Problem Session 1

Logistics

- See website for all course info (including times and locations of lecture, office hours, etc...)

  cs.toronto.edu/~lindell/teaching/2529/

- Goal of these problem sessions:
  - Explanation of HW and hints
  - Opportunity to ask questions!

Task 1 & 2: Create a pinhole camera

During the Renaissance, pinhole cameras were used to draw realistic views (perhaps used in Vermeer's paintings)

Task 1 & 2: Create a pinhole camera

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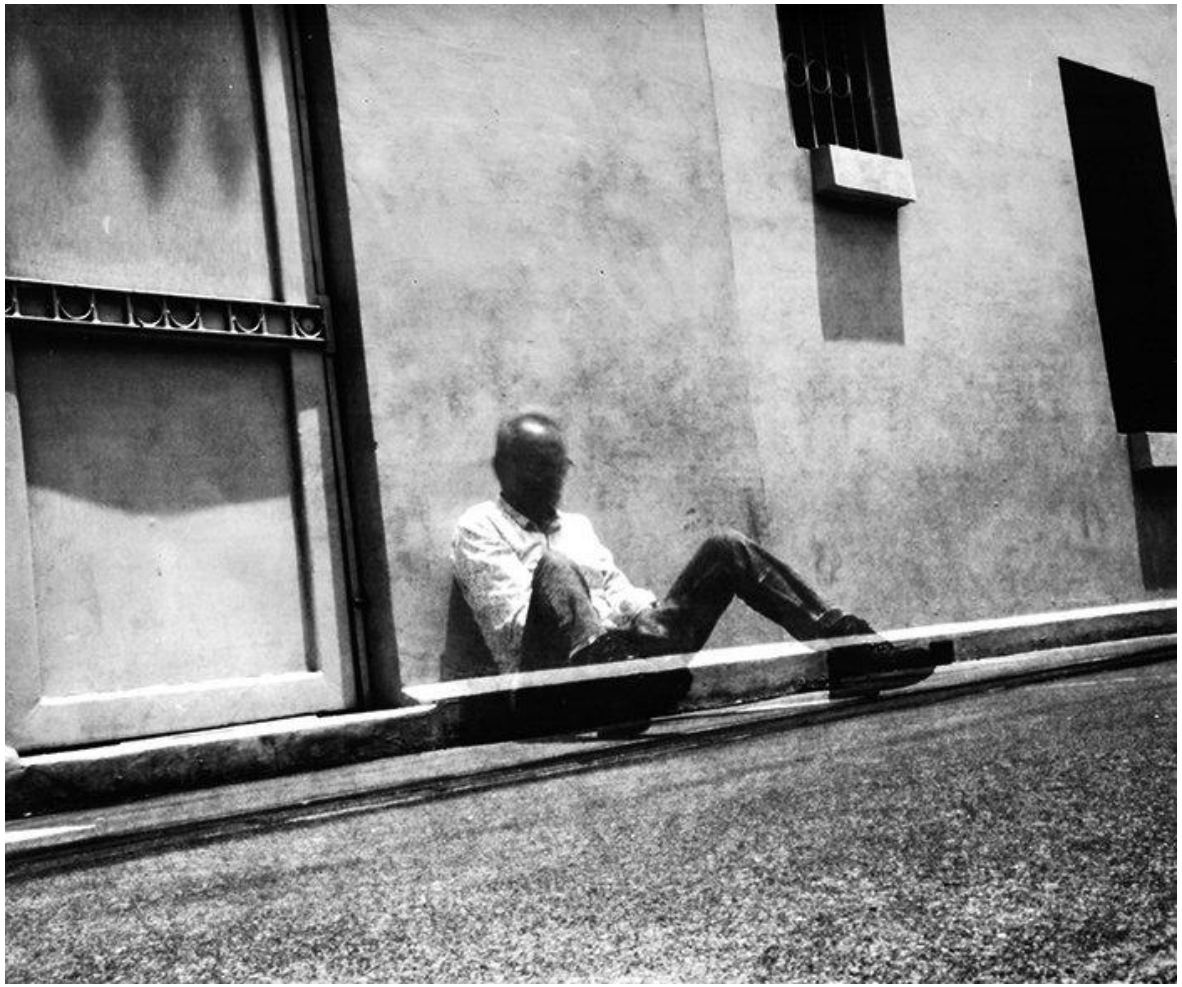


