CSC 4120/6120
Introduction to Robotics

Module 4: Computer Vision

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Welcome!

- CSC 4120/6120: Introduction to Robotics
  - M-W 5:30-7:15pm (Langdale 517)
- Instructor: Ashwin Ashok
  - Office hrs: Wed 4.15-5.15pm (Room 734@25 Park Place)
- TA: Yashaswini
  - Office hrs: Th 3.30-5.30pm, Room 650@25 Park Place
- Course Materials on Course Website
  - http://mobile.cs.gsu.edu/aashok/courses/csc4120/

Course Structure

- Modular design of a terrestrial robot
- 1 kit provided per student
- Evaluation of Module through in-class demonstration bi-weekly on Wednesdays
  - Complete the module exercises
  - Complete (design and demonstrate) 2 Assigned Problems/Questions in each Module (Module 2-5)
  - Complete 2 projects (Module 6 and 7)
    - Project 1: Same project assigned for all
    - Project 2: Each student proposes their idea and implements
- Separate curves for undergraduate and graduate students

Plagiarism and Grades

- Don’t covet thy neighbor’s code!
- We use code checker
  - Across all submissions
  - All submissions in the previous editions of the class
  - You will get caught!
- Collaboration
  - Discuss ideas
  - When in doubt, check with instructors
- Copying results in an F grade
- Grades are final – please discuss any grade requirements you have early and not after the final project demonstration!

Timeline

- Monday, Oct 7
  - 100% lecture
- Wednesday, Oct 9
  - 100% lecture
- Monday, Oct 14
  - In class working and discussion
  - Resolve issues/clarifications
  - Can do early demonstration for preliminary feedback
- Wednesday, Oct 16
  - Module 3: 2 assigned problems
  - No extensions: those demonstrating on Thu to the TA will be penalized 2pts
  - Project 2 proposals (1 page description) due by Oct 17 (midnight) – update in iCollege submission where you provided GitHub link

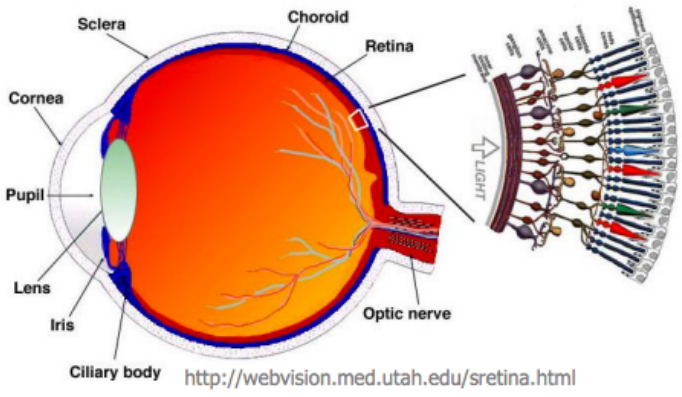
Learning Python

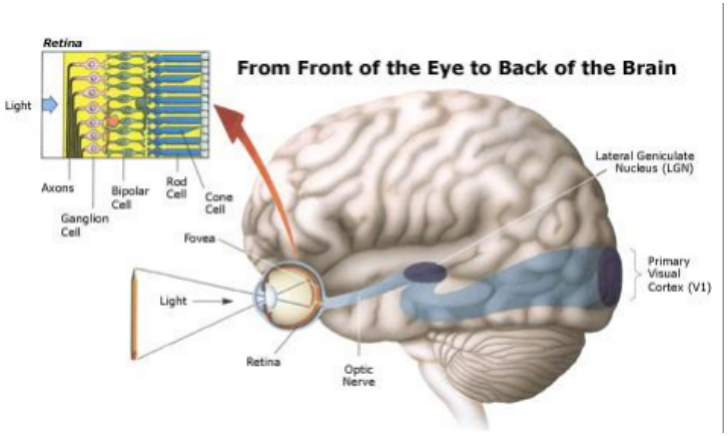
Thanks to Dr. Raj Sunderraman!

