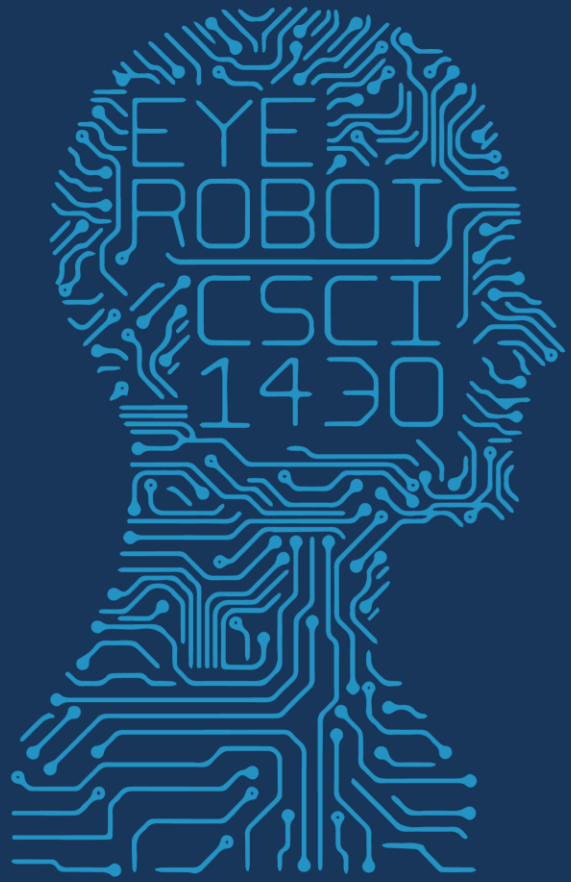
1950

Future Vision



9 February 2019

Computer Vision

Salvador Dali, 1976

Next Classes

- Spatial frequency
- Fourier transform and frequency domain
  - Frequency view of filtering
  - Hybrid images
  - Sampling
- Reminder: Textbook
  - Today's lecture covers material in 3.4

Slide: Hoiem

Why does a lower resolution image still make sense to us? What information do we lose?

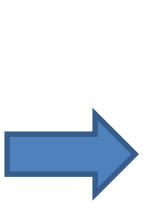
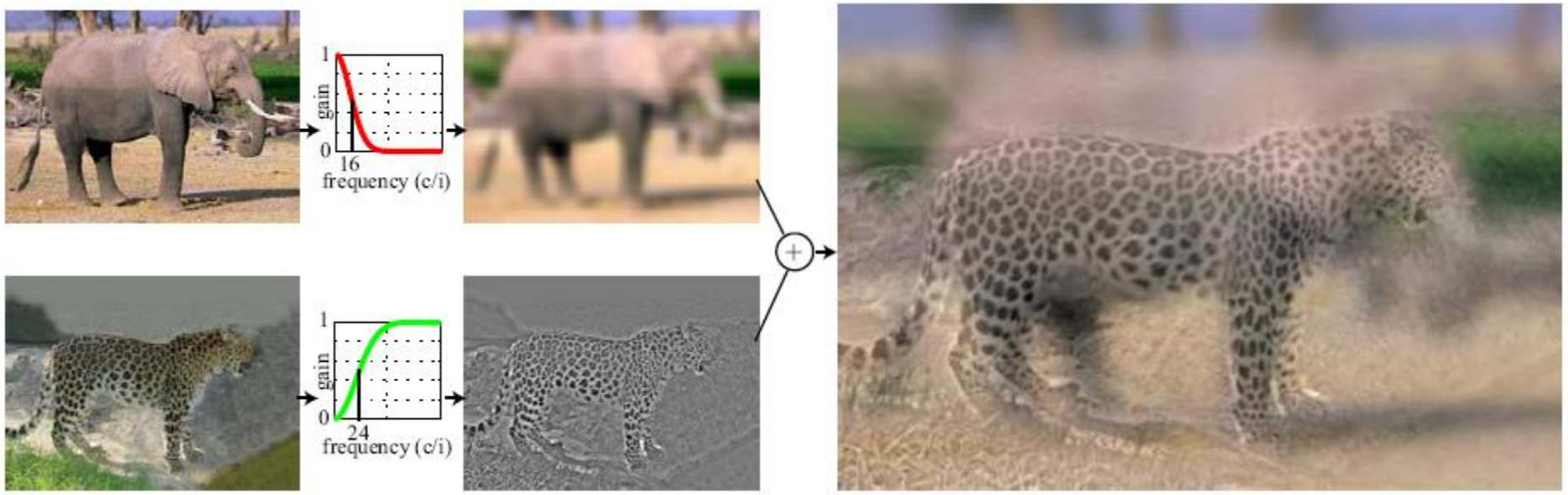


Image: http://www.flickr.com/photos/igorms/136916757/

Slide: Hoiem

Hybrid Images



- A. Oliva, A. Torralba, P.G. Schyns, "Hybrid Images," SIGGRAPH 2006

Why do we get different, distance-dependent interpretations of hybrid images?

?

