recognition (OCR)



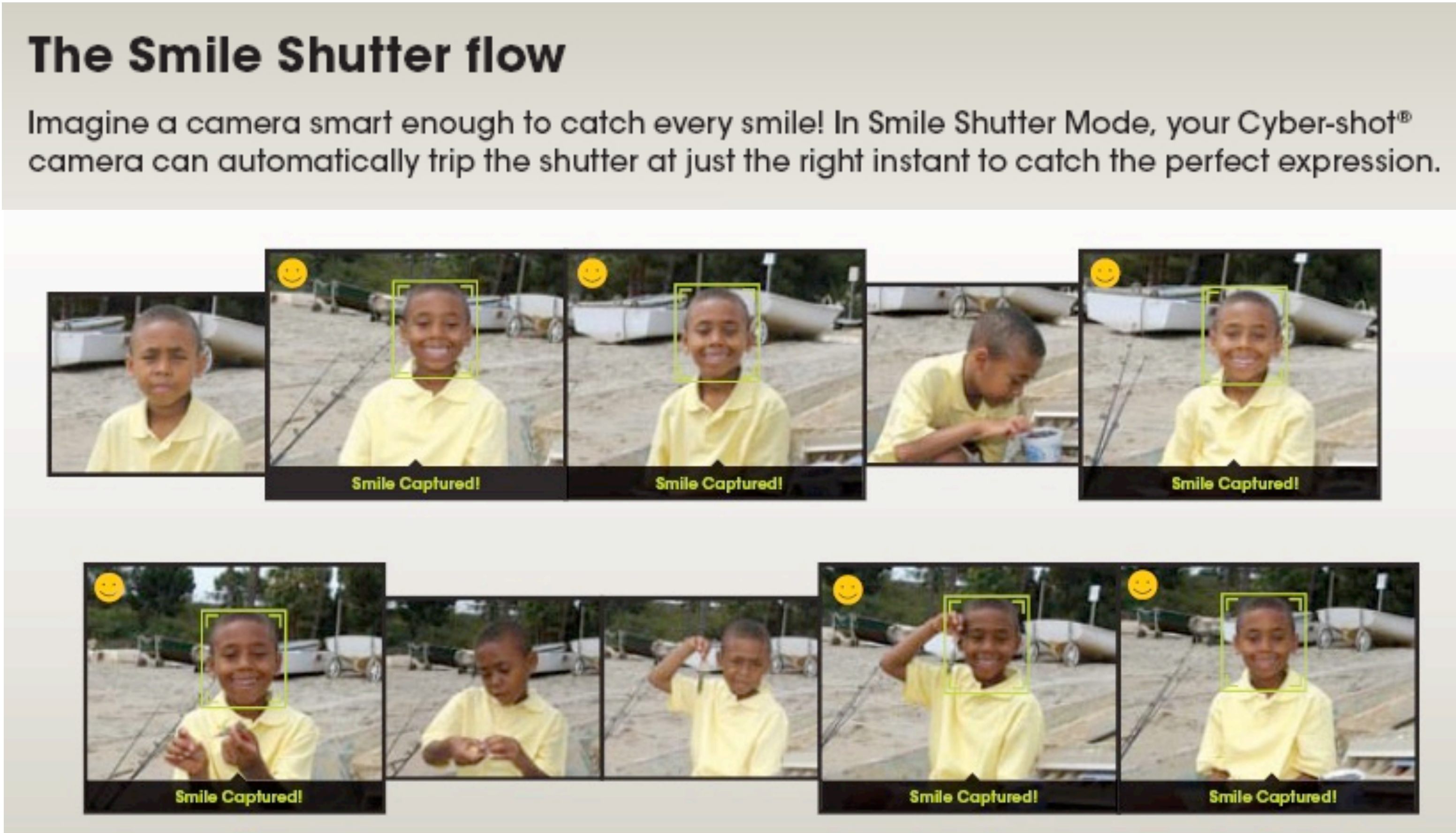
Digit recognition, AT&T labs
http://www.research.att.com/~yann/

License plate readers
http://en.wikipedia.org/wiki/Automatic_number_plate_recognition

Face Detection

- Most digital cameras detect faces (and more)

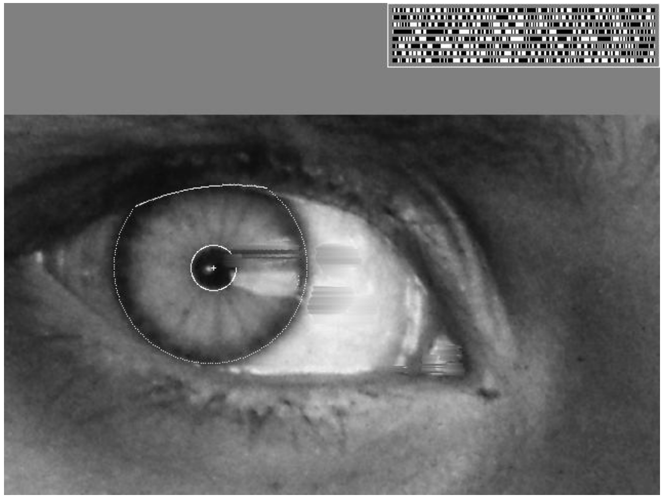
Smile detection

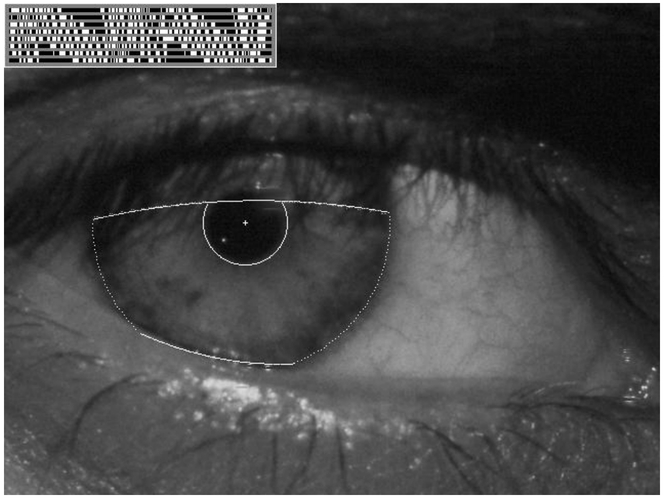


[Sony Cyber-shot® T70 Digital Still Camera]

Vision-based Biometrics

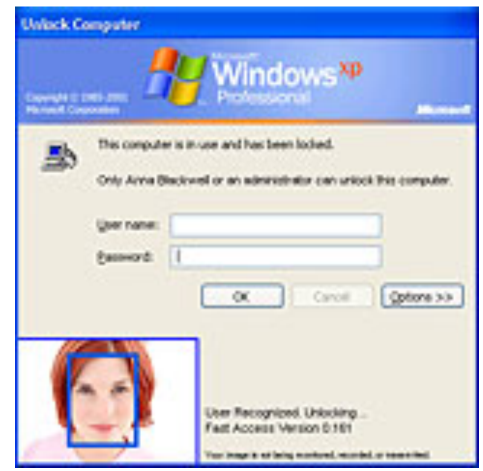
"How the Afghan Girl was Identified by Her Iris Patterns"





Login without a Password…

Fingerprint scanners on
many new laptops,
other devices



Face recognition systems now
beginning to appear more widely
http://www.sensiblevision.com/

Sports

Sportvision first down line
Nice explanation on www.howstuffworks.com

http://www.sportvision.com/video.html

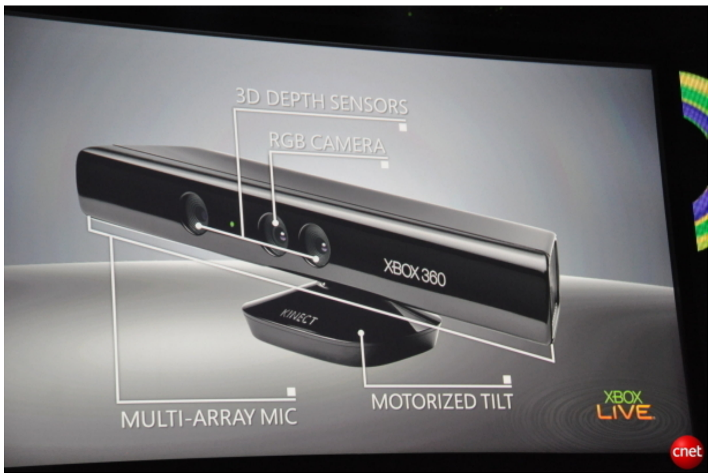
Smart cars

- [Mobileye](http://mobileye.com): vision systems currently in many cars

http://mobileye.com/technology/applications/vehicle-detection/forward-colision-warning/
http://mobileye.com/technology/applications/pedestrian-detection/pedestrian-collision-warning/

“Subaru thinks cameras are better than radar cruise”
http://www.roadandtrack.com/new-cars/news/a6852/subaru-camera-controlled-cruise/

Interactive Games: Kinect



Vision in space

NASA'S Mars Exploration Rover Spirit captured this westward view from atop a low plateau where Spirit spent the closing months of 2007.

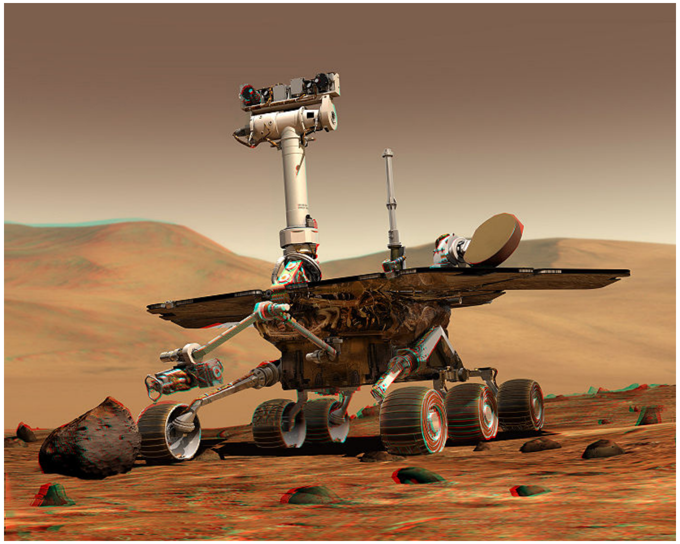
Vision systems (JPL) used for several tasks

- Panorama stitching
- 3D terrain modeling
- Obstacle detection, position tracking
- For more, read "Computer Vision on Mars" by Matthies et al.

