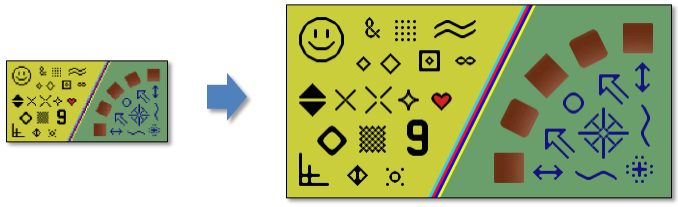
CS4670: Computer Vision

Noah Snavely

Image Resampling



Announcements

- Daniel's office hours:
  Tuesday 4:30 to 5:30
  Thursday 1:05 to 2:05
  Location: Upson 317 (Robot Teaching Lab)

From last time (with demo!)

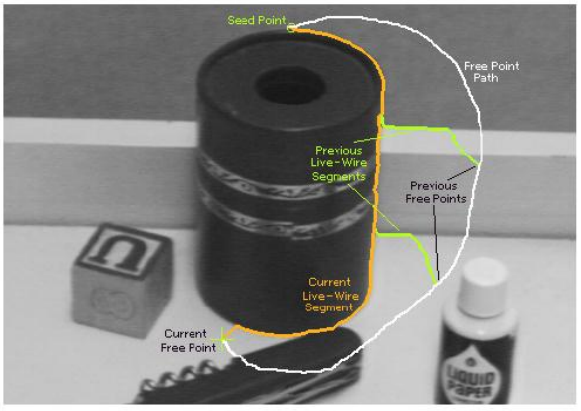


Figure 2: *Image demonstrating how the live-wire segment adapts and snaps to an object boundary as the free point moves (via cursor movement). The path of the free point is shown in white. Live-wire segments from previous free point positions (t_0, t_1, and t_2) are shown in green.*

Other notes on Project 1

- We will deal with images stored as matrices in C++
  - And we will store matrices as arrays
    - In row major order
    - RGB values are packed together
- To filter an RGB image, you will filter each color channel separately

Image

This image is too big to fit on the screen. How can we generate a half-sized version?

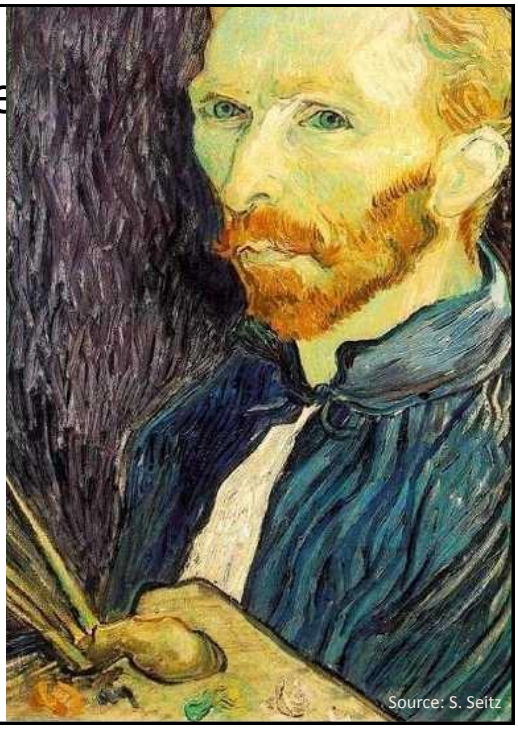
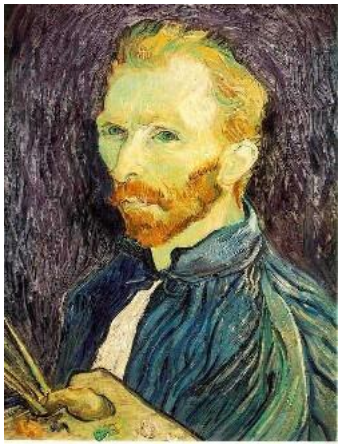