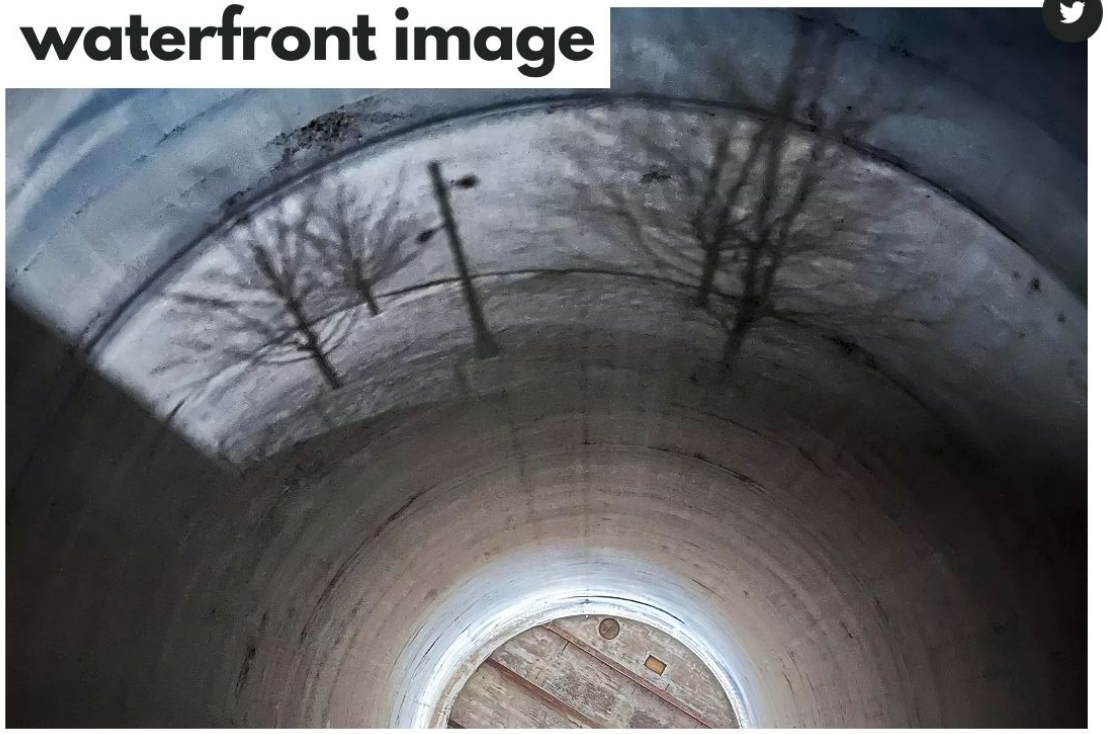
"*This photo was made in a wooden camera, 12” focal length and 0.023” diameter hole and 1’40”exposition time. Ilford 8x10 b&w paper*"

Worldwide Pinhole Photography Day

Task 1 & 2: Create a pinhole camera

blogTO

Toronto silo has a hidden camera obscura projecting a waterfront image



Bryan Bowen
@bryanmbowen · **Follow**

Fun discovery - a small crack in the eastern facade of the Canada Malting Co silos has created a perfect pinhole camera. The result: real time projection of Toronto's waterfront on the silo's interior curved surfaces. An unplugged projection show!

9:37 AM · Jan 27, 2022

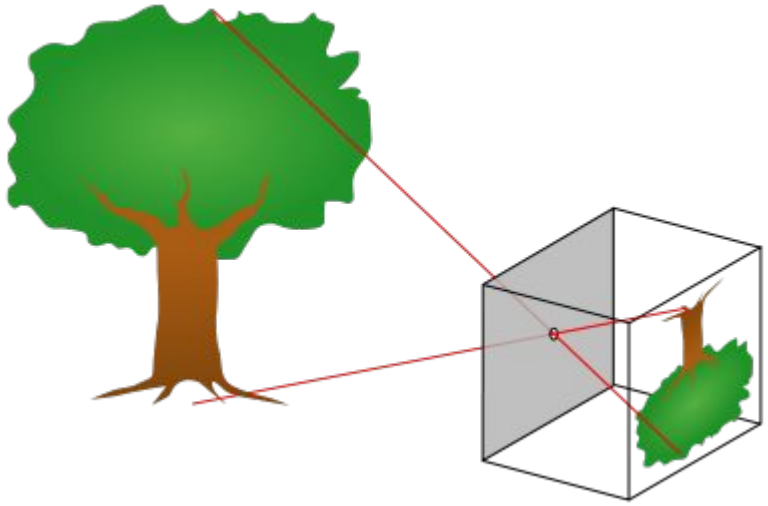
Read the full conversation on Twitter

2.8K Reply Copy link

Read 31 replies

Task 1 & 2: Create a pinhole camera

- A simple camera without a lens, effectively a light-proof box with a small hole in one side.
- Also known as camera obscura, or "dark chamber“ (Latin)