http://tinman.cs.gsu.edu/~raj/7003/su19/

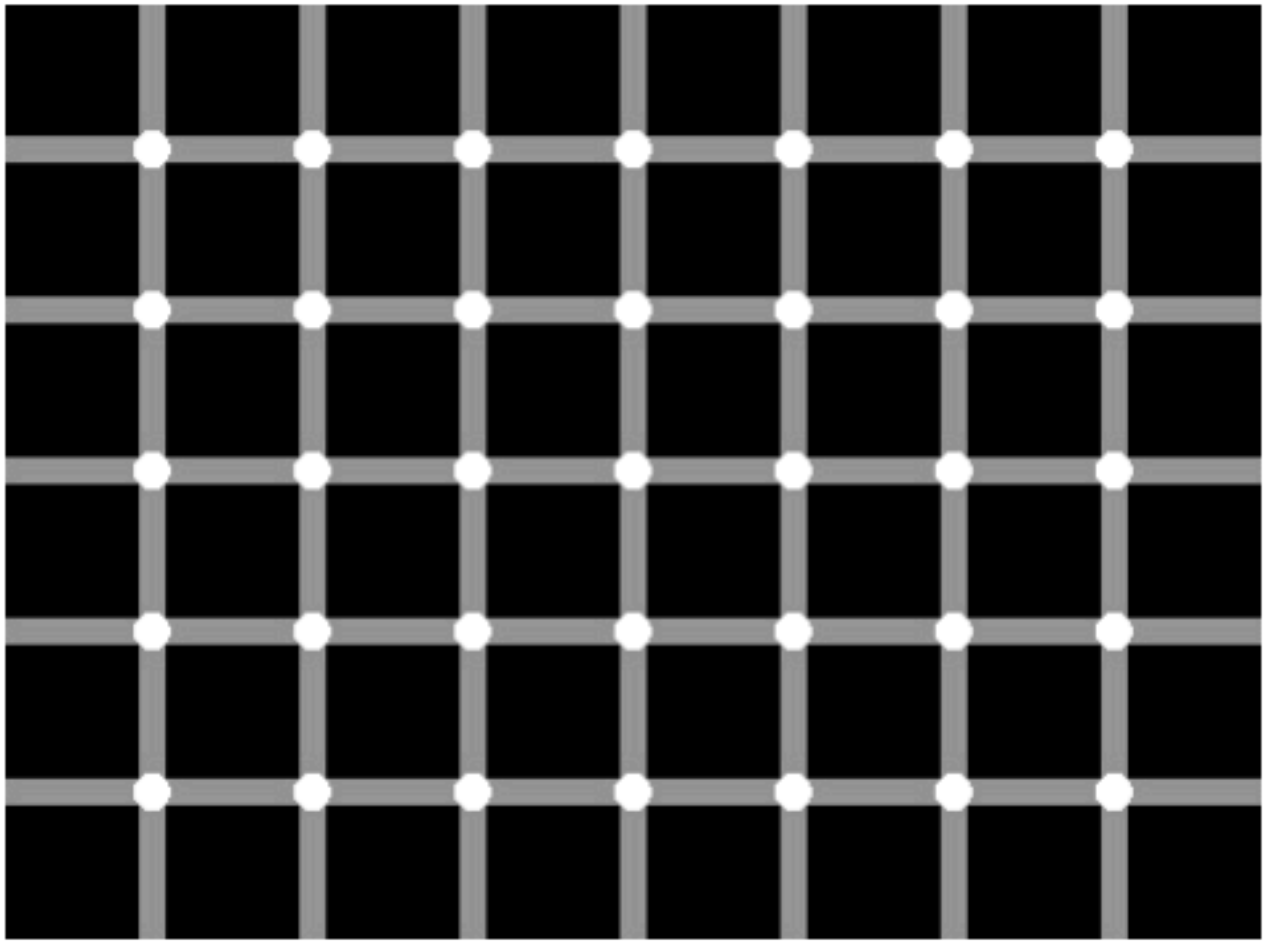
Vision In Nature

- Of all our senses, vision aids us the most
- Retina ~ 1000mm^2 and millions of photoreceptors
- Provides lots of information ~ 3Gb/s
- Brain dedicates significant processing power to processing signals from our eyes
- Visual system very sophisticated but not perfect