Image sub-sampling



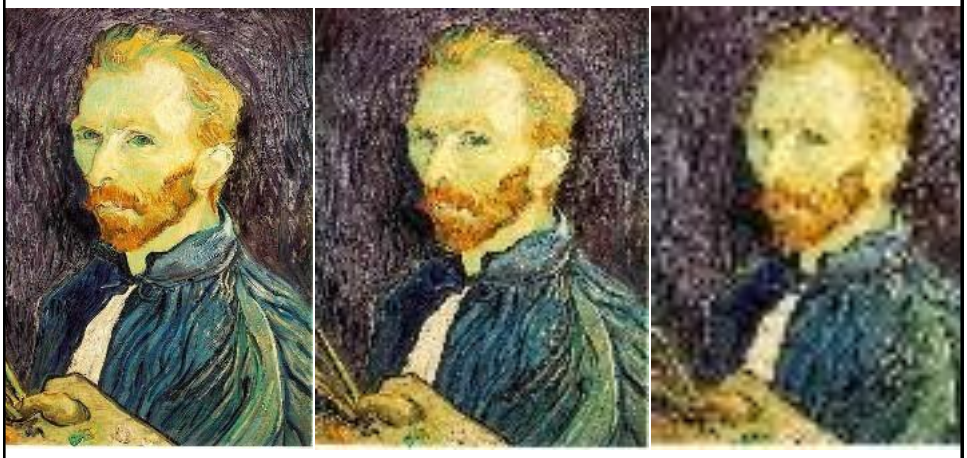
Throw away every other row and column to create a 1/2 size image
- called *image sub-sampling*

1/4

1/8

Source: S. Seitz

Image sub-sampling



1/2 1/4 (2x zoom) 1/8 (4x zoom)

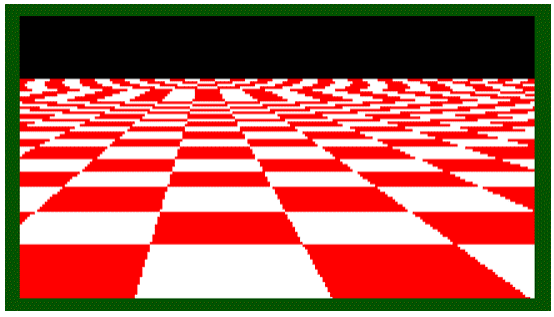
Why does this look so crufty?

Source: S. Seitz

Image sub-sampling

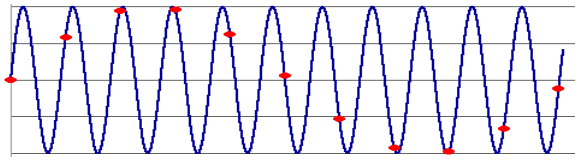
Source: F. Durand

Even worse for synthetic images



Source: L. Zhang

Aliasing



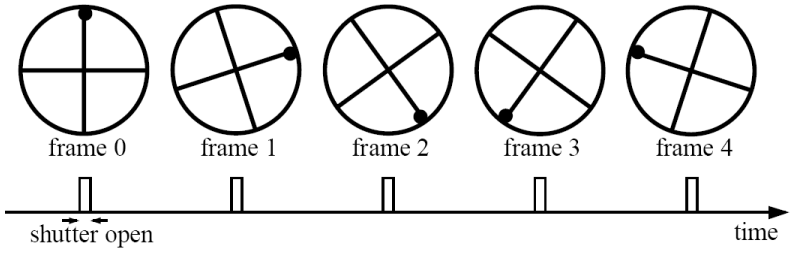
- Occurs when your sampling rate is not high enough to capture the amount of detail in your image
- Can give you the wrong signal/image—an *alias*
- To do sampling right, need to understand the structure of your signal/image
- Enter Monsieur Fourier…
- To avoid aliasing:
  - sampling rate ≥ 2 * max frequency in the image
    - said another way: ≥ two samples per cycle
  - This minimum sampling rate is called the **Nyquist rate**

Source: L. Zhang

Wagon-wheel effect

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):

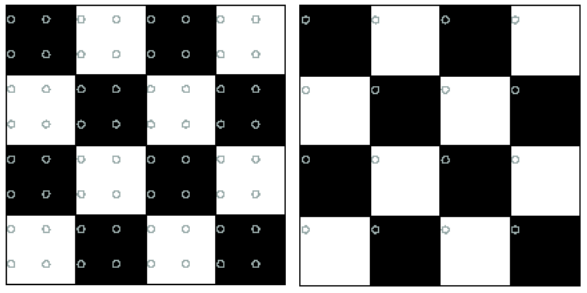


Without dot, wheel appears to be rotating slowly backwards! (counterclockwise)

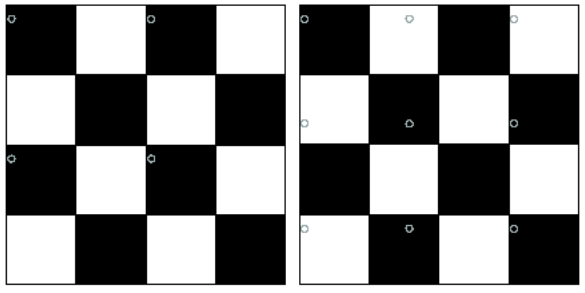
(See http://www.michaelbach.de/ot/mot_wagonWheel/index.html)