Optimal pinhole diameter:

$$d = 2\sqrt{f\lambda}$$

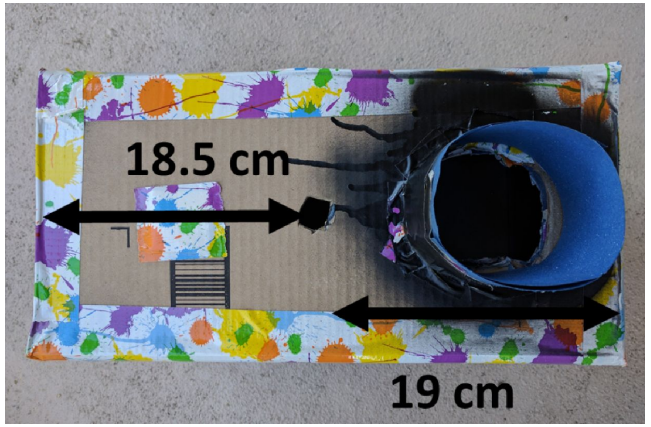
f: distance from pinhole to image plane
λ: wavelength of light

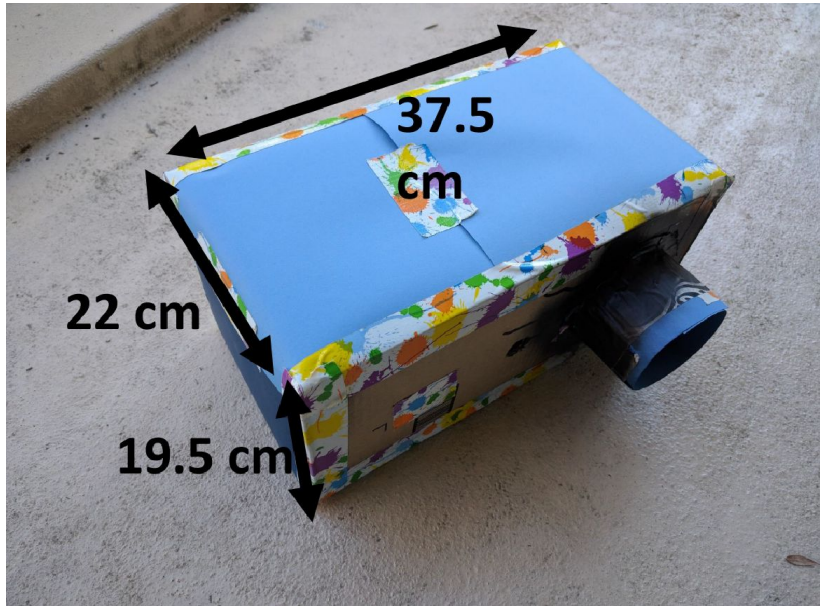
Task 1 & 2: Create a pinhole camera

Pinhole

Camera lens
Goes here

Task 1 & 2: Create a pinhole camera





Task 1 & 2: Create a pinhole camera

If using a smartphone camera, download an app that allows for long exposures.

App Store Preview

Yamera (Manual Camera) 4+

Manual Focus, Exposure and WB.