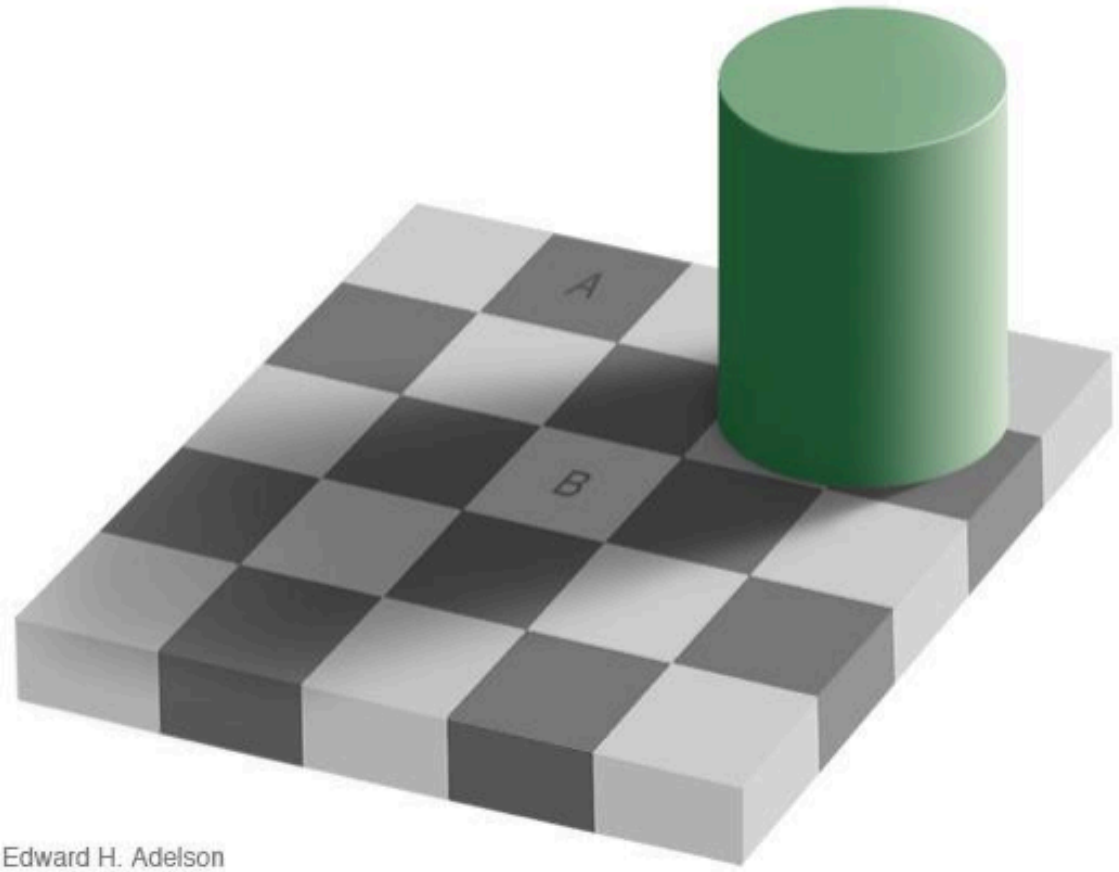




Count The Black Dots

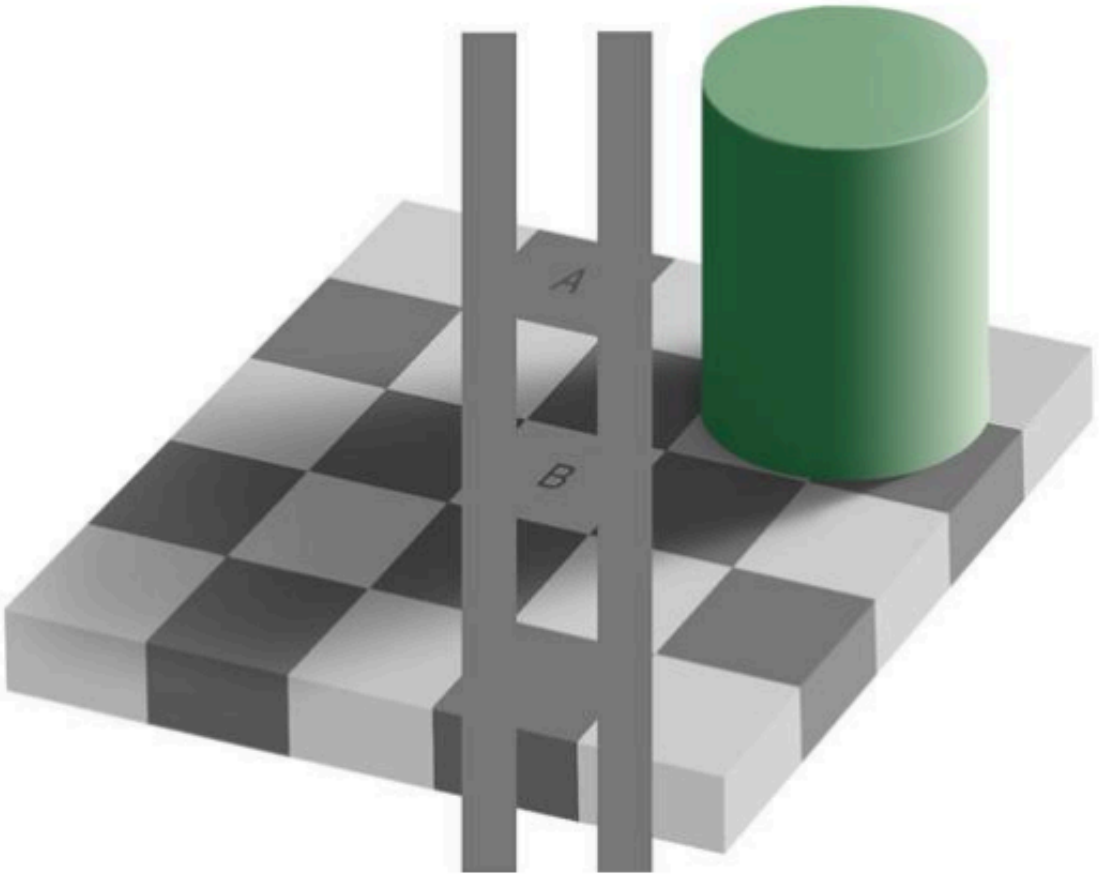