Source: L. Zhang

Nyquist limit – 2D example



Good sampling



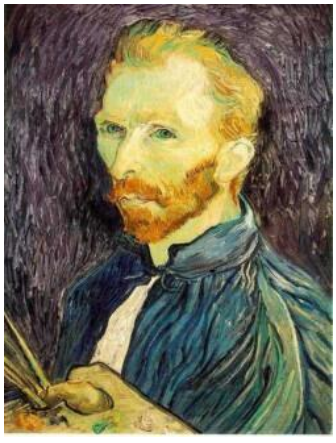
Bad sampling

Aliasing

- When downsampling by a factor of two
  - Original image has frequencies that are too high

- How can we fix this?

Gaussian pre-filtering



Gaussian 1/2

G 1/4

G 1/8

- Solution: filter the image, *then* subsample

Source: S. Seitz

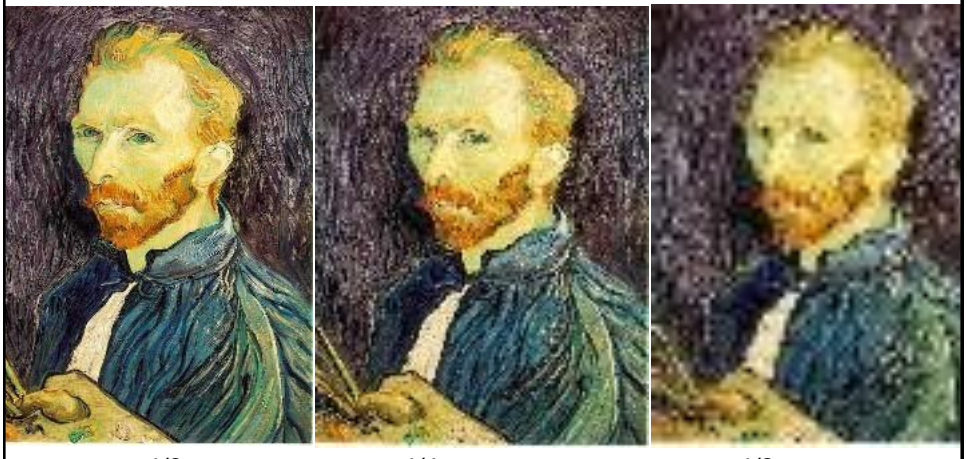
Subsampling with Gaussian pre-filtering

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

- Solution: filter the image, *then* subsample

Source: S. Seitz

Compare with...



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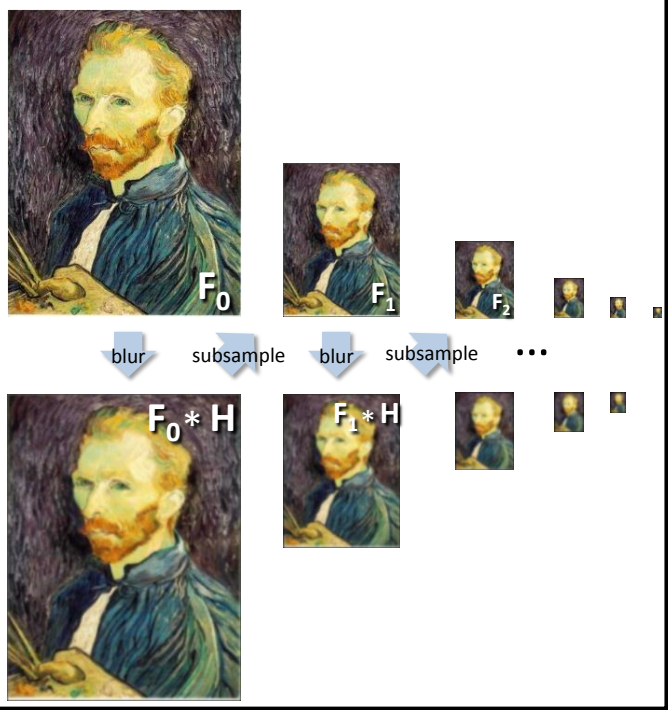
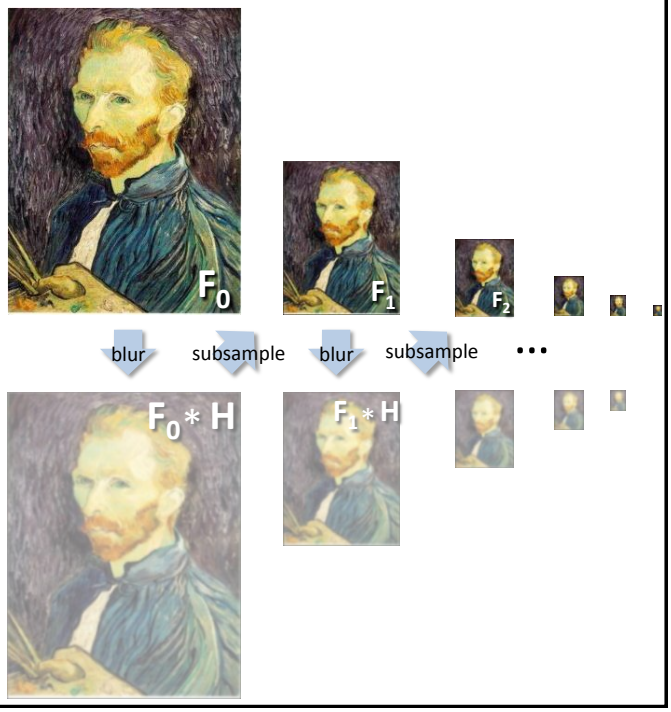
Source: S. Seitz