AppMadang

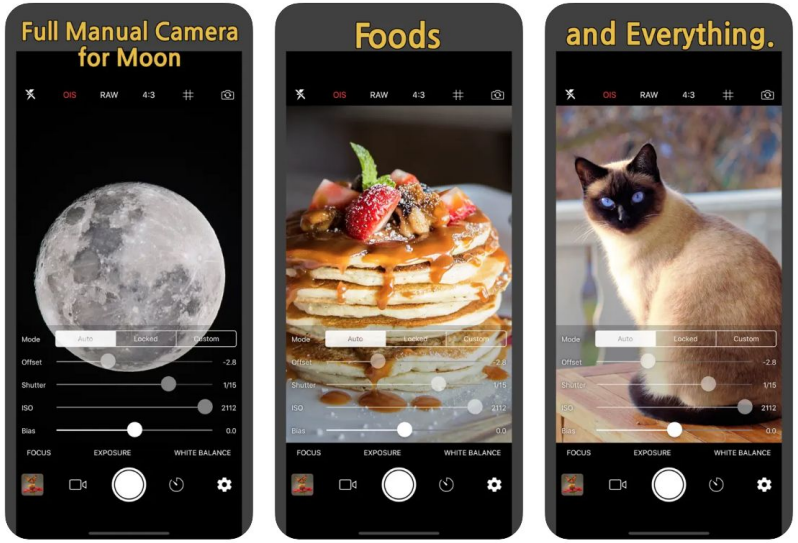
Designed for iPad

4.6 • 358 Ratings

Free · Offers In-App Purchases

View in Mac App Store ↗

Screenshots iPad iPhone



Manual Camera DSLR (Lite)

Lenses Inc.

Contains ads

3.5★ 7.32K reviews | 1M+ Downloads | E Everyone

Install

You don't have any devices

About this app →

This Manual Camera DSLR Lite Version have all features just like the Pro Version, but we limit resolution for photo up to 8MP , video up to 1080p , and maximum recording duration is 5 minutes

Yet this app still able to turn your phone into professional camera like, with fully manual camera control on ISO, shutter speed, exposure, manual focus and another features like a professional camera, which can bring your mobile photography to the next level. Take the best capture of your photo and even...

Task 1 & 2: Create a pinhole camera

(c) 5mm

(b) 3mm

(a) 0.1mm

Task 1 & 2: Create a pinhole camera

(c) 5mm

(b) 3mm

(a) 0.1mm

Task 1 & 2: Create a pinhole camera

(c) 5mm

(b) 3mm

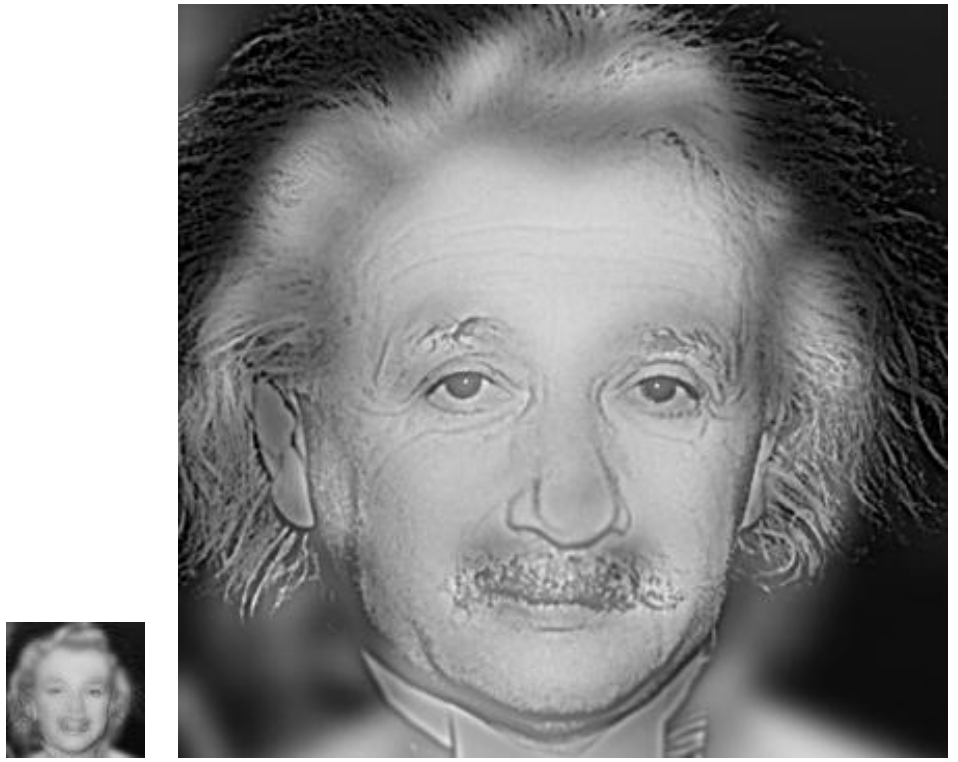
(a) 0.1mm

Task 3: Create a hybrid image

A hybrid image is an image that is perceived in one of two different ways, depending on viewing distance

Aude Oliva, Antonio Torralba and Philippe G. Schyns (2006). "Hybrid images" (PDF). *ACM Transactions on Graphics* (SIGGRAPH 2006 issue) **25** (3): 527–532.