Which Square is Darker? A or B?



Edward H. Adelson

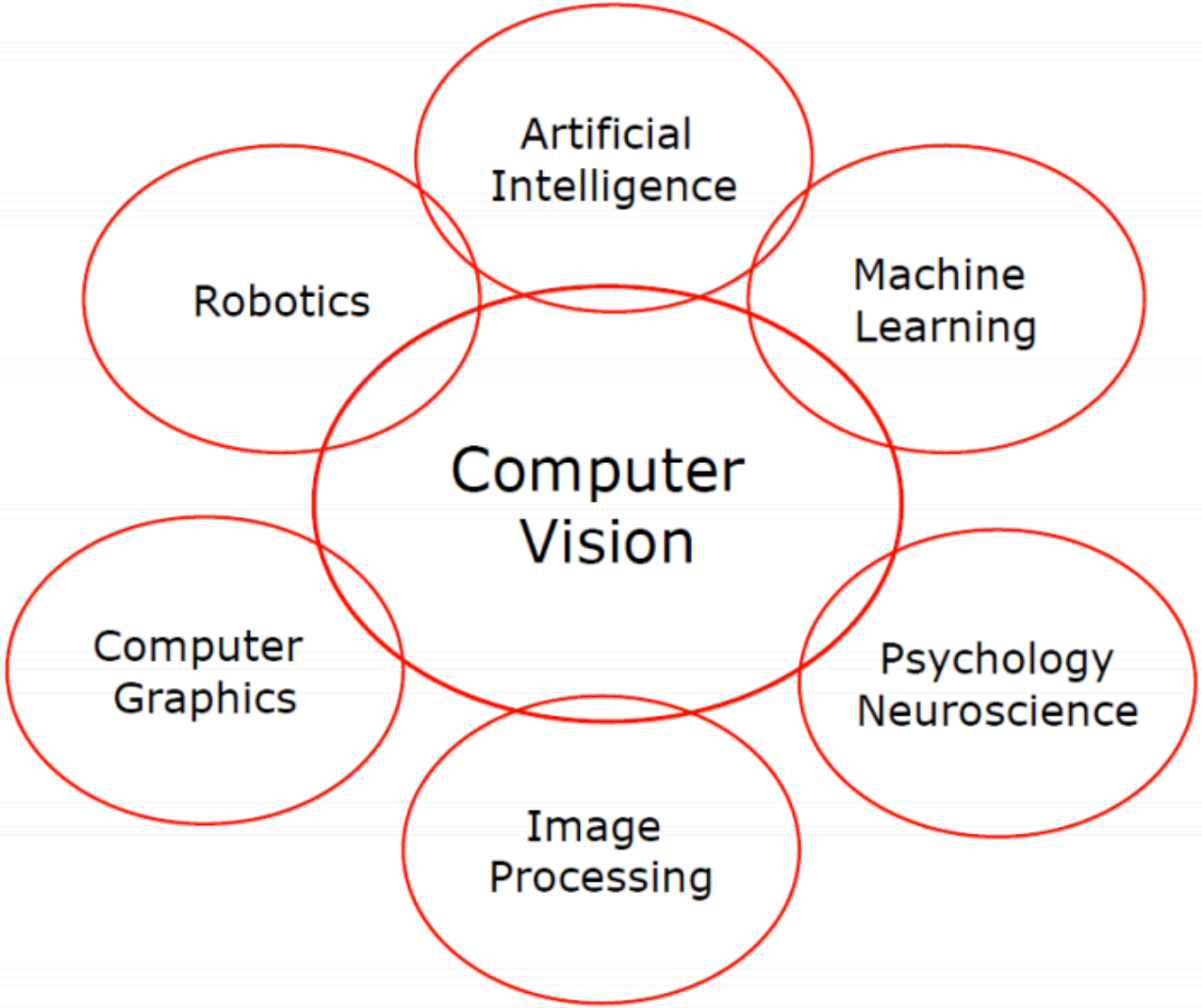
Which Square is Darker? A or B?