Gaussian pre-filtering

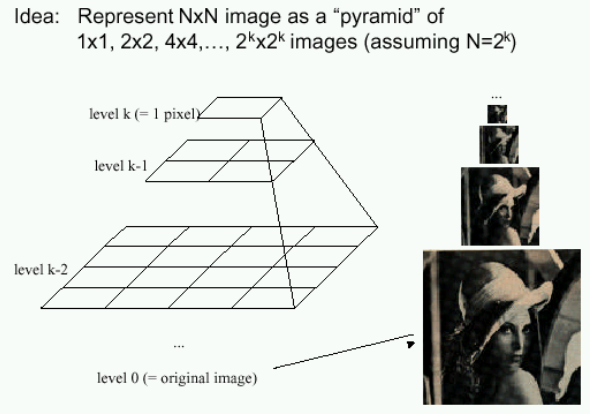
- Solution: filter the image, *then* subsample



Gaussian pyramid



Gaussian pyramids [Burt and Adelson, 1983]

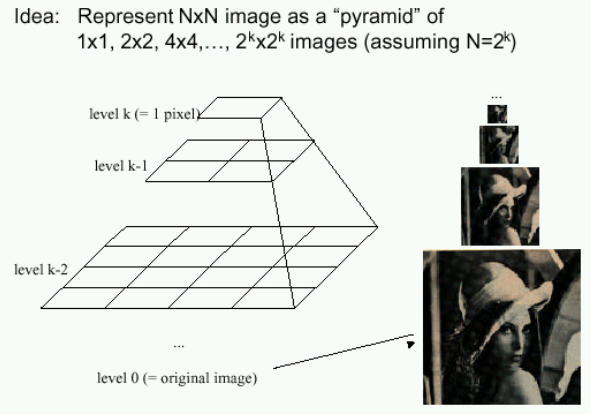


- In computer graphics, a *mip map* [Williams, 1983]
- A precursor to *wavelet transform*

Gaussian Pyramids have all sorts of applications in computer vision

Source: S. Seitz

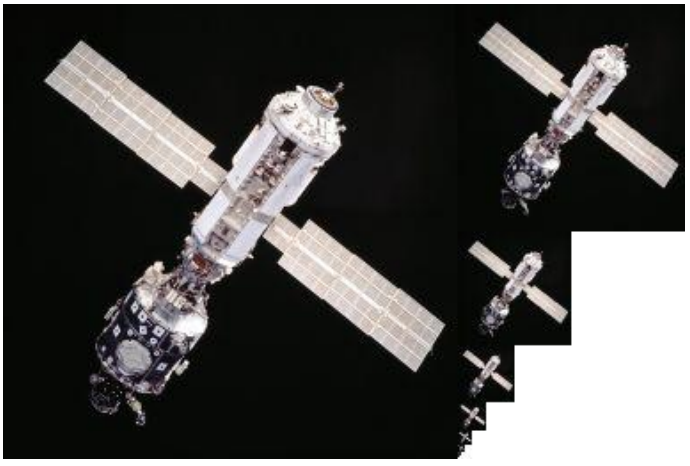
Gaussian pyramids [Burt and Adelson, 1983]



- How much space does a Gaussian pyramid take compared to the original image?