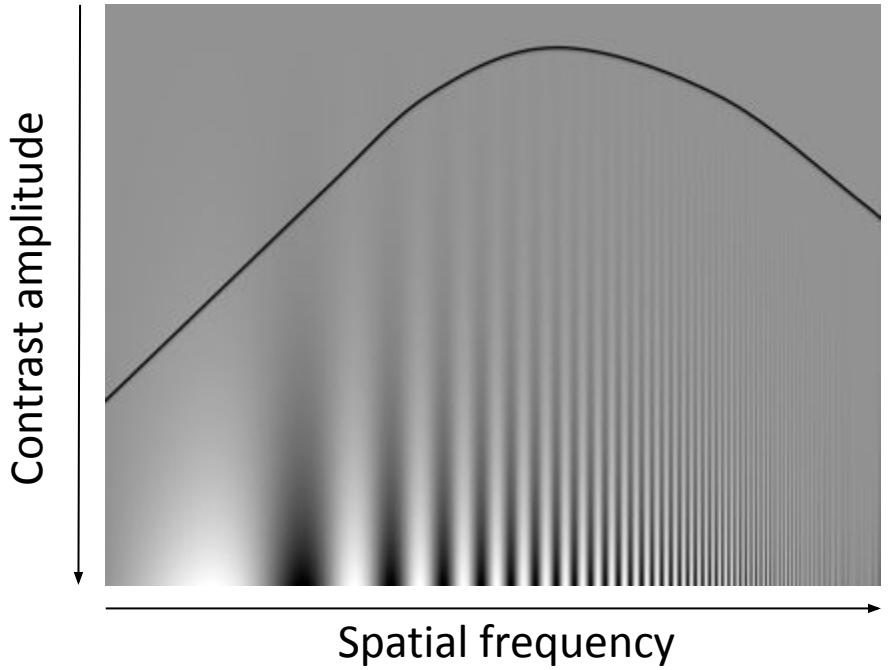
http://cvcl.mit.edu/hybrid_gallery/gallery.html



Task 3: Create a hybrid image

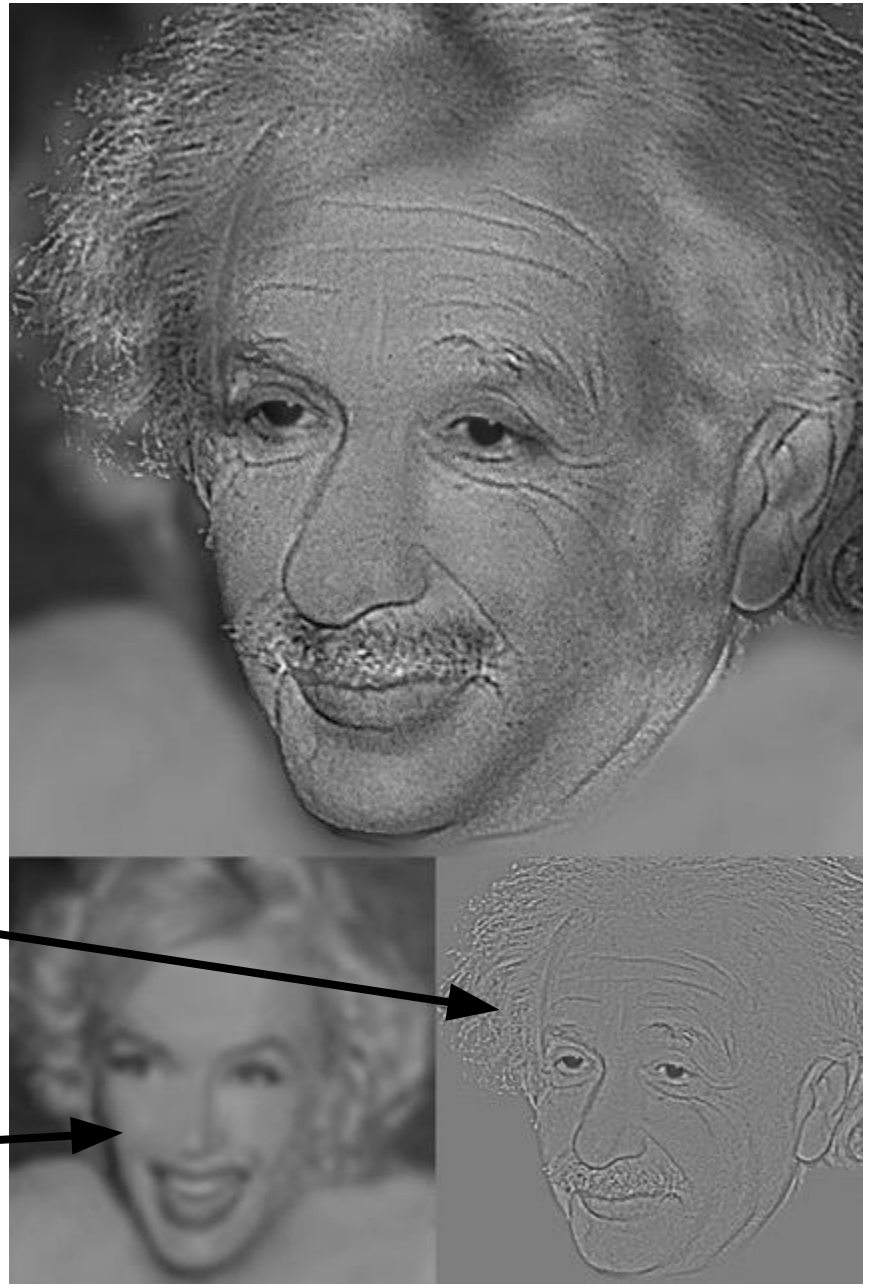
⟶ Contrast sensitivity changes with frequency