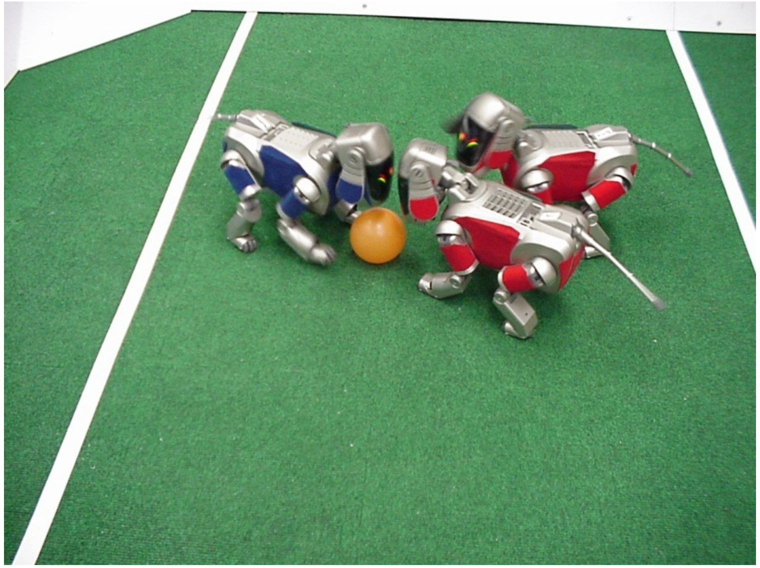
Industrial robots

Vision-guided robots position nut runners on wheels

Mobile Robots

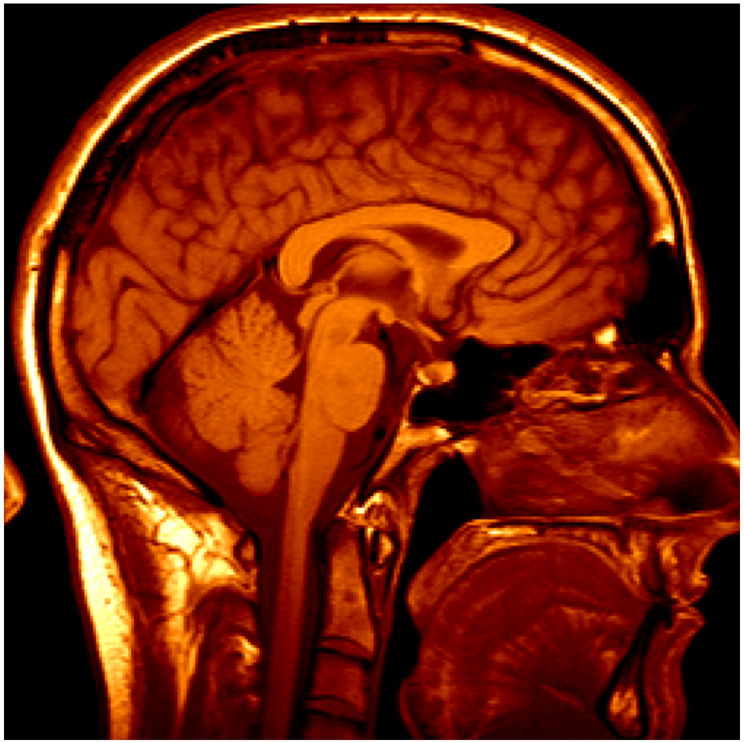


NASA's Mars Spirit Rover
http://en.wikipedia.org/wiki/Spirit_rover



http://www.robocup.org/

Medical Imaging



3D imaging
MRI, CT

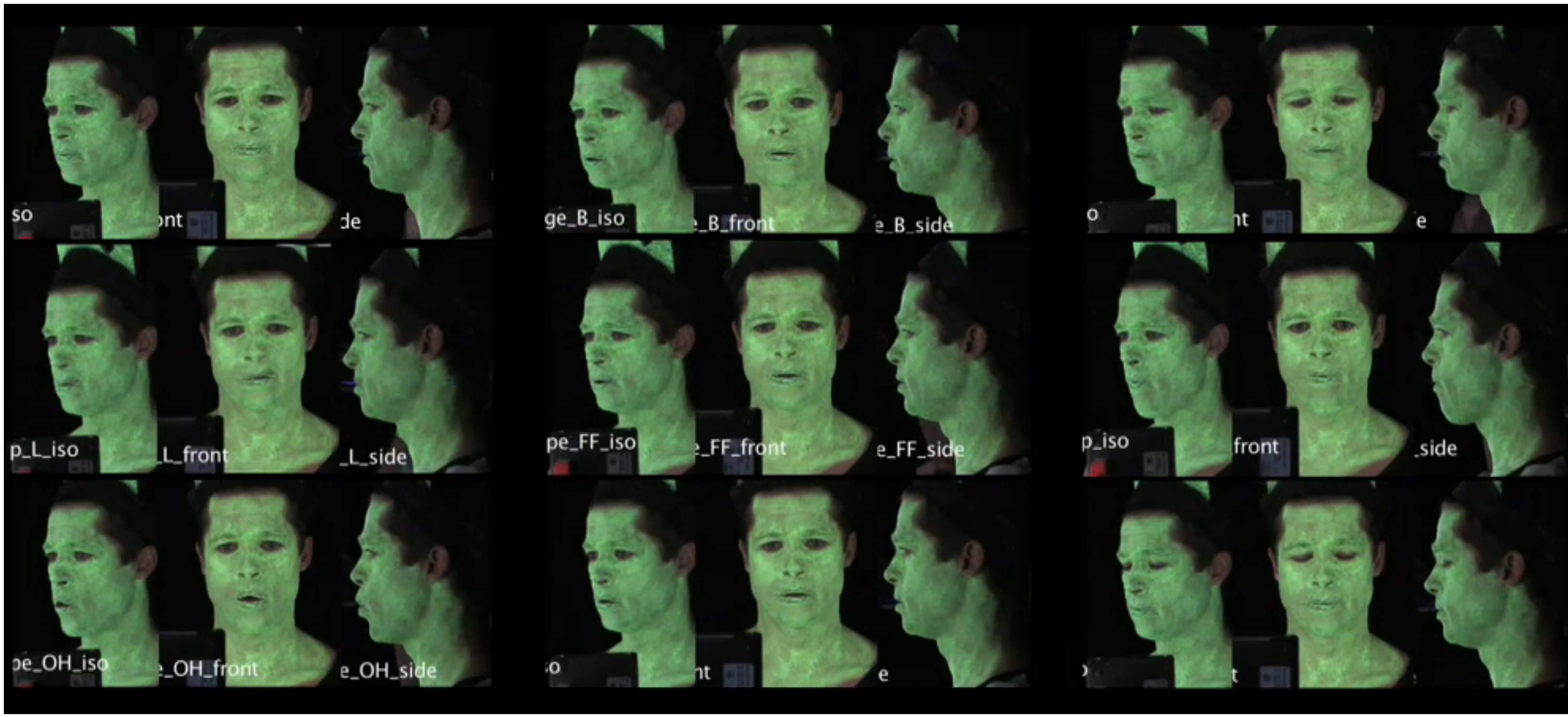
Image guided surgery
[Grimson et al., MIT]

The Curious Case of Benjamin Button (2008)





The Curious Case of Benjamin Button (2008)



DIGITAL DOMAIN

The Curious Case of Benjamin Button (2008)

The Curious Case of Benjamin Button (2008)

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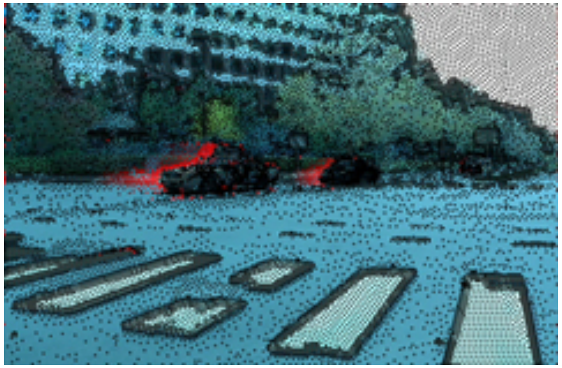
The Curious Case of Benjamin Button (2008)

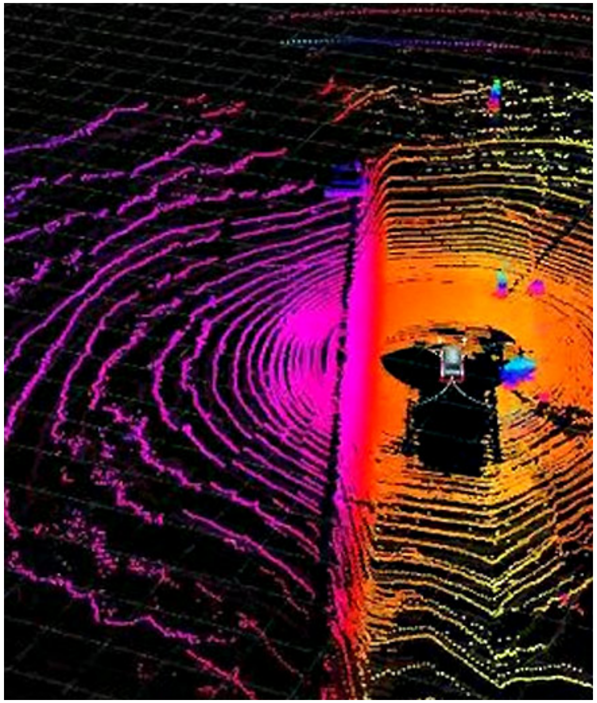
The DARPA Grand Challenge

- 2004: goal drive 150 miles in the Mojave desert autonomously
  - Longest any participant traveled: 7.4 miles
- 2005: 5 teams completed race
  - Won by Stanley from Stanford (VW Touareg)