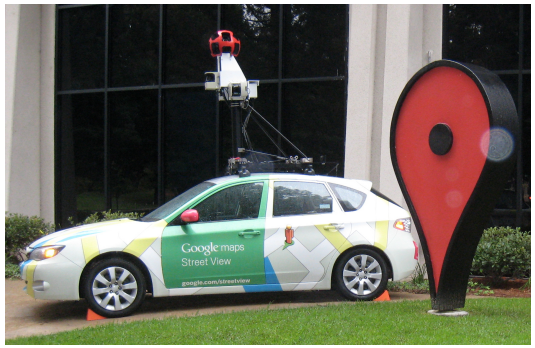
Vision For Robots

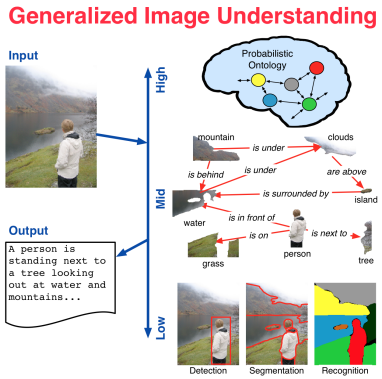
- Picture is worth a thousand words
- Hard to copy from Biology
- Capture Light → Convert to digital image → detect "salient" features
- Vision increasingly popular
  - Expressiveness
  - Cost
  - HW advances
  - Increase in computational power