For medium frequency you need less contrast than for high or low frequency to detect the sinusoidal fluctuation.



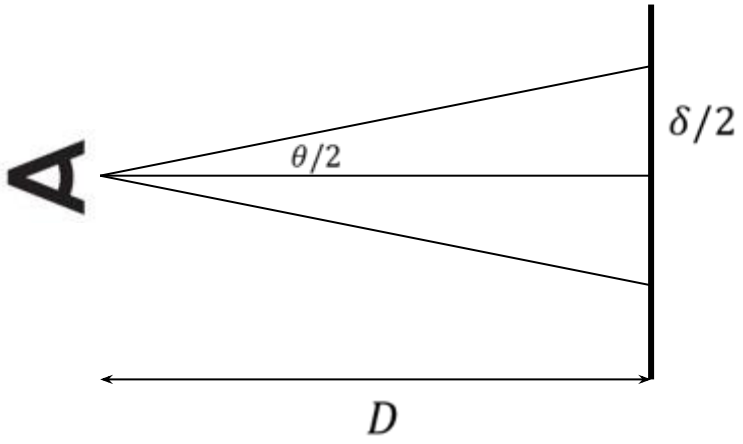
Task 3: Create a hybrid image

Low spatial frequencies of first image + High spatial frequencies of second image = Image with an interpretation that changes with viewing distance



Task 3: Create a hybrid image

- dpi = dots per inch, defines the physical size of a pixel on paper
- Pixels per degree, depends on the distance



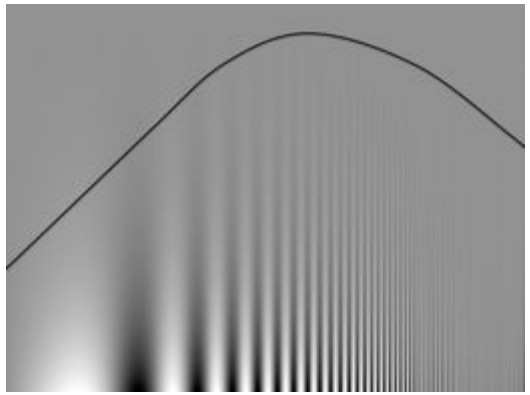
$$\frac{\delta}{2D} = \tan\left(\frac{\theta}{2}\right)$$

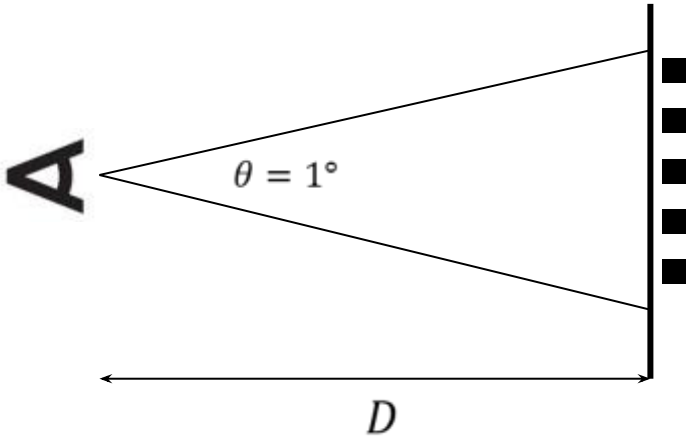
$$\delta = 2\mathrm{D}\tan\left(\frac{\theta}{2}\right)$$

To obtain the pixels per degree, $\theta = 1°$.
Calculate δ → How many pixels are in δ ?