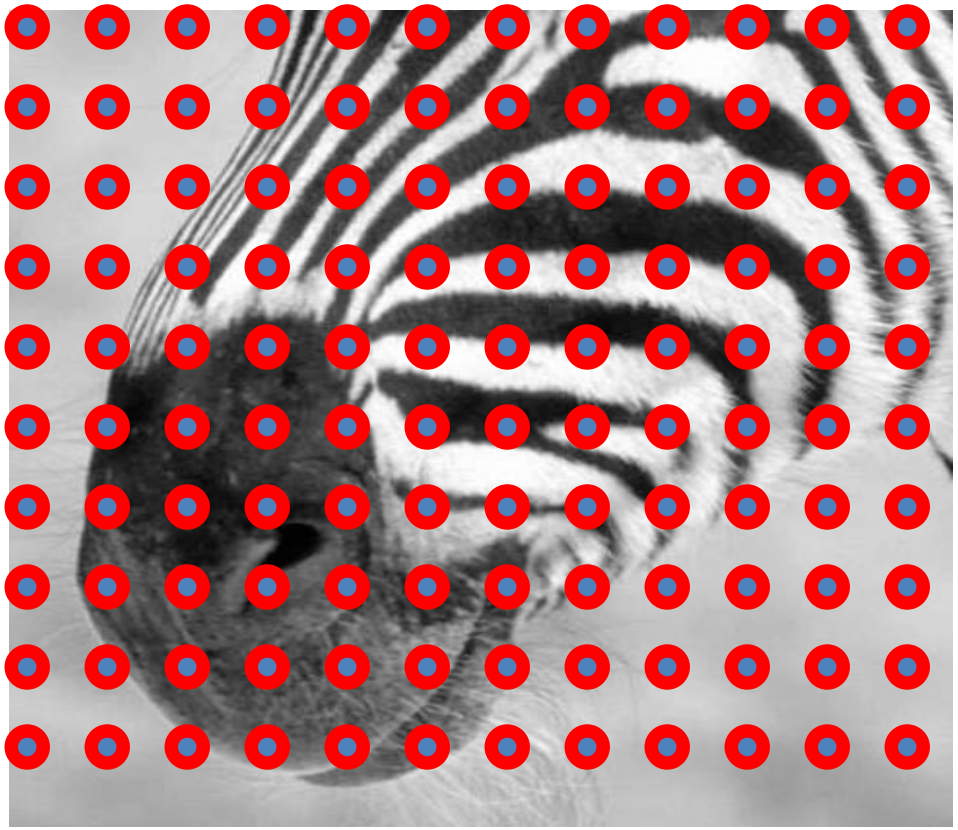
Slide: Hoiem

Sampling

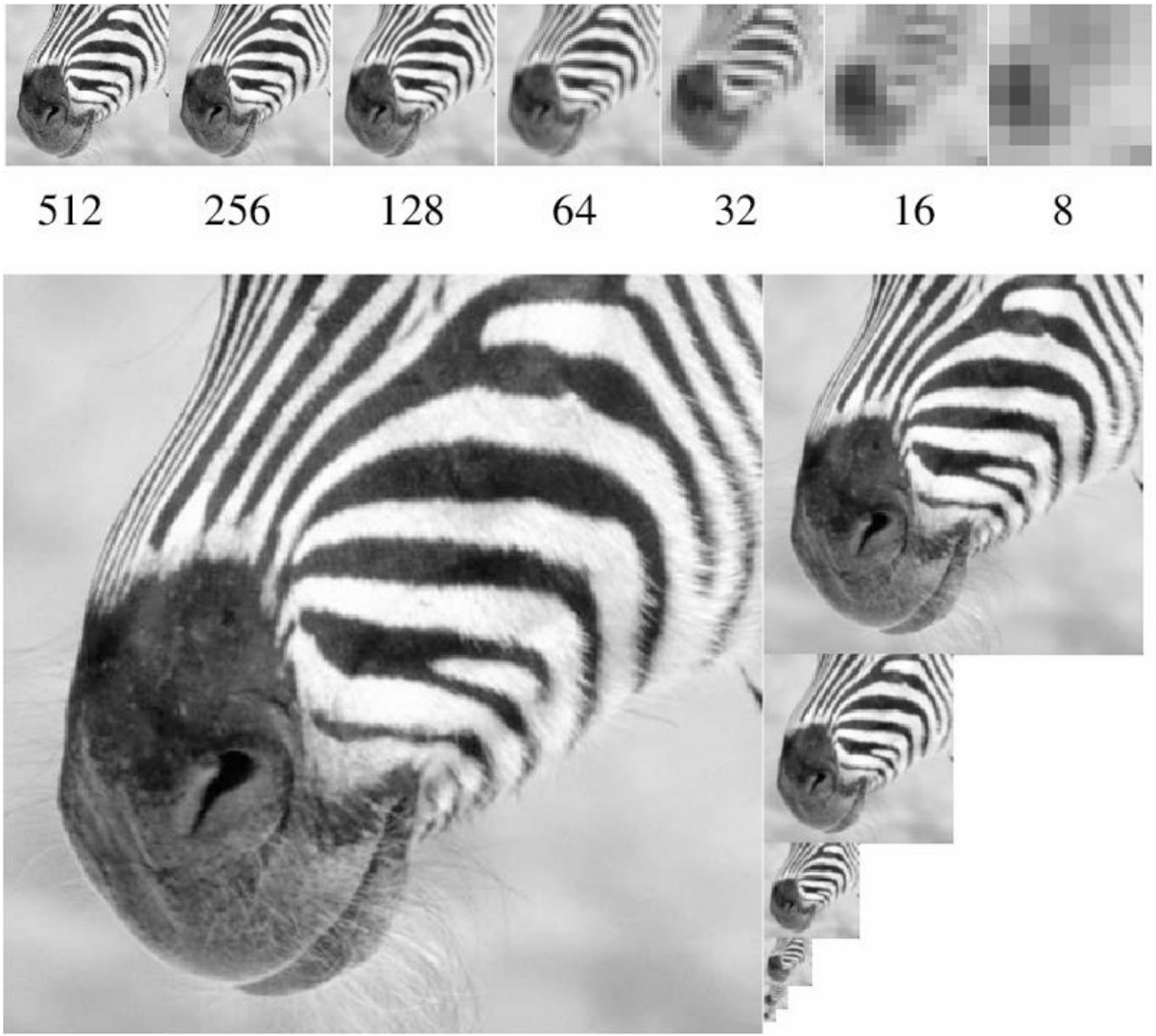
Why does a lower resolution image still make sense to us? What do we lose?

Image: http://www.flickr.com/photos/igorms/136916757/

Subsampling by a factor of 2



Throw away every other row and column to create a 1/2 size image



A ‘bar’ in the big images is a hair on the zebra’s nose; in smaller images, a stripe; in the smallest, the animal’s nose

Figure from David Forsyth

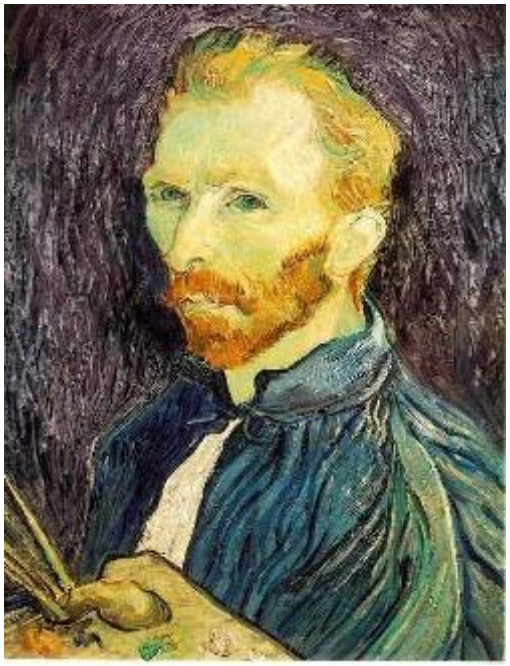
Algorithm for downsampling by factor of 2

1. Start with image of w x h
2. Sample every other pixel
   - im_small = image[::2:, ::2]
3. Repeat until im_small is 1 pixel large.

Numpy syntax:
::2 -> start at 0, end at 'end', increase every 2, until the end.
e.g.,
0,2,4,6,…,w

(if w is not even, then this goes to w-1)

Image sub-sampling

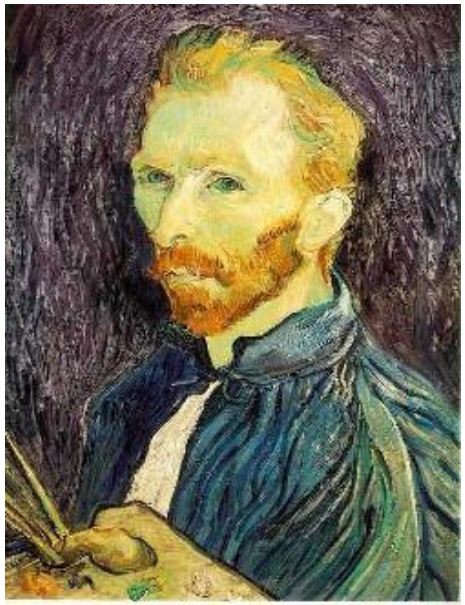


Throw away every other row and column to create a 1/2 size image.