The DARPA Urban Challenge

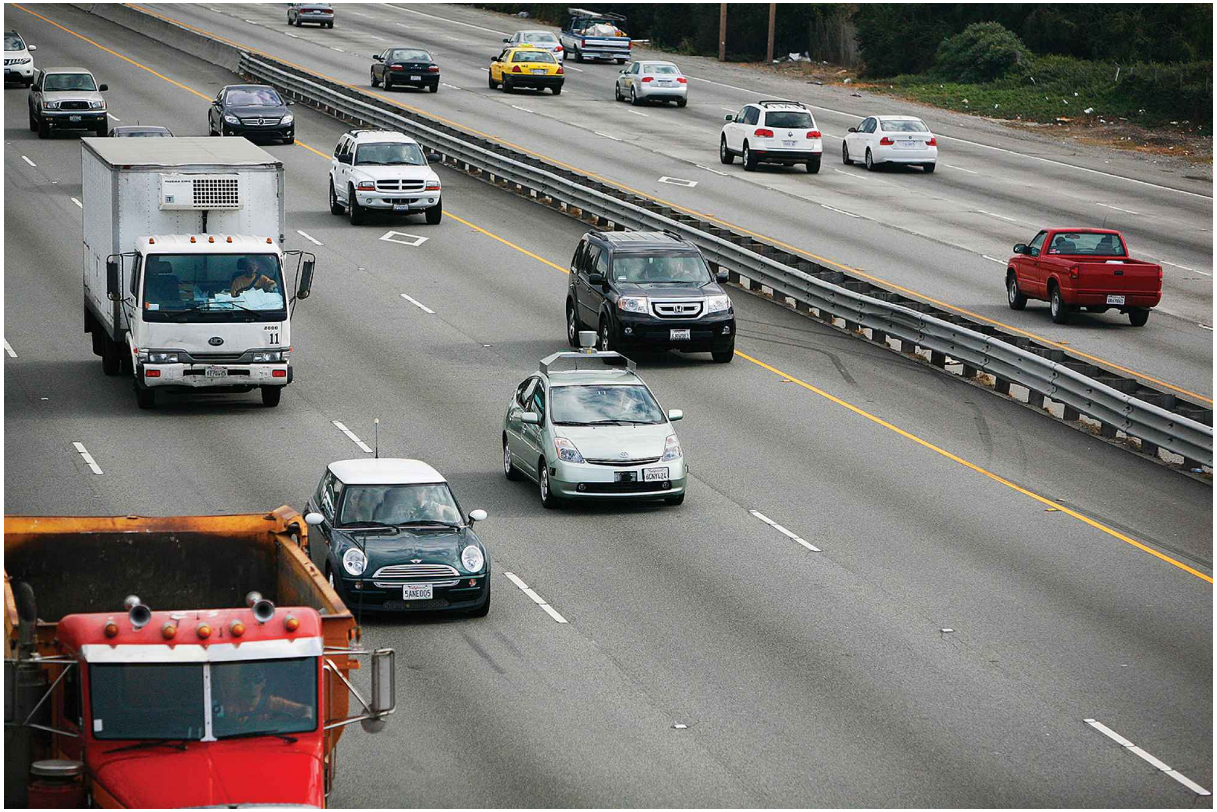
- 2007: navigate “urban” environment to complete missions
- 50 human-driven cars also on road
- Maps and locations of stop signs given to teams
- Improved laser sensors





Google Car

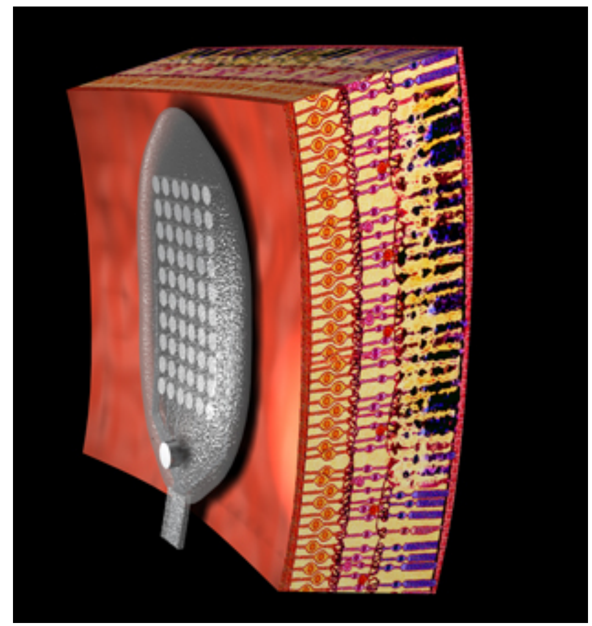
- Passed 1,000,000 accident-free miles

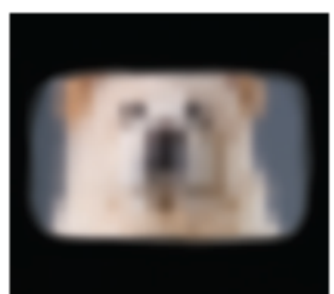


- What are the remaining obstacles?

The Real Bionic Woman

- Electrodes implanted in Lisa's eye
- Connected to camera mounted on glasses
- 6x10 image
- Brain has to be trained
- Lisa can see moon, fireworks





OrCam

- Smart camera mounted on glass frames
- Speaks through earpiece
- Recognizes text and objects

The World in Six Days

Building the World in Six Days

CVPR 2015

Paper 964

Visual Turing Test (UW)

Shan, Adams, Curless, Furukawa and Seitz (2013)

Dynamic Reconstruction

Tools Needed for Course

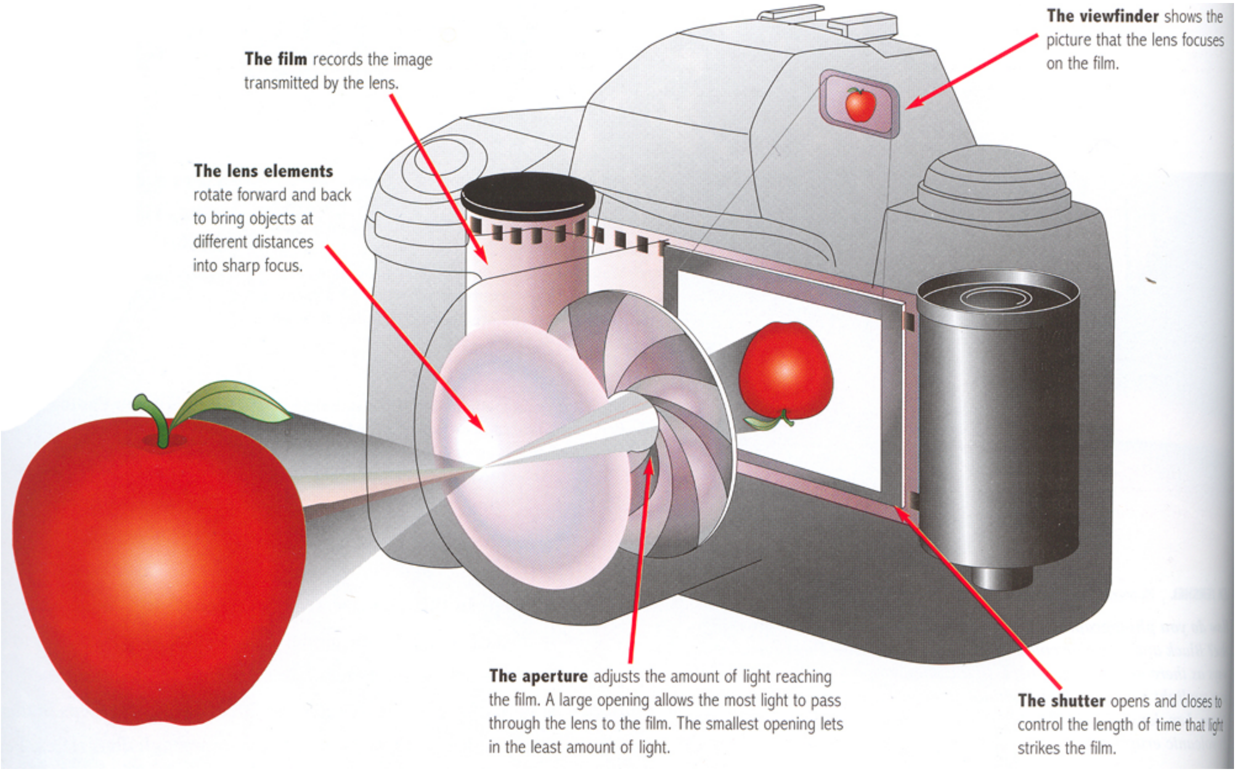
- Math
  - Linear Algebra
  - Signal Processing (to be covered)
  - Some calculus
  - Some geometry
  - Some probability
- Computer Science
  - Algorithms
  - Programming
    - Suggested matlab or python
    - Other languages acceptable if you can manipulate images effortlessly