Task 3: Create a hybrid image

- Peak of the contrast sensitivity function (CSF) is at 5 cycles per visual degree

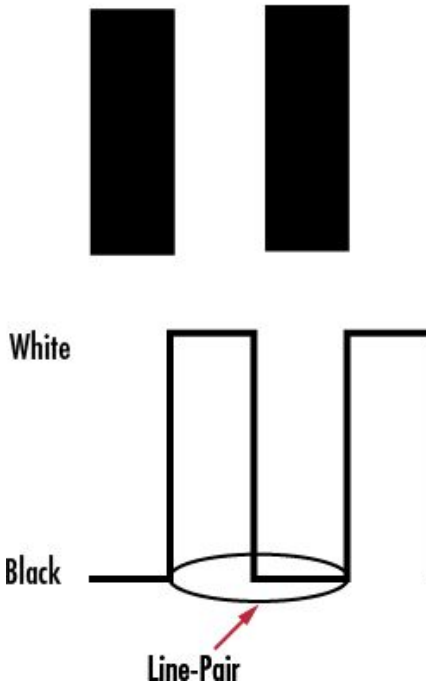




- 5 (cycles / degree) * ‘x’ (degrees / pixel) = ? cycles / pixel
- The spatial frequency with peak contrast sensitivity changes with distance D and screen DPI.

Task 3: Create a hybrid image

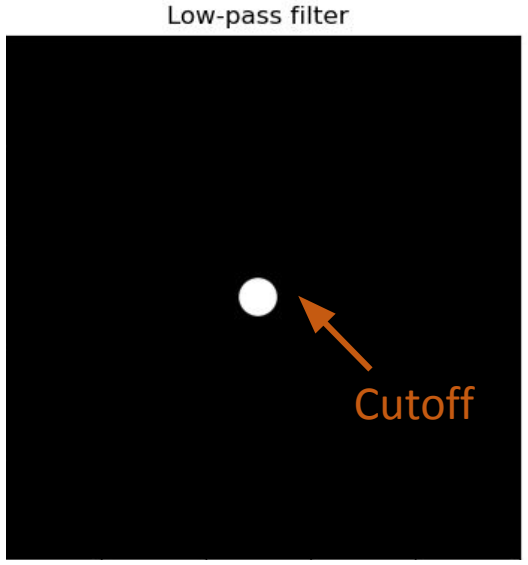
- Image frequency
  - Physical frequency, e.g. cycles per mm, on the page
  - Nyquist rate = sampling rate = 2x max frequency in image
    - By definition, sensor sampling rate is 1 cycle/pixel
    - Max frequency in image is (confusingly) called the Nyquist frequency
  - Therefore, Nyquist frequency is 0.5 cycles/pixel