Computer Vision



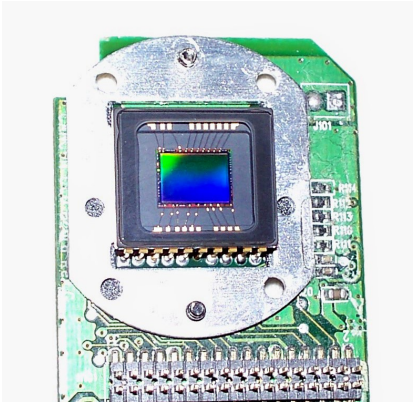
Applications





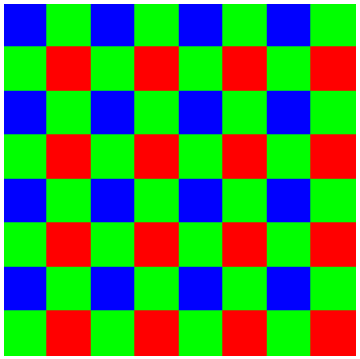
Digital Camera

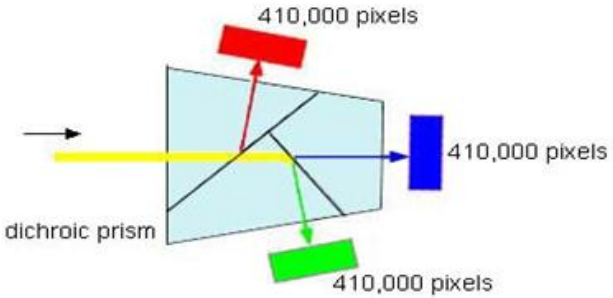
- Two kinds
  - Charge Coupled Device (CCD)
  - Complementary Metal Oxide on Silicon (CMOS)
- CCD
  - Pixels made of light-sensitive discharging capacitors
  - Read serially
  - Inconsistency and dynamic range
- CMOS
  - Read in parallel
  - Simpler, consumes less power
  - Traditionally outperformed by CCD cameras in quality, but have caught up nowadays



Camera Output

- Single-chip Bayer filter
  - Visual system sensitive to high frequency detail in luminance
  - Demosaicing: Interpolate to get all values
- Three-chip color camera
- Photodiodes typically most sensitive at near-IR end
- Blue channel gain is higher
- Separate control for white balance





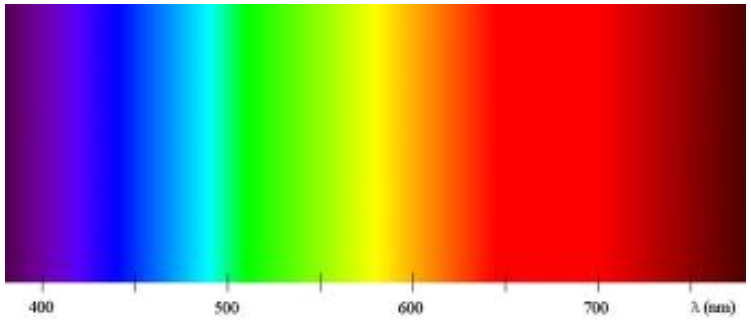
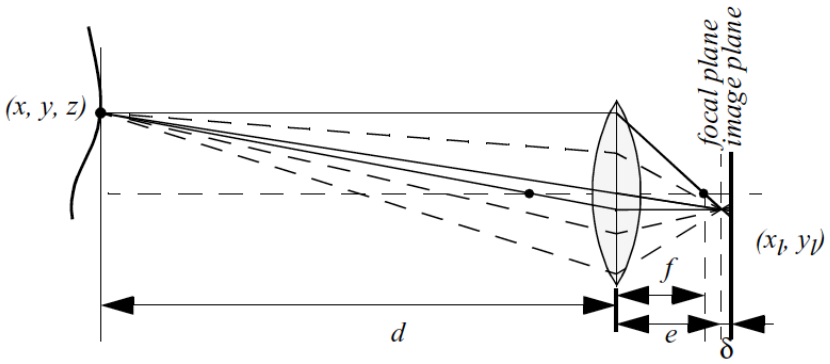