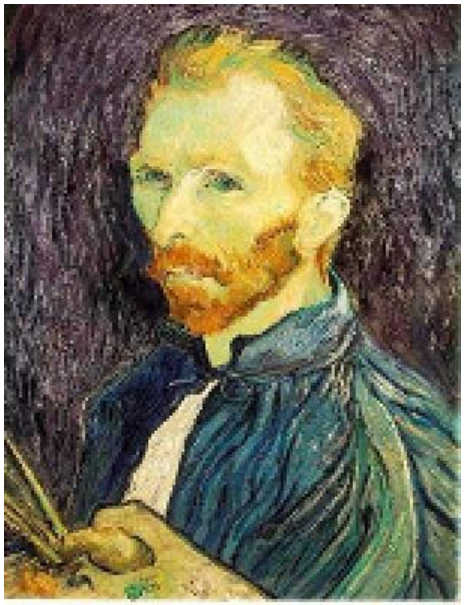
1/4

1/8

Subsampling without filtering



1/2

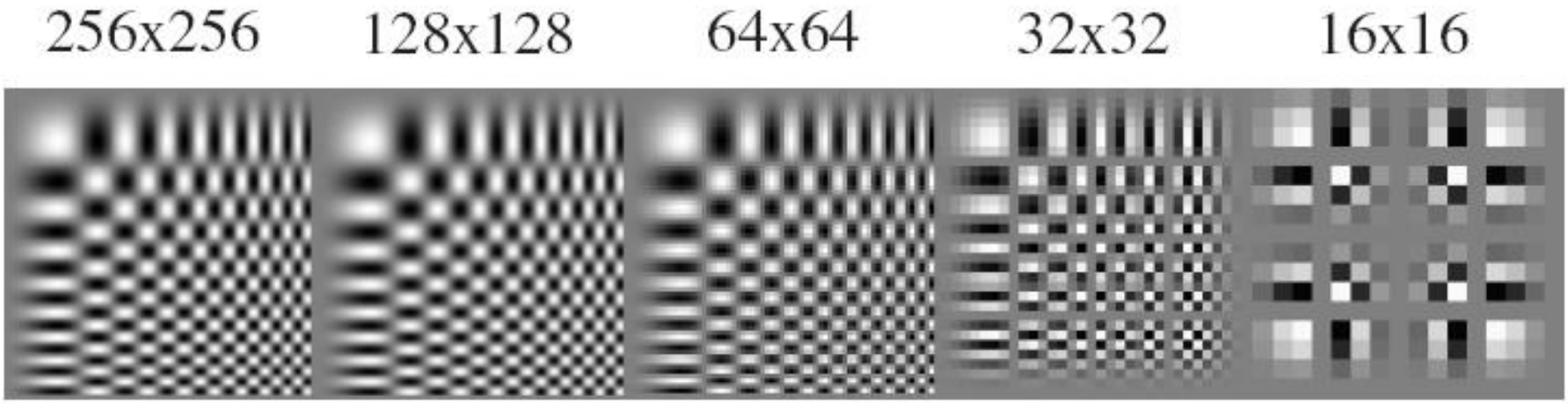


1/4 (2x subsample)

1/8 (4x subsample)

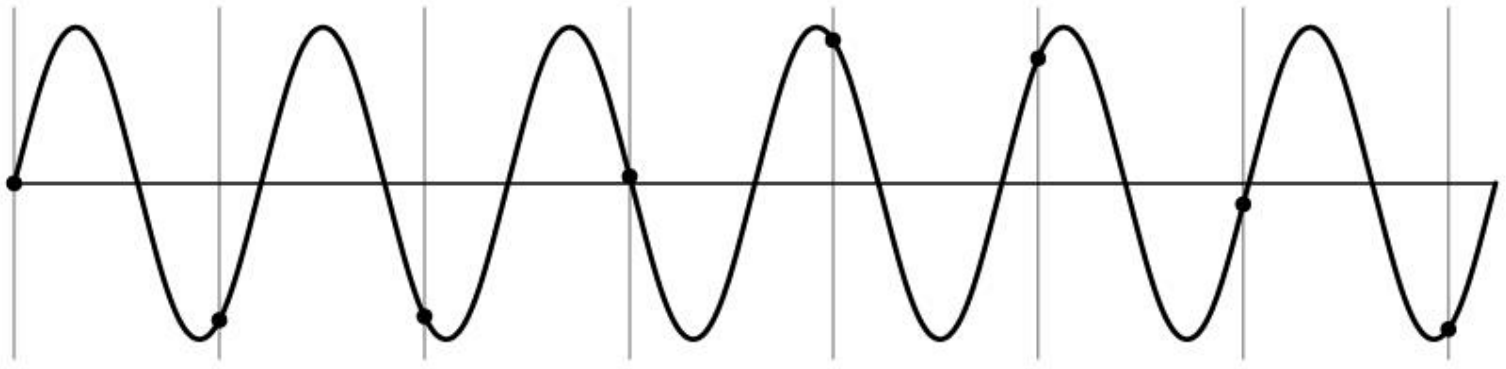
Steve Seitz

Sampling and aliasing



Aliasing problem

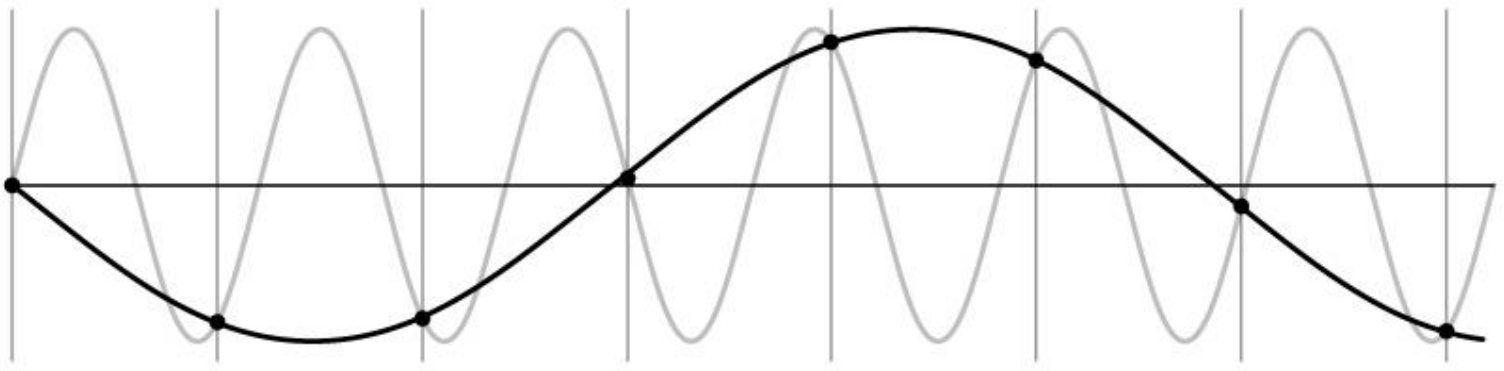
- 1D example (sinewave):



Source: S. Marschner

Aliasing problem

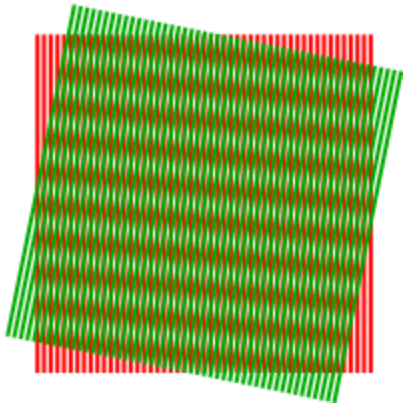
- 1D example (sinewave):