Camera Body

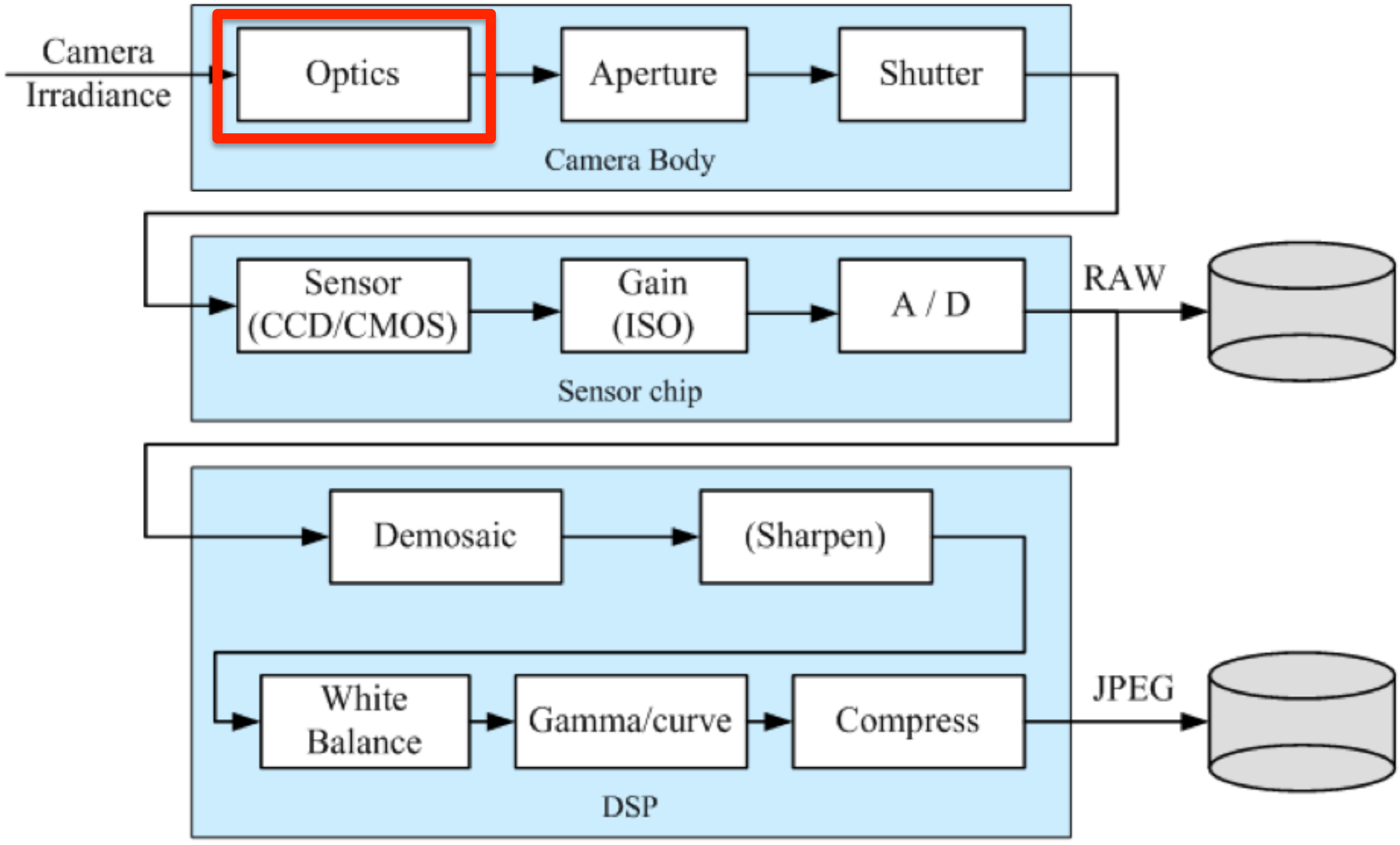
Slides by G. Doretto

Camera Body

- Lens and viewpoint determine perspective
- Aperture and shutter speed determine exposure
- Aperture and other effects determine depth of field
- Film or sensor record image



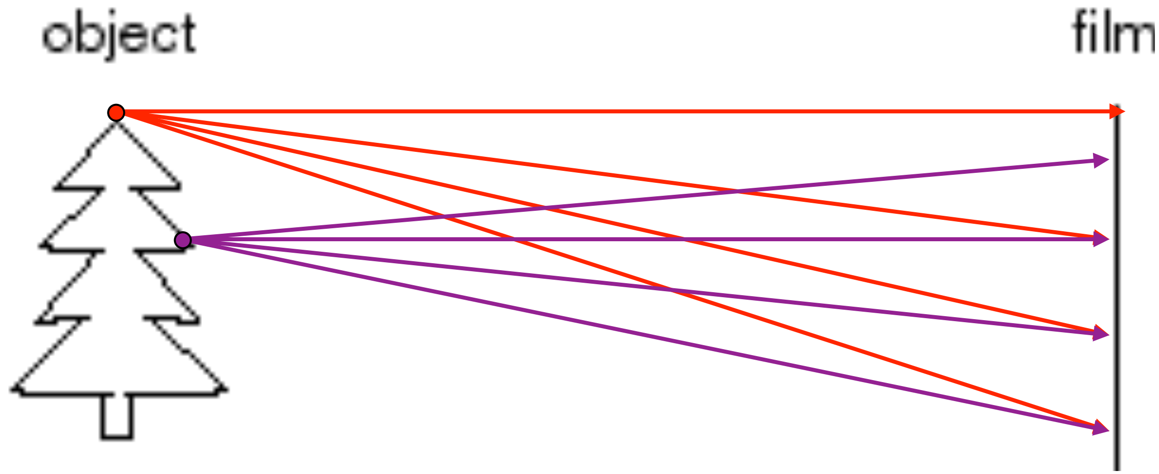
Camera Body: Optics



Camera Body: Optics

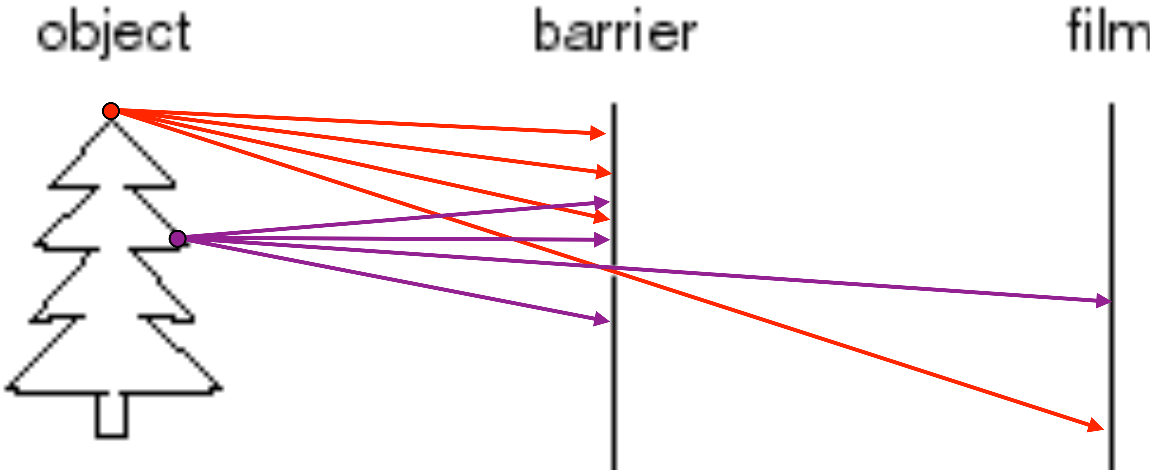
- Pinhole camera model
- Focusing light: Thin lens model
- Field of view (zoom)

How do we see the world?



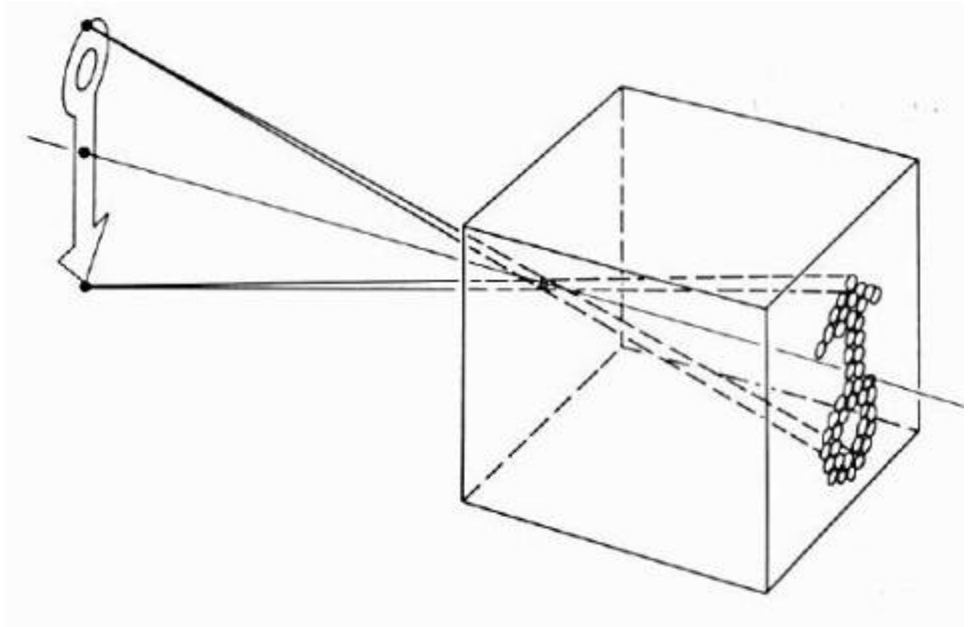
- Let's design a camera
  - Idea 1: put a piece of film in front of an object
  - Do we get a reasonable image?

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?