Image Formation

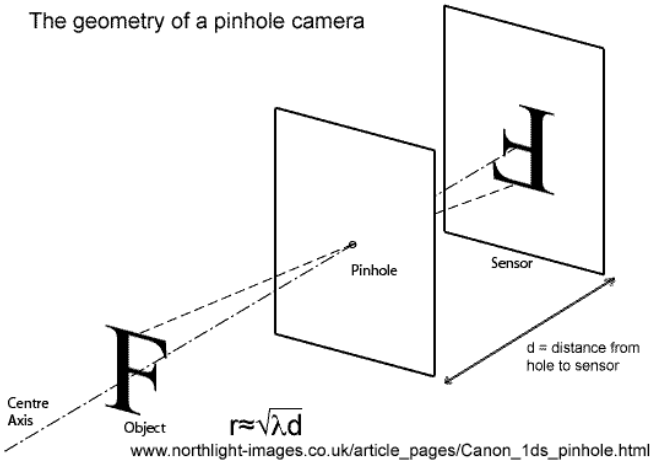


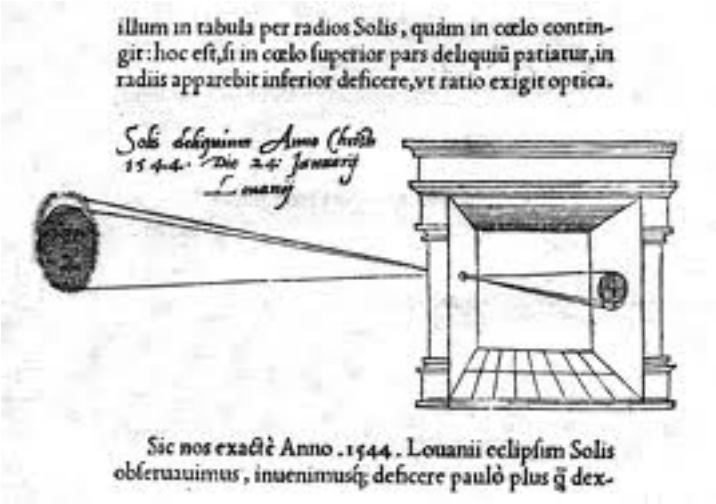
$$\frac{1}{f} = \frac{1}{d} + \frac{1}{e}$$

- Distance behind the lens at which a focused image is formed (*e*) is related to the distance at which the object is (*d*) and the focal length of the lens (*f*)
- *Depth from focus*: Estimate distance of object given *f* and *e*
- *Blur circle*: If image plane is not at *e*, object is cast as a blur

Pinhole Camera

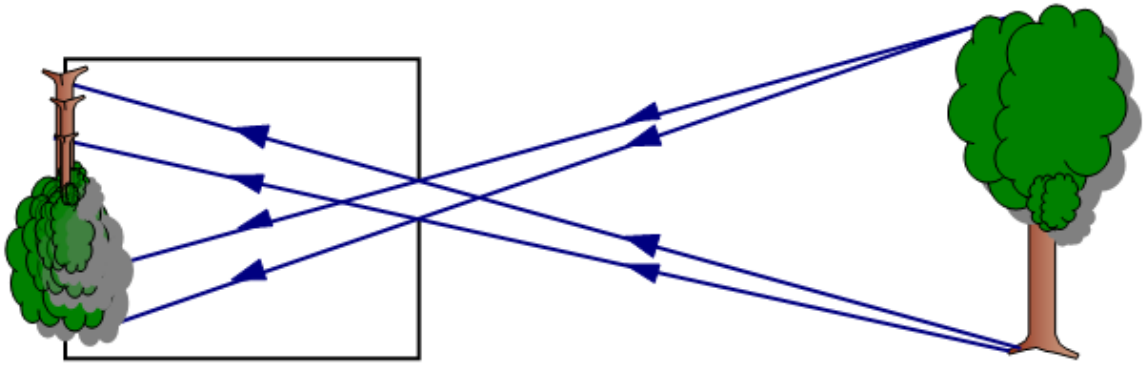
- Capture a beam of rays through a single point
- Center of projection/Optical center
- Image formed on image plane
- *Camera Obscura*
  - First mention in book by mathematician Reinerus Gemma-Frisius




illum in tabula per radios Solis, quàm in cœlo contingit: hoc eſt, ſi in cœlo ſuperior pars deliquiũ patiatur, in radiis apparebit inferior deficere, vt ratio exigit optica.

Sic nos exactè Anno .1544. Louanii eclipſim Solis obſeruauimus, inuenimusq; deficere paulò plus q̃ dex-