Source: S. Marschner

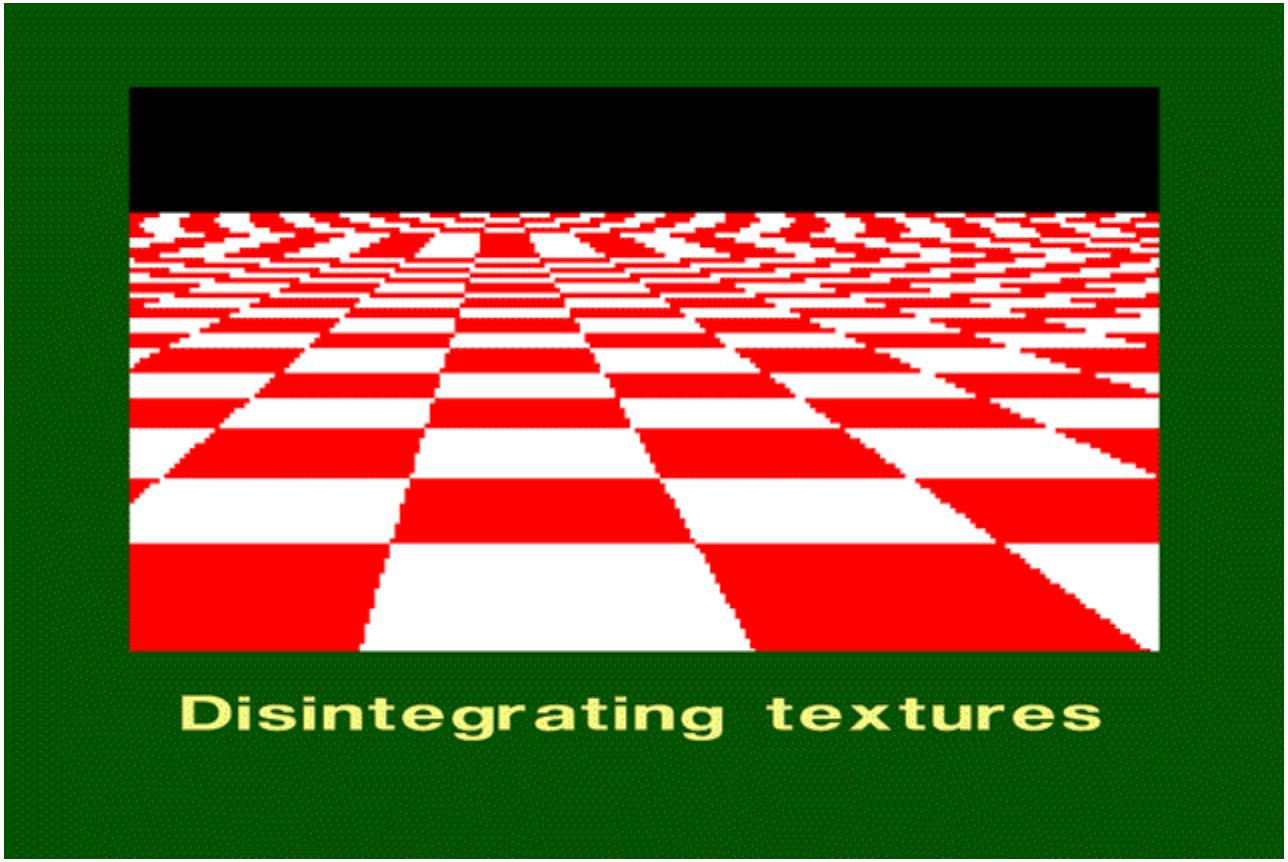
Aliasing problem

- Sub-sampling may be dangerous….
- Characteristic errors may appear:
  - “car wheels rolling the wrong way in movies”
  - “checkerboards disintegrate in ray tracing”
  - “striped shirts look funny on color television”
    - Moiré patterns