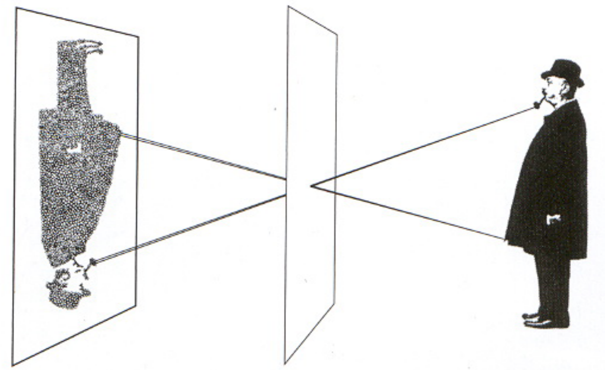
Pinhole camera model



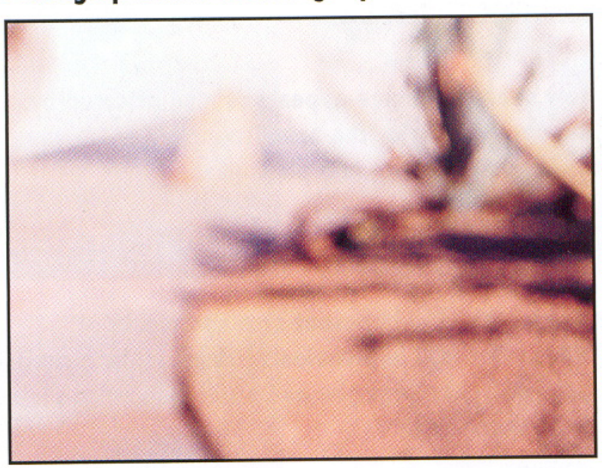
- Pinhole model:
  - Captures **pencil of rays** – all rays through a single point
  - The point is called **Center of Projection (COP)**
  - The image is formed on the **Image Plane**
  - **Effective focal length** f is distance from COP to Image Plane

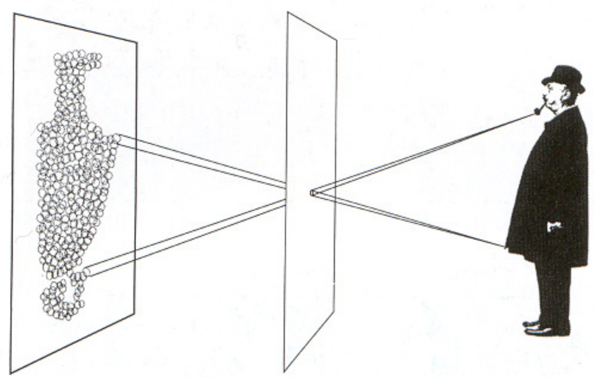
Pinhole size?

Photograph made with small pinhole



Photograph made with larger pinhole





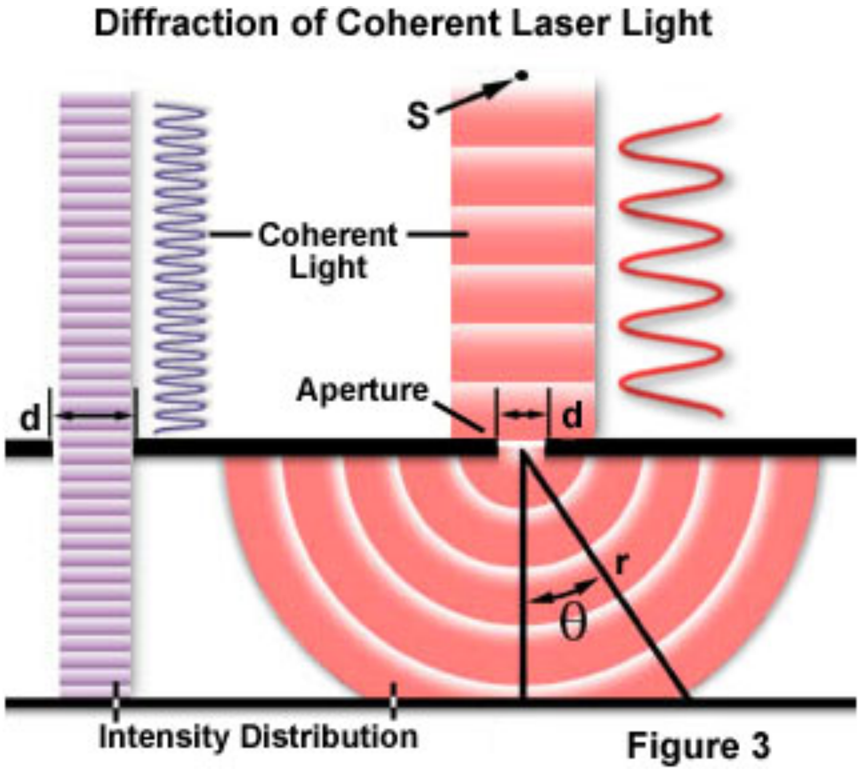
From Photography, London et al.

Light Diffraction

Light Diffraction Through Clouds

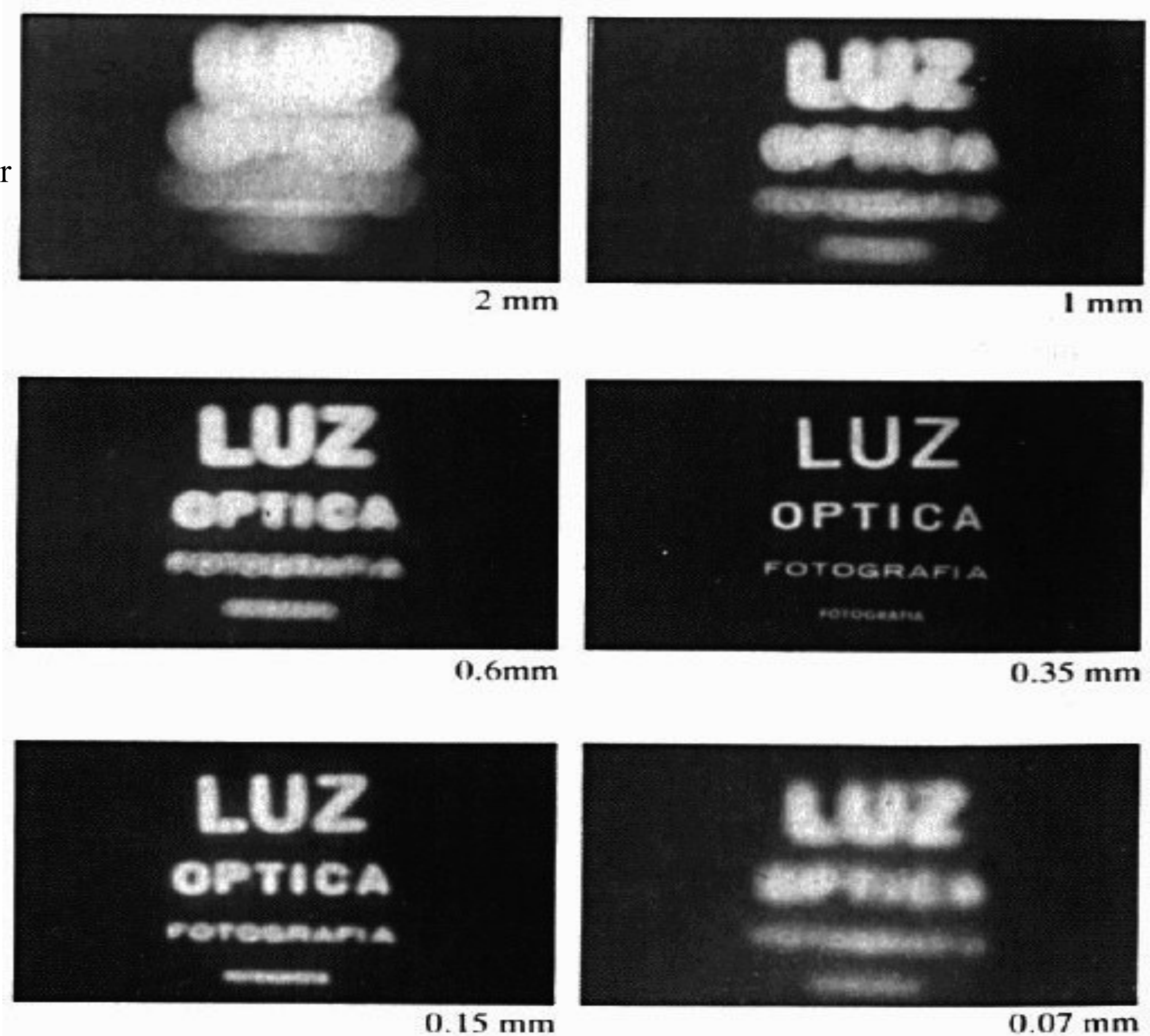
Figure 1

Light Diffraction



Shrinking the aperture

Large pinhole
➔ Geometric blur



Optimal pinhole
➔ Very little light

Small pinhole
➔ Diffraction blur

Camera Body: Optics

- Pinhole camera model
- Focusing light: Thin lens model
- Field of view (zoom)

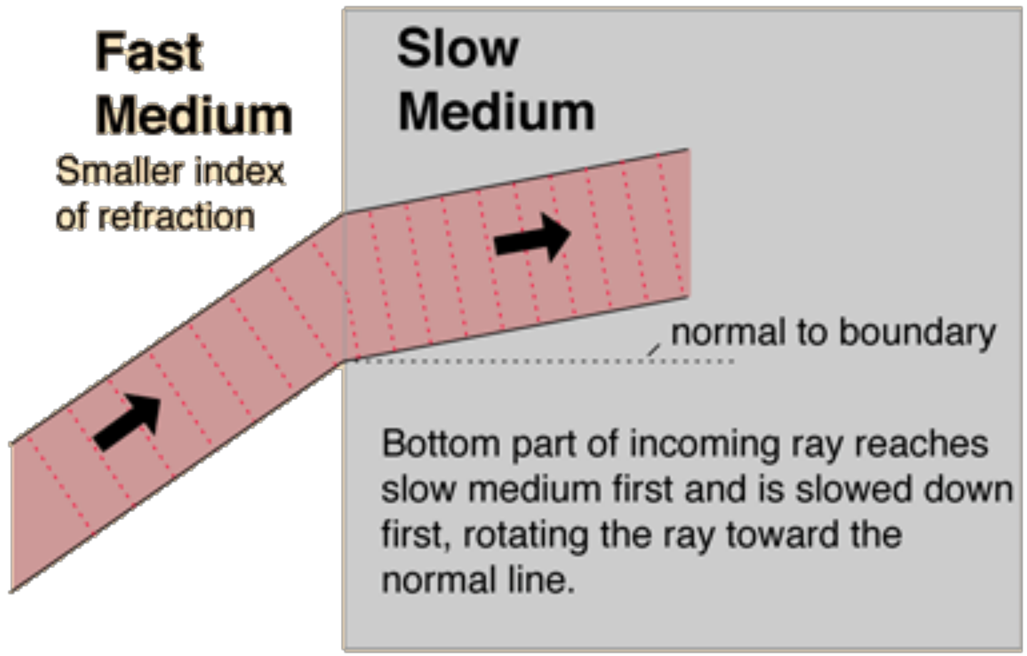
Problem with pinhole?