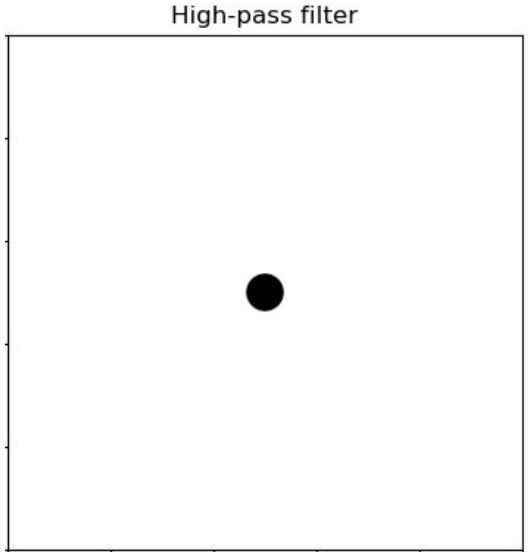


Cycle

Task 3: Create a hybrid image

High-pass and low-pass filters





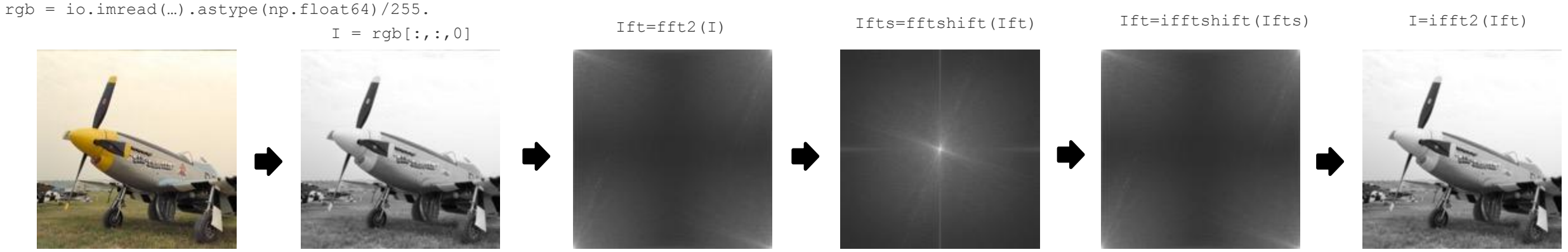
Python functions: np.meshgrid, np.fft.{fft2, ifft2, fftshift, ifftshift}

Task 3: Create a hybrid image

Result

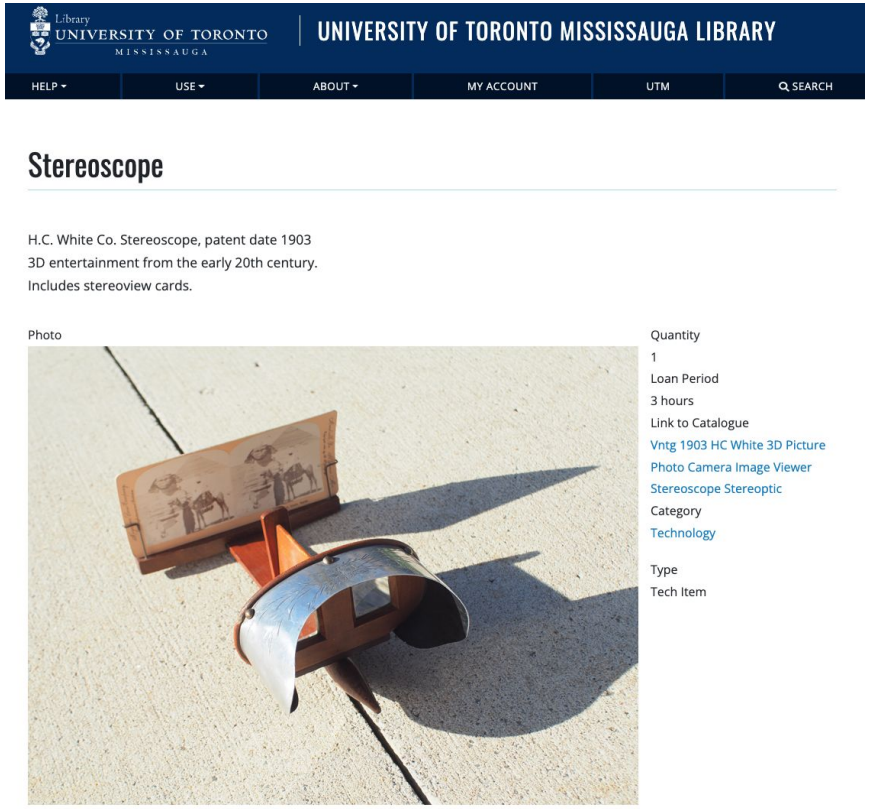
Task 3: Advice

- When you load 8 bit images (e.g., jpg or png), they are in the range 0-255, which is often inconvenient and may give you unexpected results for some functions. Convert them to double and normalize them, for example by using `img = img.astype(np.float64)/255.`
  - Beware that skimage.io.imread loads images in RGB channel order, whereas cv2.imread loads them in BGR channel order
- To combine the low- and high-pass filtered spectra, just add the frequency components in the Fourier domain for each color channel.
- Use `fftshift()` / `ifftshift()`. When you call `fft2()` on an image, the frequency axis goes from 0 frequency, up to the highest frequency, and back down to zero. The `fftshift()` function will shift the spectrum so that 0 frequency is in the middle. Likewise, you need to call `ifftshift()` before using `ifft2()`.



Fun additions

- Try the Stereoscope at UTM Library



- Blur visual cues: https://www.youtube.com/watch?v=Wf4_bcrJ864