Source: D. Forsyth; Wikipedia

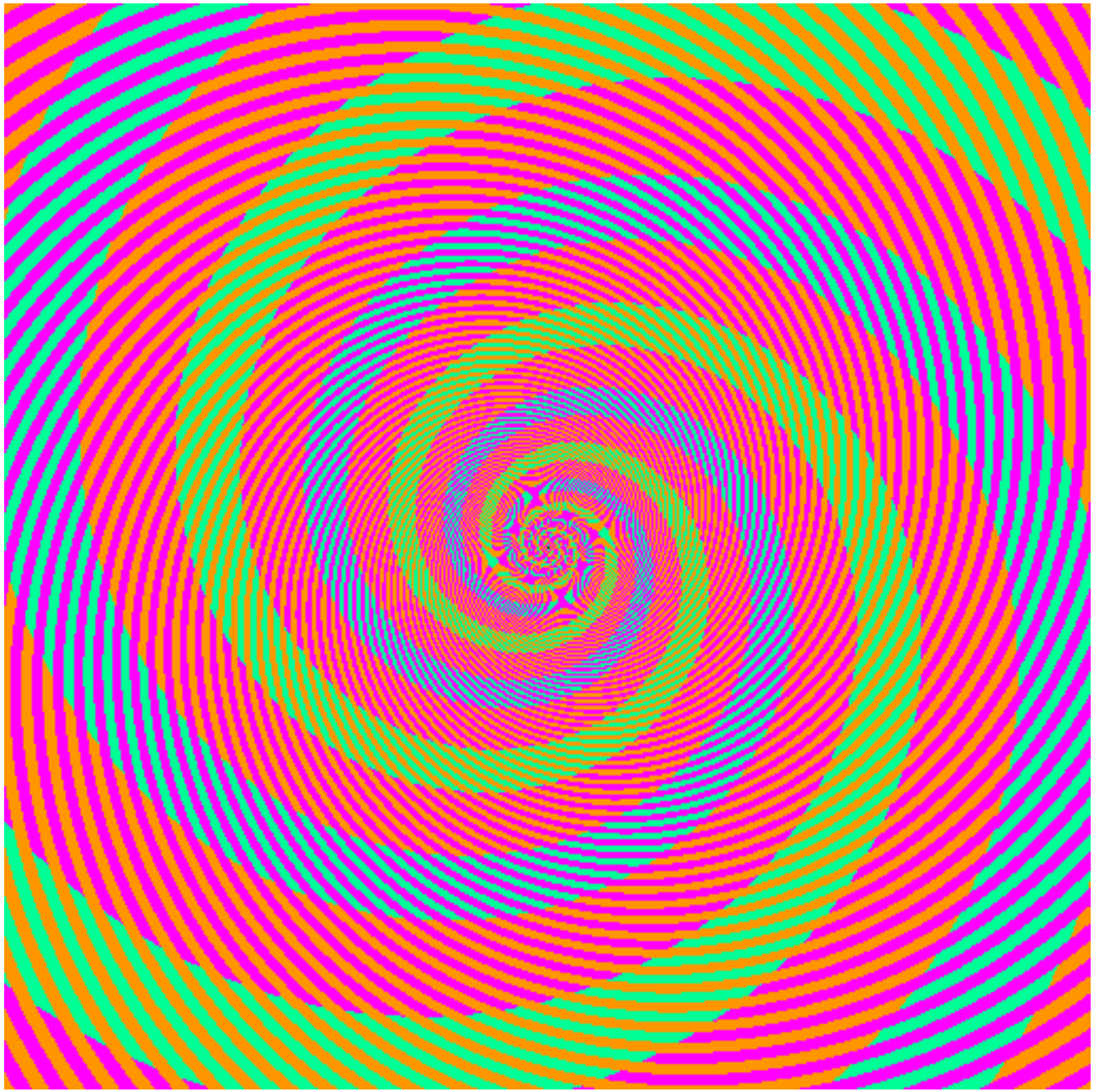
Aliasing in graphics

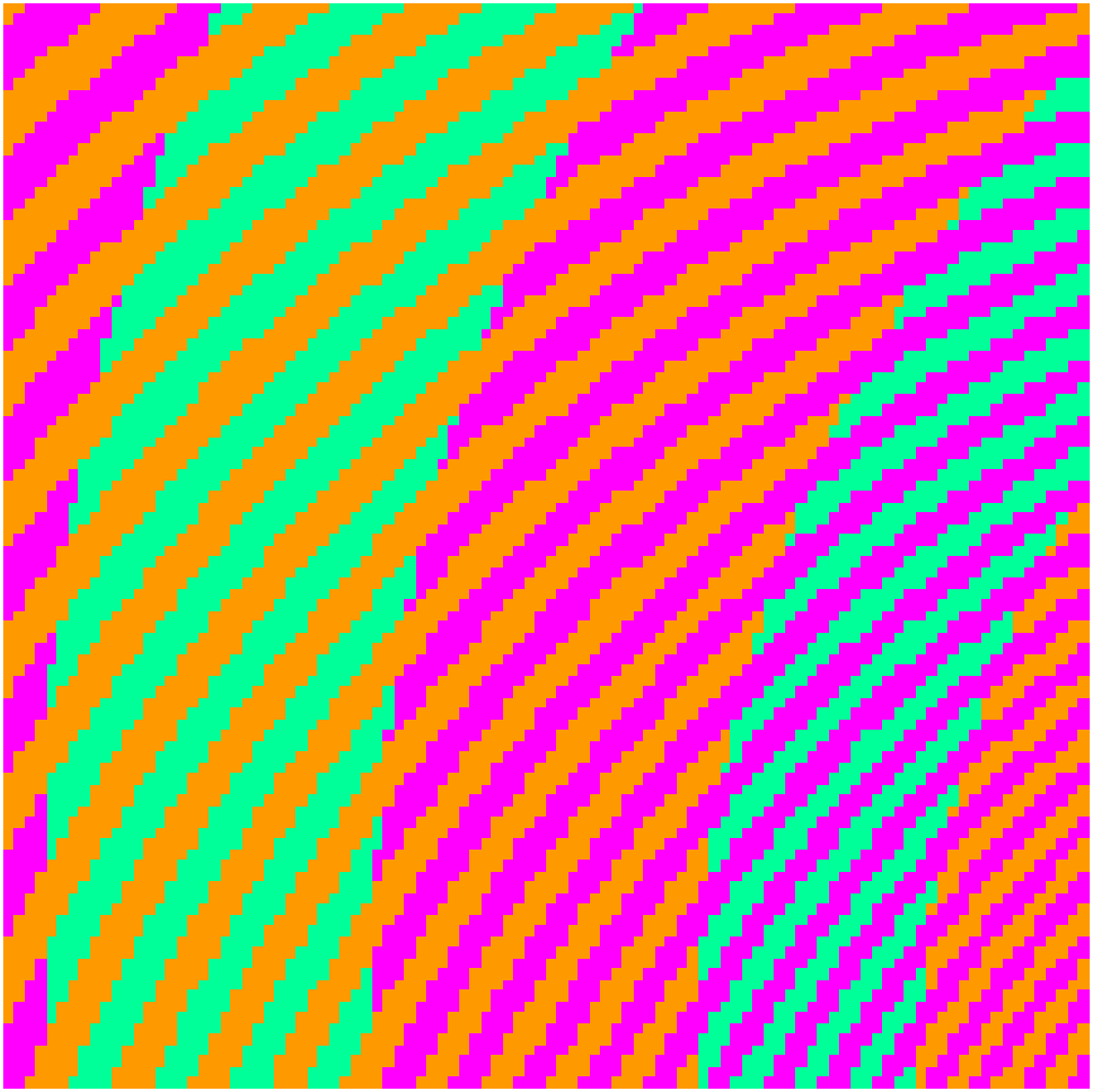


Source: A. Efros

Aliasing and Moiré patterns

Gong 96, 1932, Claude Tousignant, Musée des Beaux-Arts de Montréal





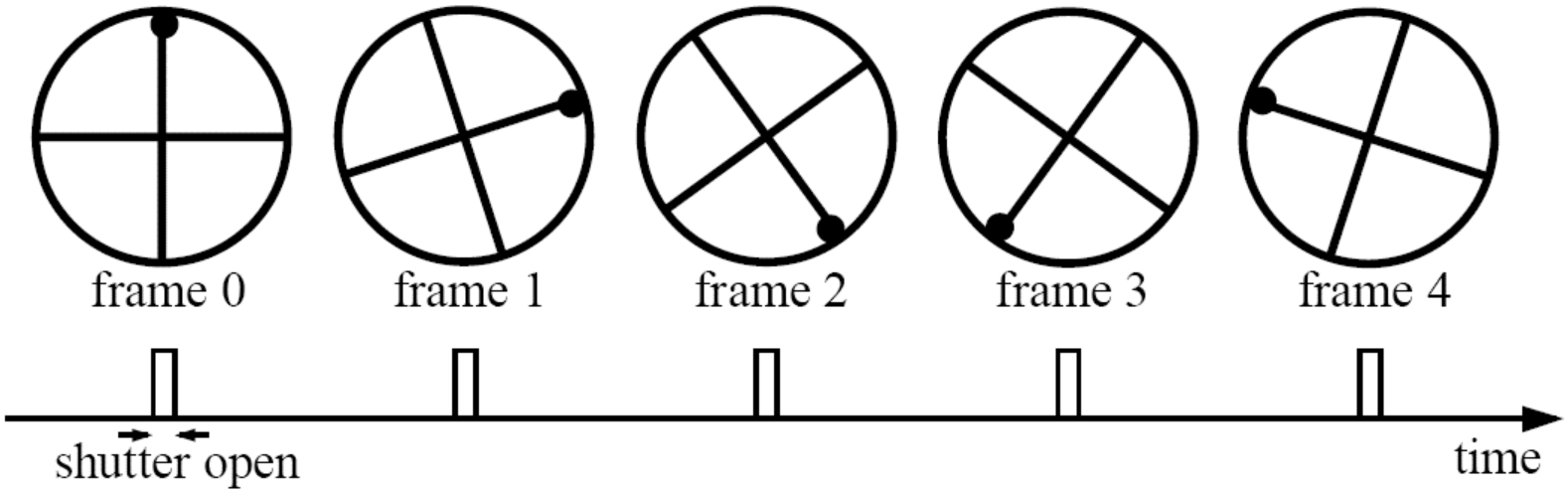
The blue and green colors are actually the same

http://blogs.discovermagazine.com/badastronomy/2009/06/24/the-blue-and-the-green/

Aliasing in video

Imagine a spoked wheel moving to the right (rotating clockwise). Mark wheel with dot so we can see what's happening.