- Not enough light!
- Diffraction limits sharpness

Solution: refraction!

From Photography, London et al.

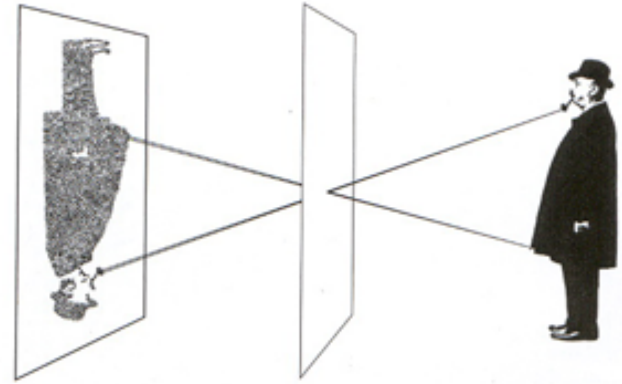
Solution: refraction!



From Photography, London et al.

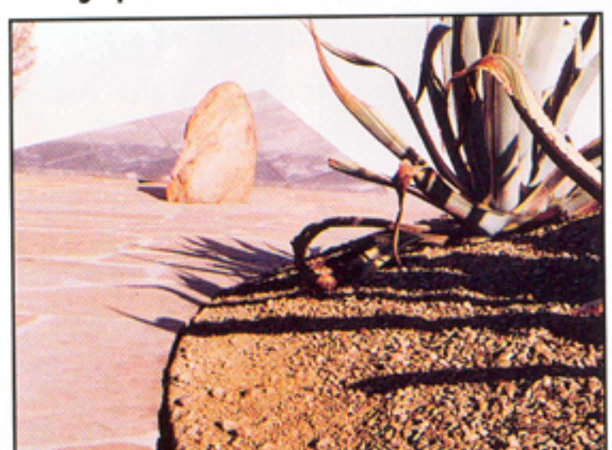
- Gather more light!
- But need to be focused

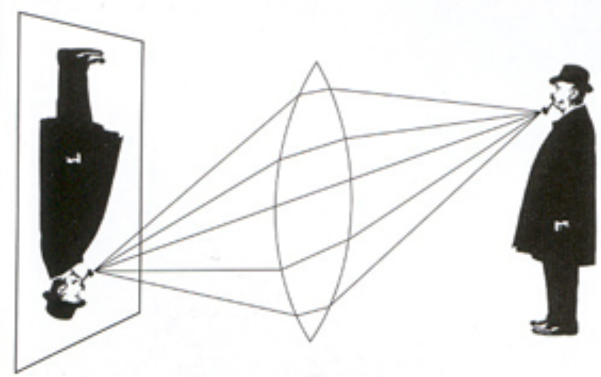
Photograph made with small pinhole



To make this picture, the lens of a camera was replaced with a thin metal disk pierced by a tiny pinhole, *equivalent in size to an aperture of f/182. Only a few rays of light from each point on the subject got through the tiny opening, producing a soft but acceptably clear photograph. Because of the small size of the pinhole, the exposure had to be 6 sec long.*

Photograph made with lens



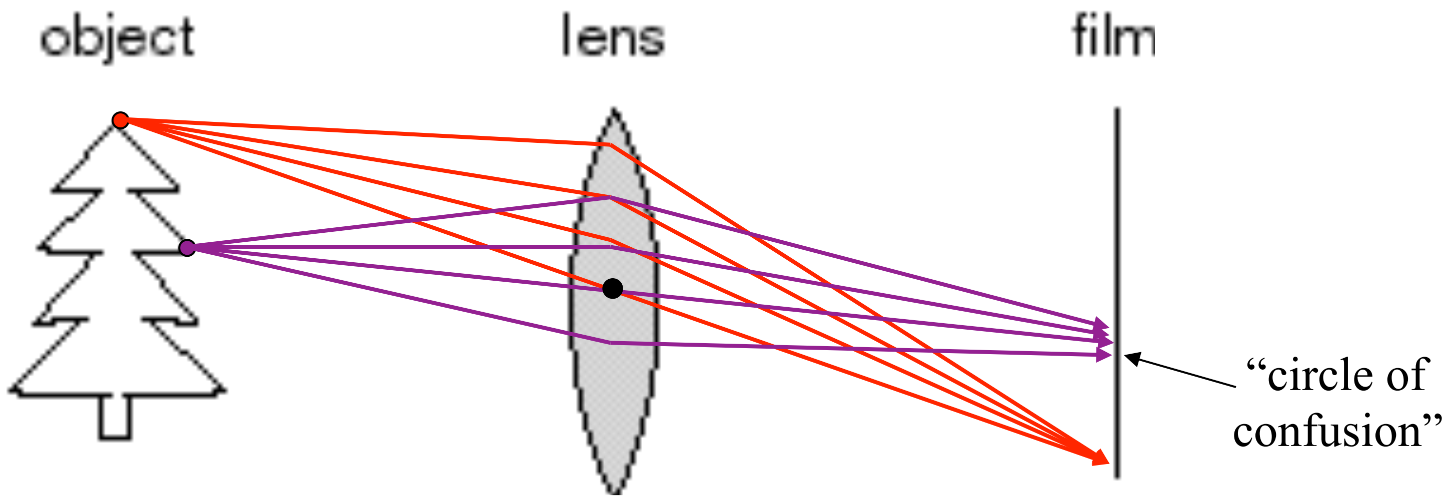


This time, using a simple convex lens with an f/16 aperture, *the scene appeared sharper than the one taken with the smaller pinhole, and the exposure time was much shorter, only 1/100 sec.*

The lens opening was much bigger than the pinhole, letting in far more light, but it focused the rays from each point on the subject precisely so that they were sharp on the film.

From Photography, London et al.

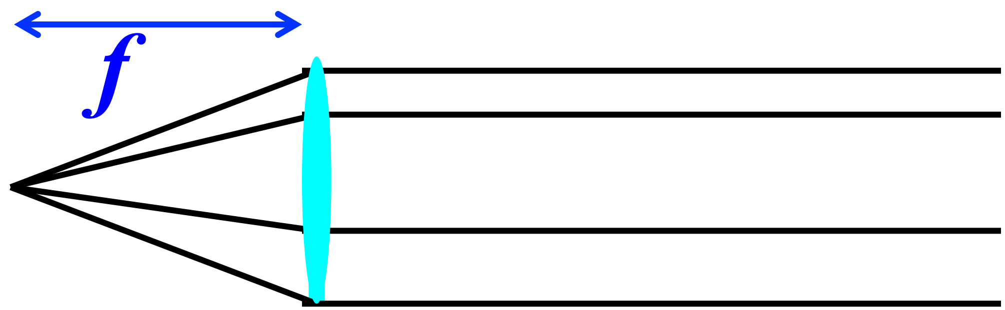
Focus and Defocus



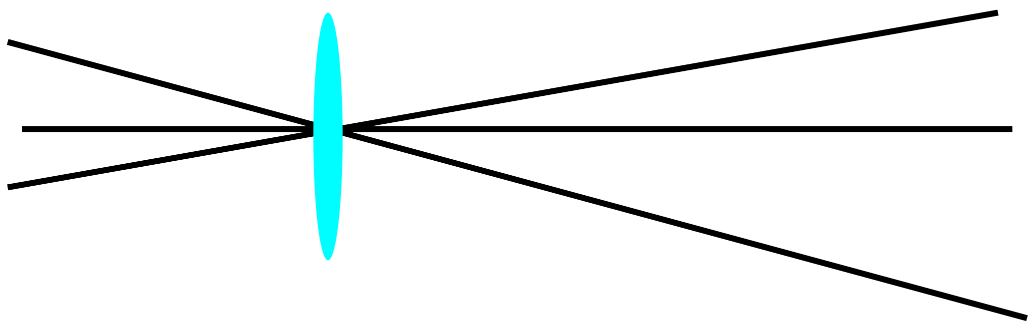
- A lens focuses light onto the film
  - There is a specific distance at which objects are “in focus”
    - other points project to a “circle of confusion” in the image
  - Changing the shape of the lens changes this distance

Thin lens optics

- Simplification of geometrical optics for well-behaved lenses
- All parallel rays converge to one point on a plane located at the focal length *f*