Pinhole Camera Design

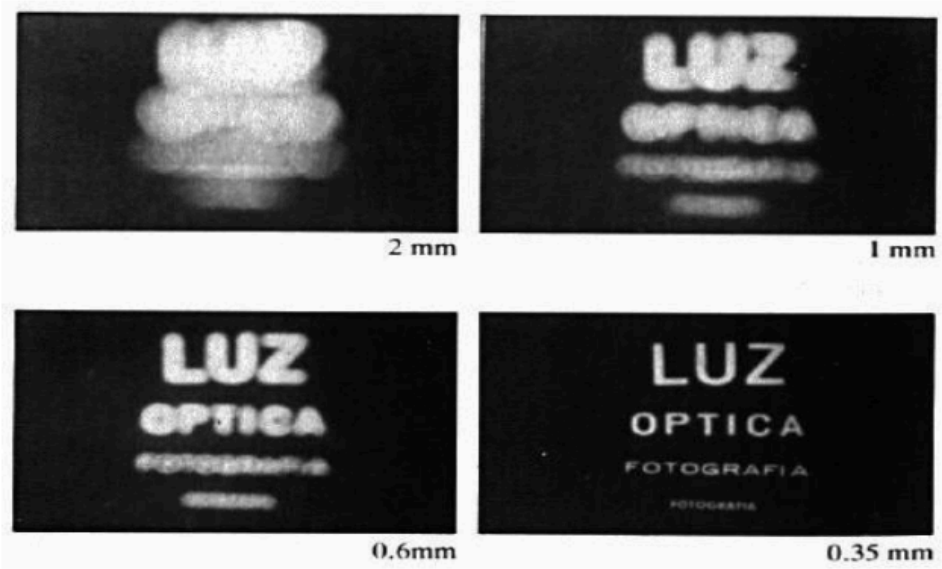


Fuzzy out of focus image with a large pinhole

- Size of aperture along with distance from scene determines if the object is in focus or blurry

Pinhole Camera Design - II

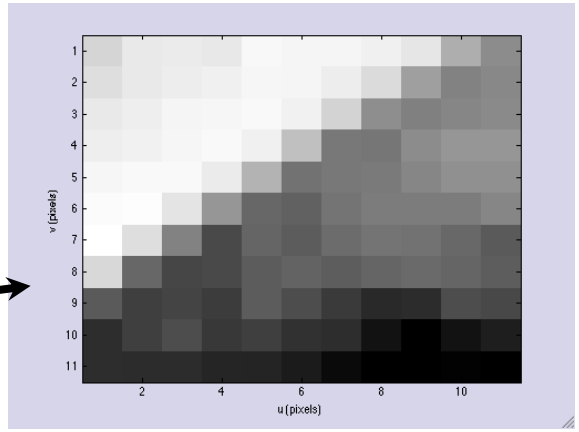
- Make aperture tiny?
  - Less light gets through
  - Increase exposure?
  - Diffraction effects



Images courtesy Steve Seitz

Digital Images

Images and Pixels

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61
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Images and Pixels (2)

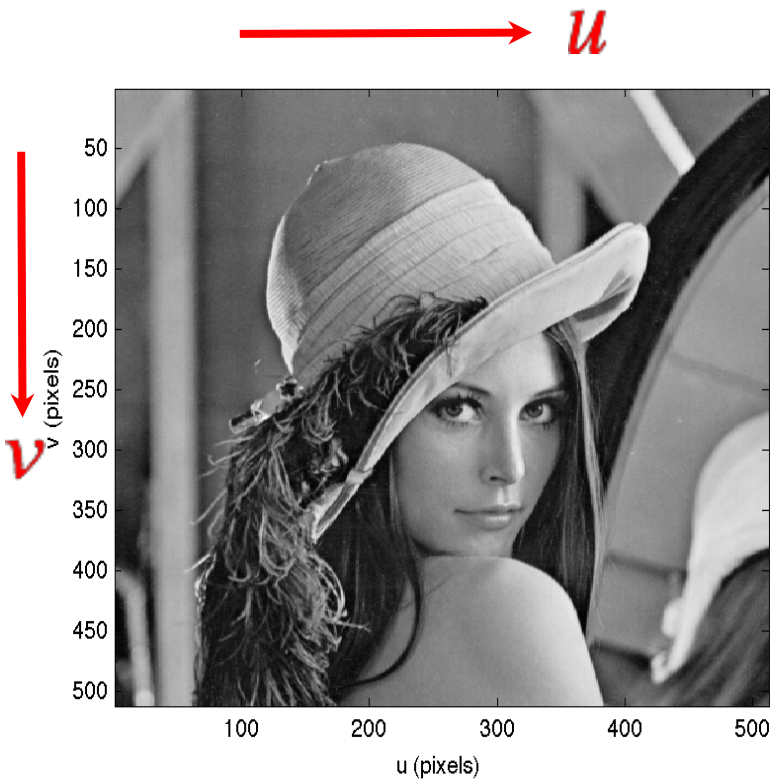

Image Formats

- Heaps to choose from
- Consider the container format separate from the image data
  - JPEG file is correctly an EXIF container