If camera shutter is only open for a fraction of a frame time (frame time = 1/30 sec. for video, 1/24 sec. for film):



Without dot, wheel appears to be rotating slowly backwards! (counterclockwise)

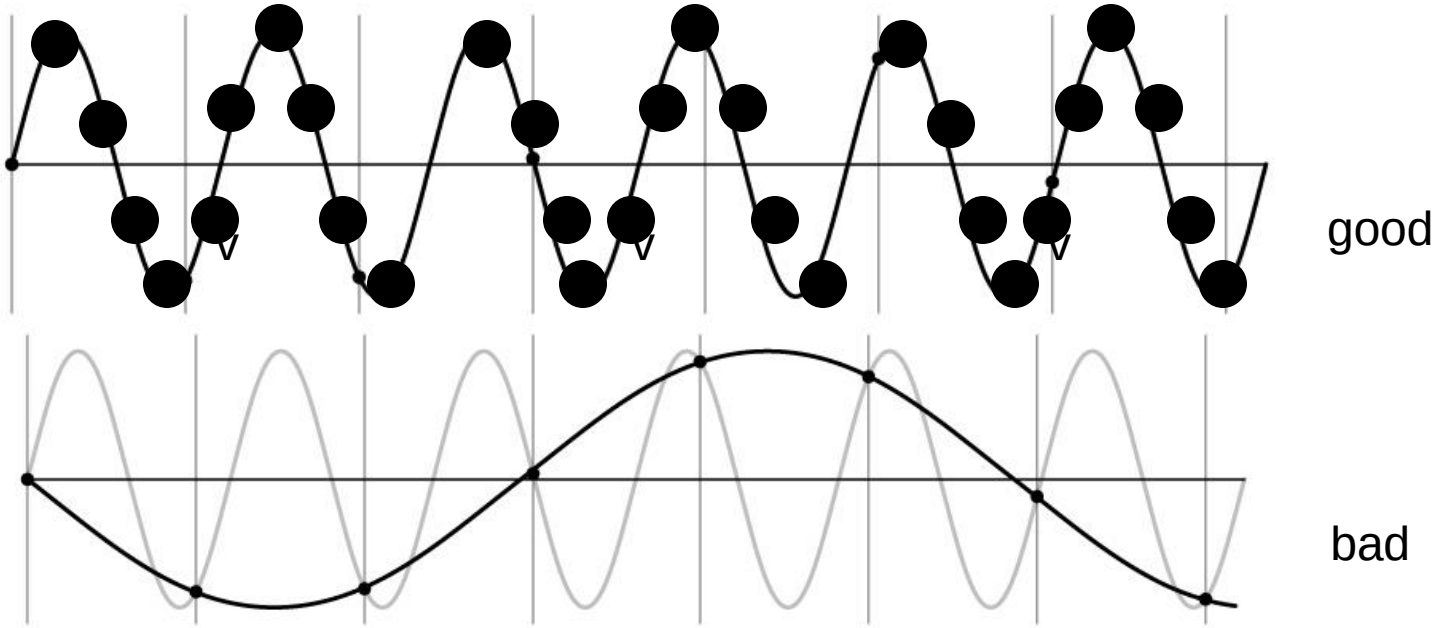
Slide by Steve Seitz

Videos

[YouTube; JoinBuzzirk; phrancque]

Nyquist-Shannon Sampling Theorem

- When sampling a signal at discrete intervals, the sampling frequency must be $\geq 2 \times f_{max}$
- f_{max} = max frequency of the input signal
- This will allows to reconstruct the original perfectly from the sampled version



How to fix aliasing?

Solutions?

Better sensors

Solutions:

- Sample more often

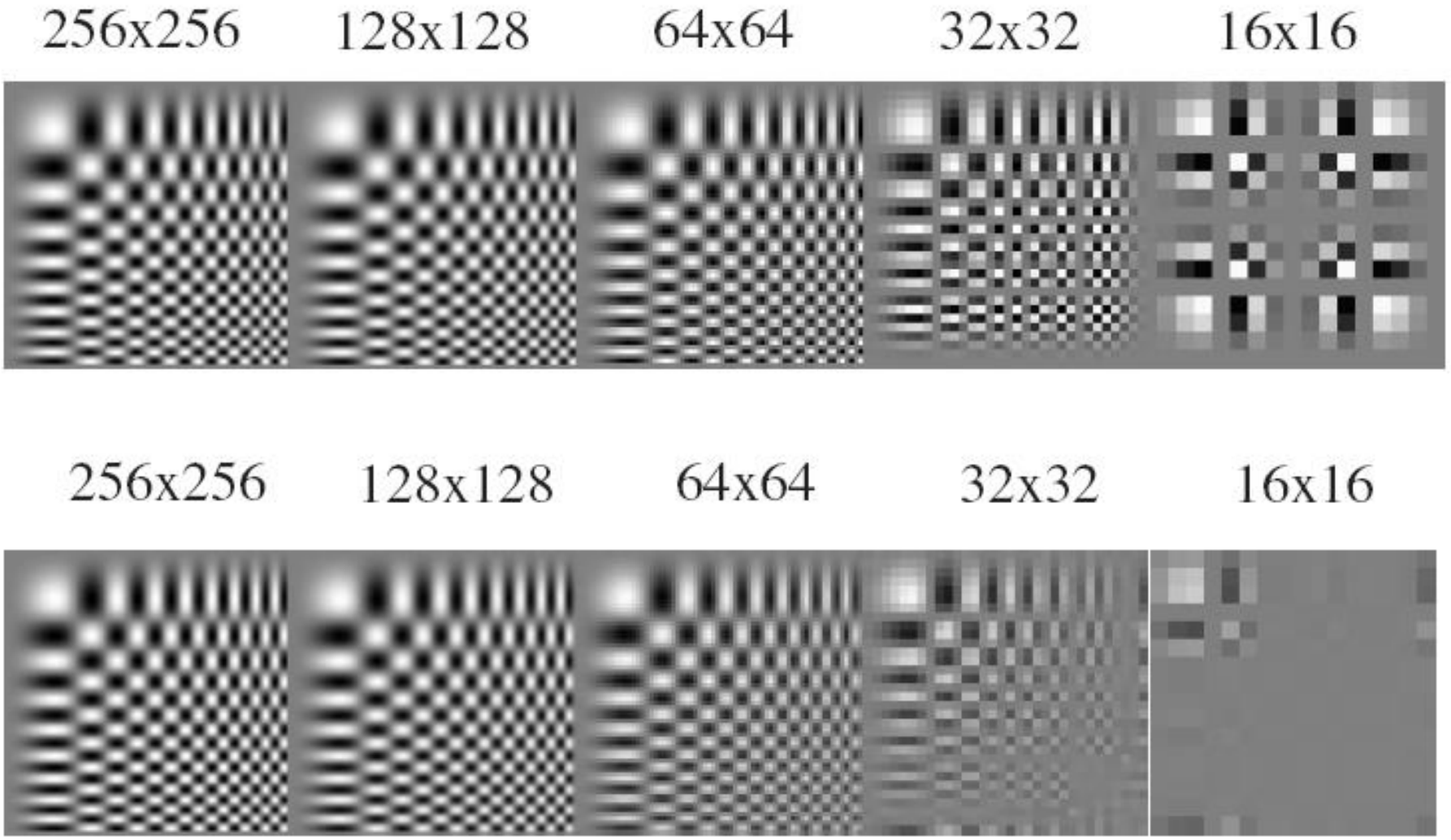
Anti-aliasing

Solutions:

- Sample more often

- Get rid of all frequencies that are greater than half the new sampling frequency
  - Will lose information
  - But it's better than aliasing
  - Apply a smoothing (*low pass*) filter

Anti-aliasing



Forsyth and Ponce 2002

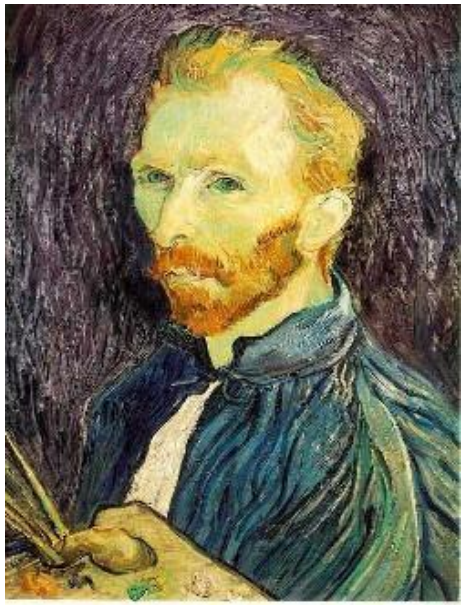
Algorithm for downsampling by factor of 2

1. Start with image(h, w)
2. Apply low-pass filter

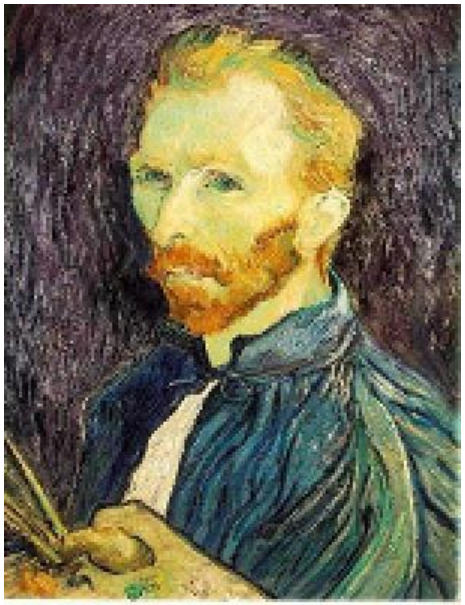
   im_blur = imfilter(image, fspecial('gaussian', 7, 1))
3. Sample every other pixel

   im_small = im_blur(1:2:end, 1:2:end);

Subsampling without filtering



1/2



1/4 (2x subsample)

1/8 (4x subsample)

Steve Seitz

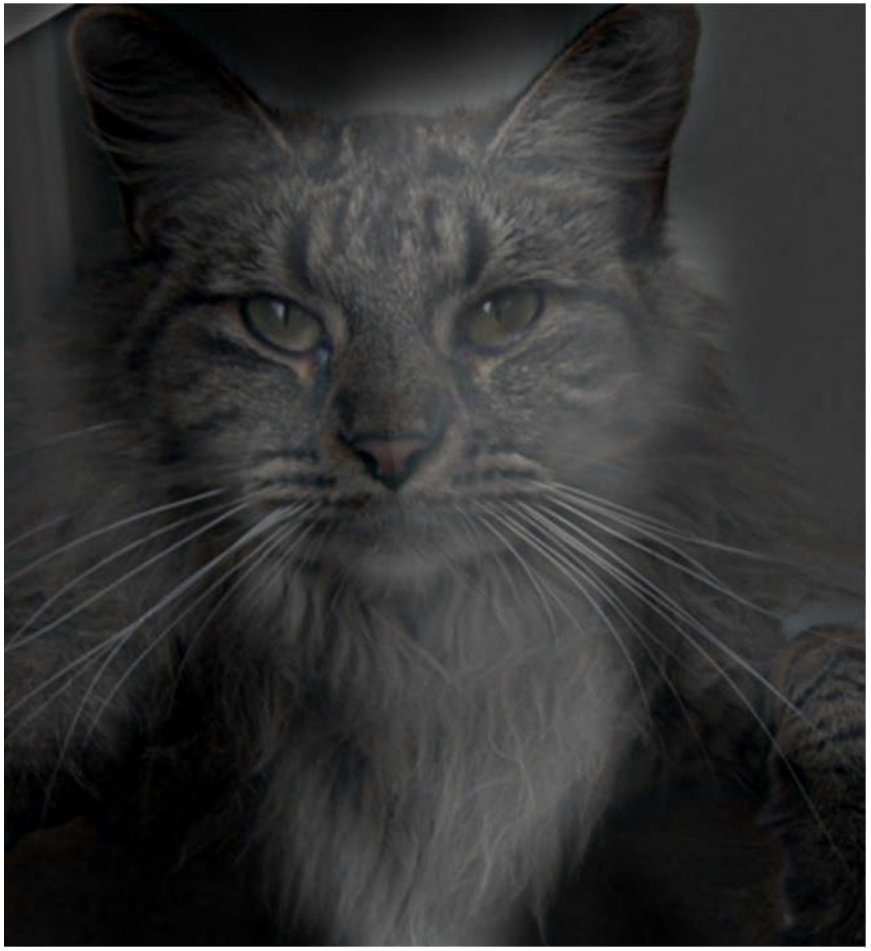
Subsampling with Gaussian pre-filtering

Gaussian 1/2 G 1/4 G 1/8

Gaussian Pyramid [Burt and Adelson, 1983]

Steve Seitz

Why do we get different, distance-dependent interpretations of hybrid images?