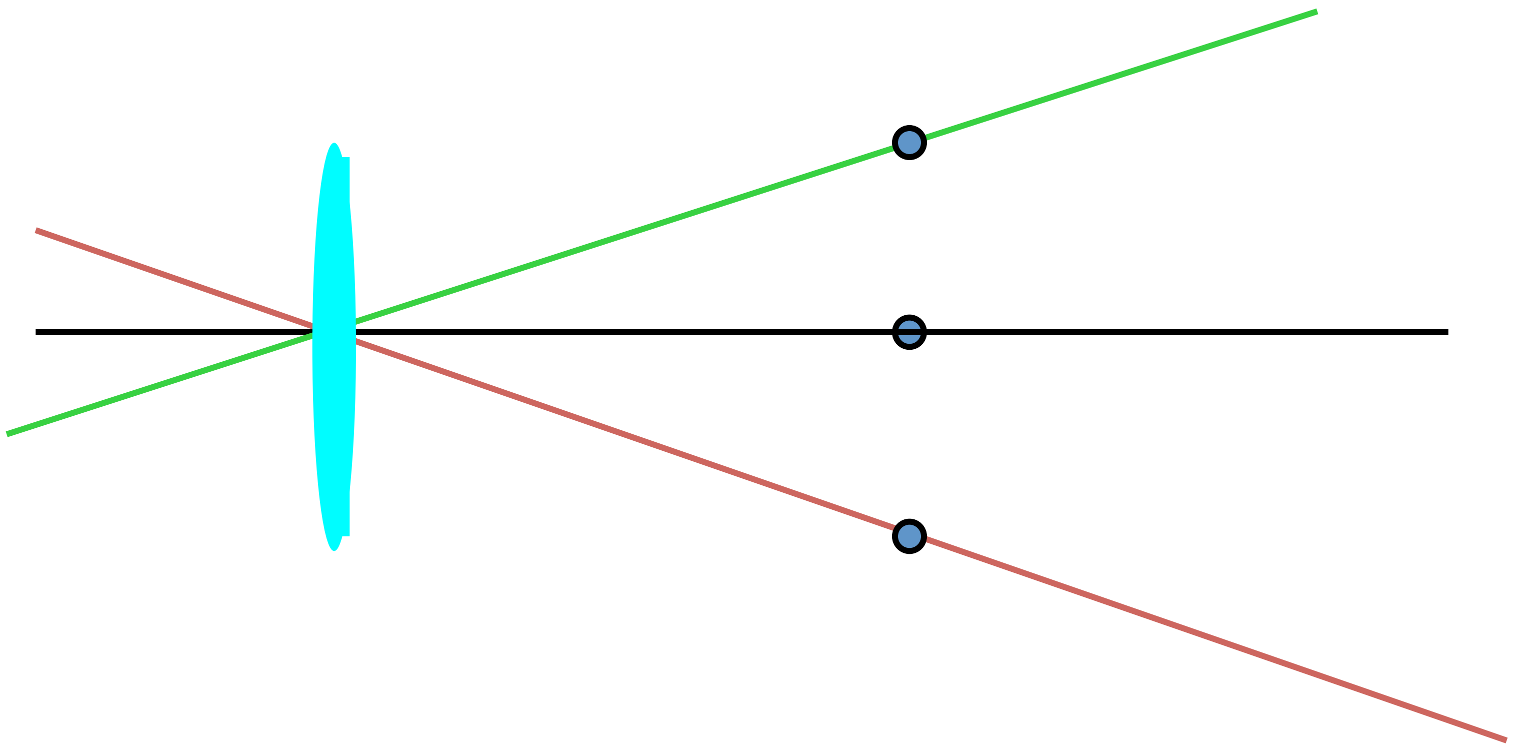


- All rays going through the center are not deviated
  - Hence same perspective as pinhole



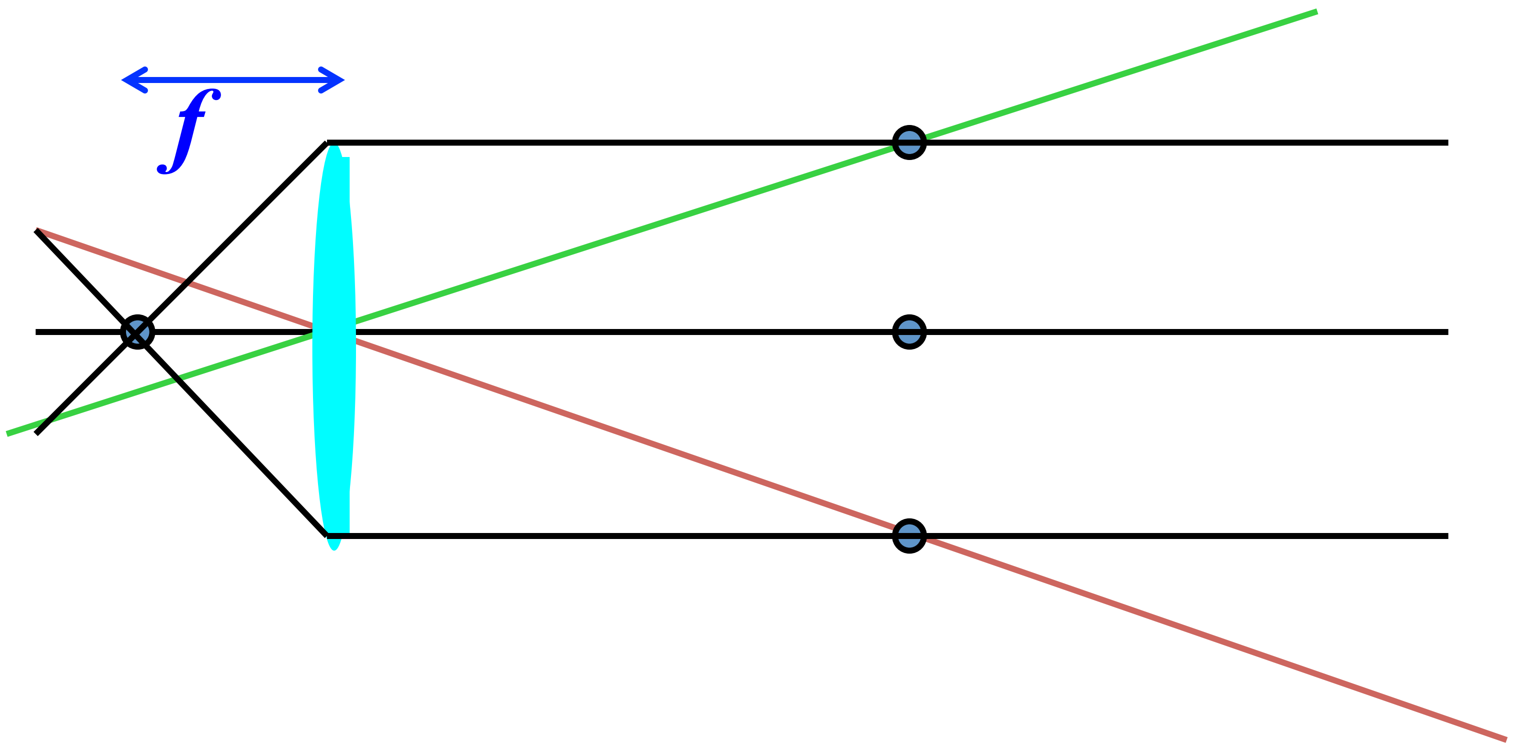
How to trace rays

- Start by rays through the center



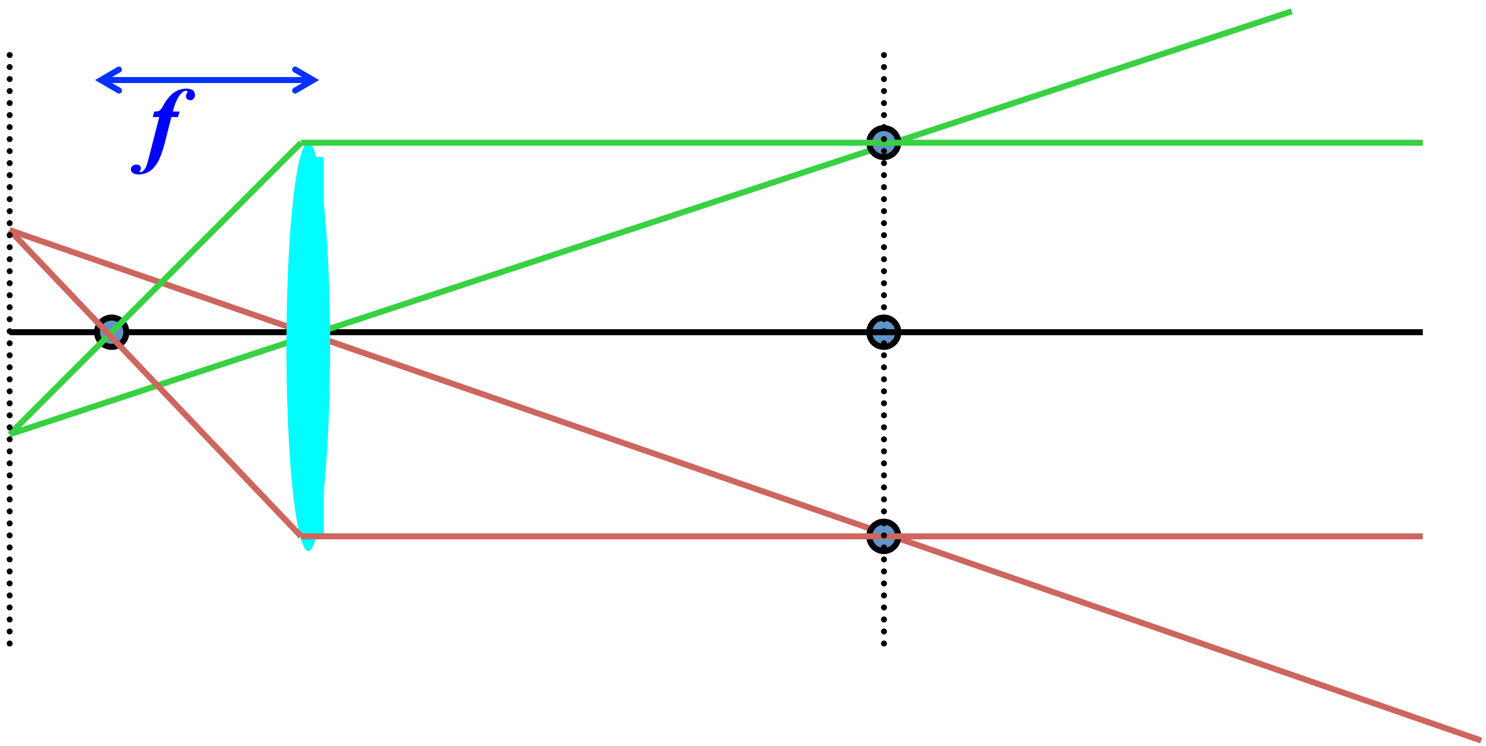
How to trace rays

- Start by rays through the center
- Choose focal length, trace parallels

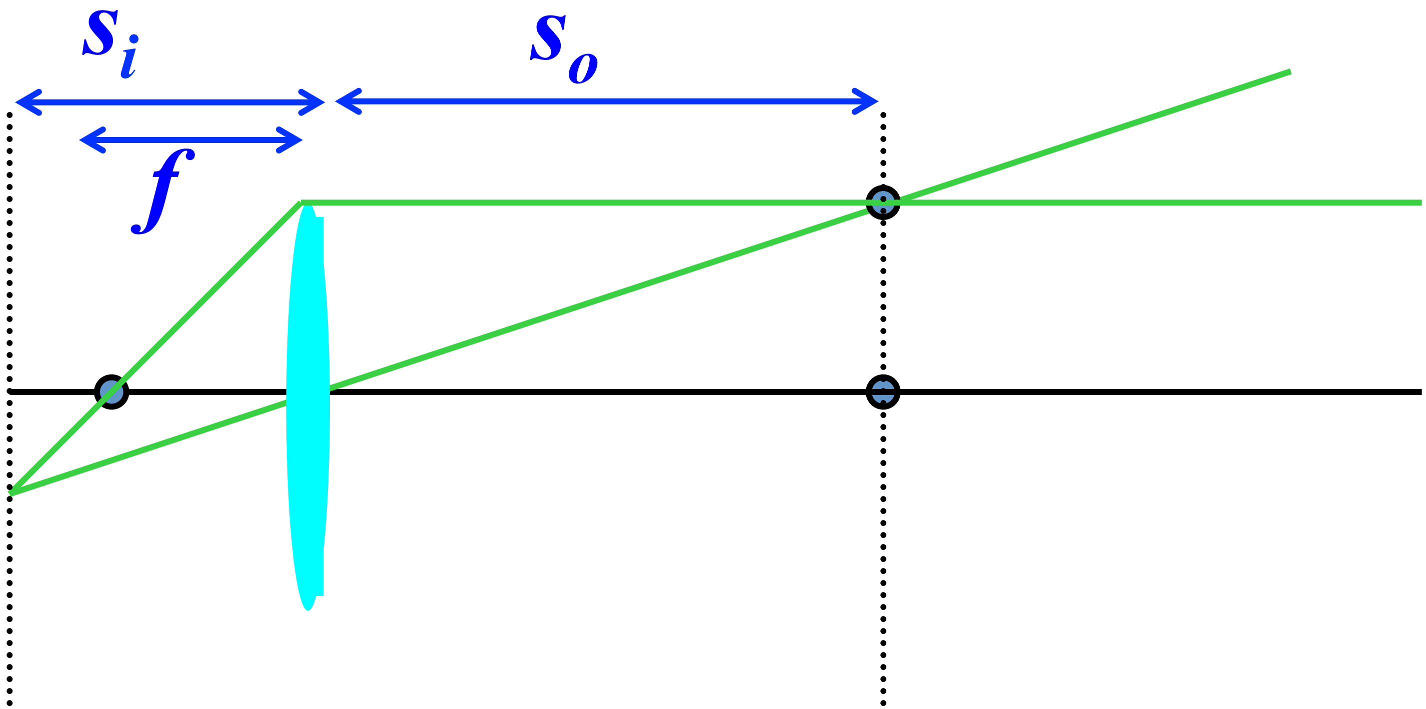


How to trace rays

- Start by rays through the center
- Choose focal length, trace parallels
- You get the focus plane for a given scene plane
  - All rays coming from points on a plane parallel to the lens are focused on another plane parallel to the lens



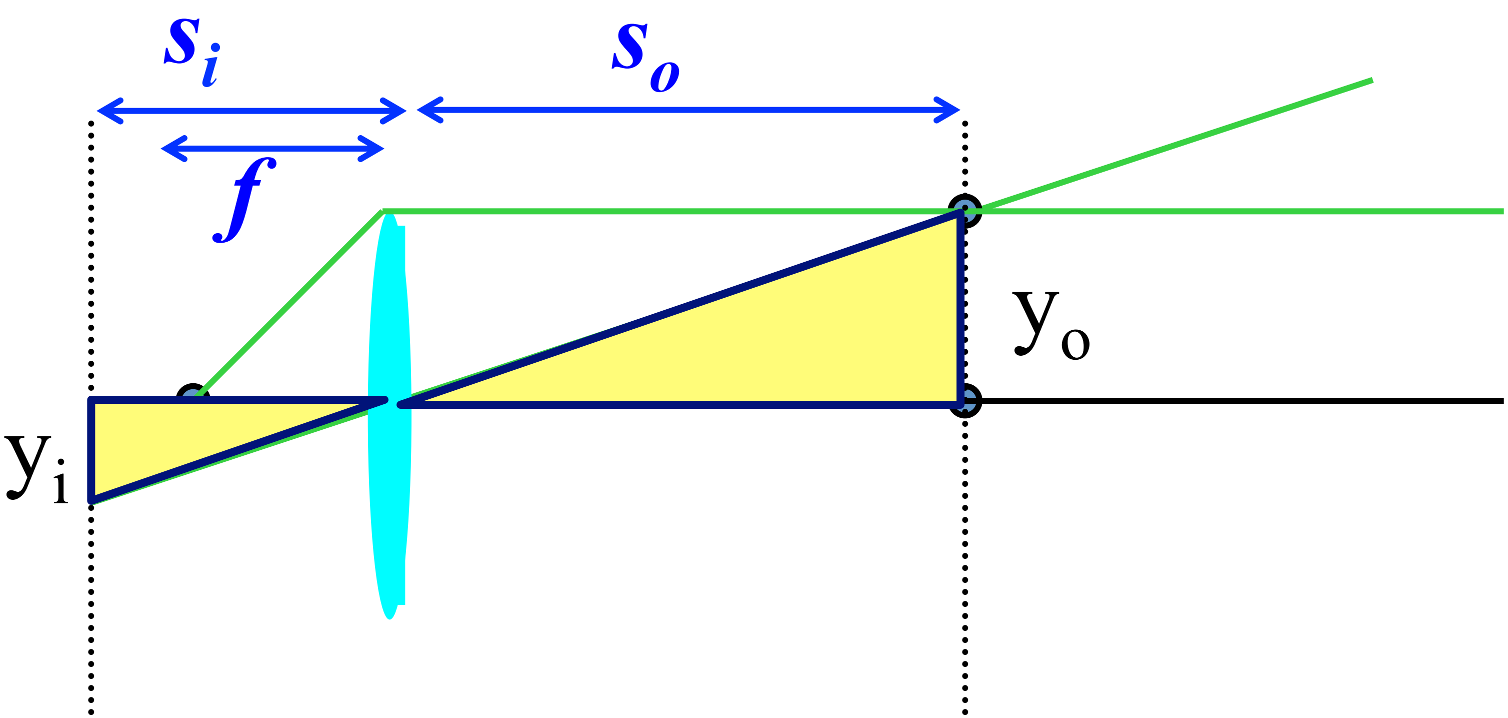
Thin lens formula



Thin lens formula

Similar triangles everywhere!

$$y_i/y_o = s_i/s_o$$

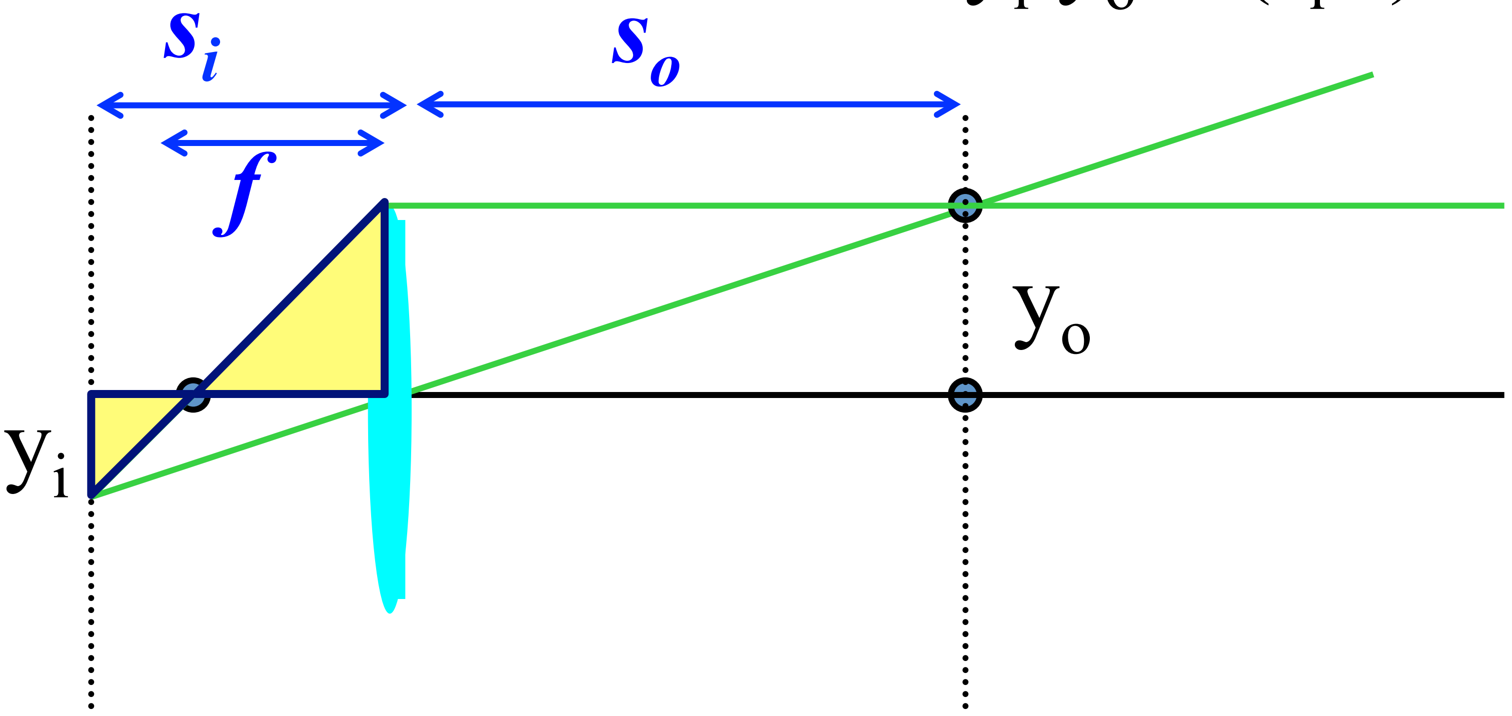


Thin lens formula

Similar triangles everywhere!

$$y_i/y_o = s_i/s_o$$

$$y_i/y_o = (s_i\text{-}f)/f$$



Thin lens formula

$$\boxed{\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f}}$$