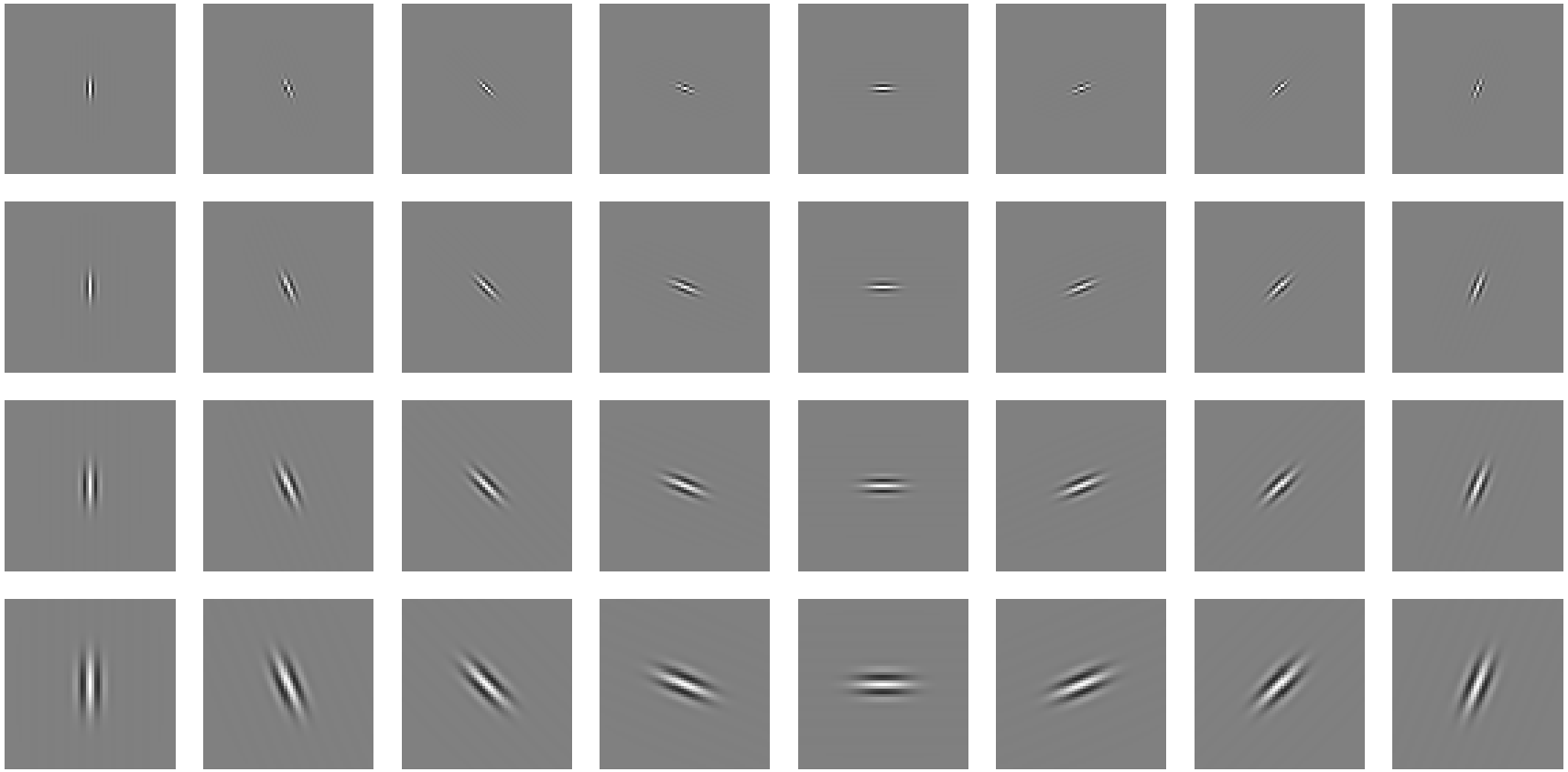


?

Hays

Clues from Human Perception

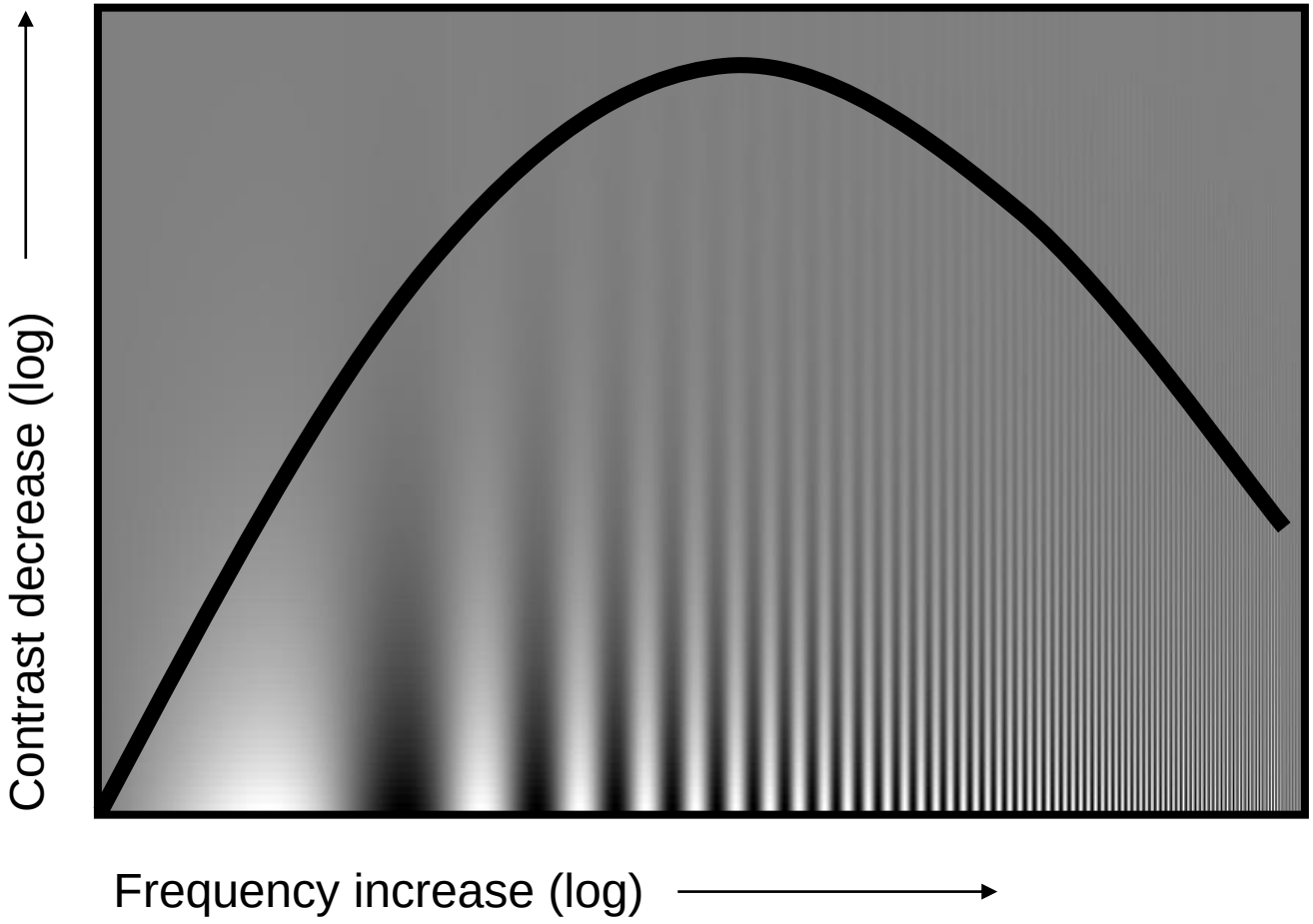
- Early processing in humans filters for orientations and scales of frequency.



Early Visual Processing: Multi-scale edge and blob filters

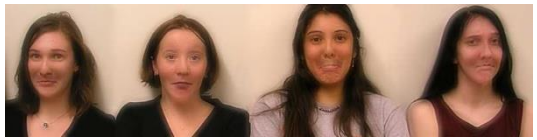
Campbell-Robson contrast sensitivity curve

Perceptual cues in the mid-high frequencies dominate perception.



Application: Hybrid Images

When we see an image from far away, we are effectively subsampling it!



A. Oliva, A. Torralba, P.G. Schyns, SIGGRAPH 2006

Salvador Dali
"Gala Contemplating the Mediterranean Sea, which at 30 meters becomes the portrait of Abraham Lincoln", 1976

Salvador Dali invented Hybrid Images?

Salvador Dali
"Gala Contemplating the Mediterranean Sea, which at 30 meters becomes the portrait of Abraham Lincoln", 1976