Source: S. Seitz

Gaussian Pyramid

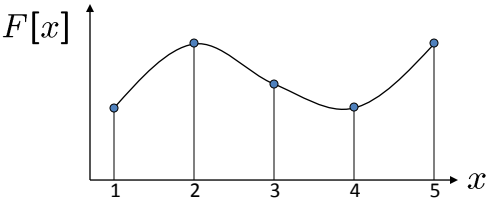


Questions?

Upsampling

- This image is too small for this screen: 
- How can we make it 10 times as big?
- Simplest approach:
  repeat each row
  and column 10 times
- ("Nearest neighbor
  interpolation")

Image interpolation



d = 1 in this example

Recall how a digital image is formed

$$F[x, y] = \text{quantize}\{f(xd, yd)\}$$

- It is a discrete point-sampling of a continuous function
- If we could somehow reconstruct the original function, any new image could be generated, at any resolution and scale

Adapted from: S. Seitz

Image interpolation

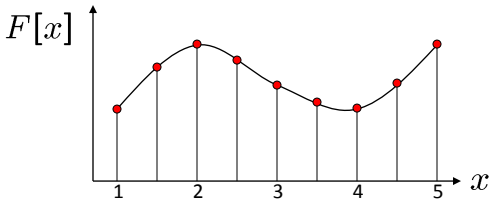


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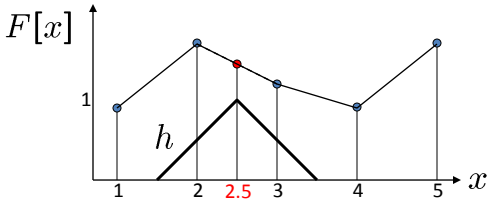
Image interpolation



d = 1 in this example

- What if we don't know f ?
  - Guess an approximation: $\tilde{f}$
  - Can be done in a principled way: filtering
  - Convert F to a continuous function:

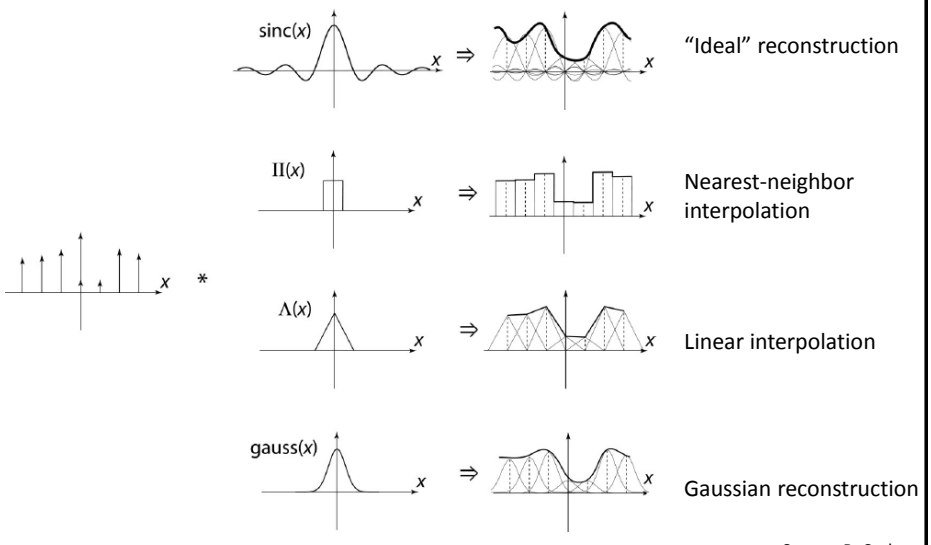
    $$f_F(x) = F(\tfrac{x}{d}) \text{ when } \tfrac{x}{d} \text{ is an integer, 0 otherwise}$$

  - Reconstruct by convolution with a *reconstruction filter, h*

    $$\tilde{f} = h * f_F$$

Adapted from: S. Seitz

Image interpolation

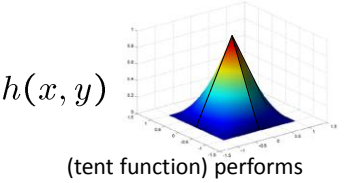


Source: B. Curless

Reconstruction filters

- What does the 2D version of this hat function look like?

performs
linear interpolation



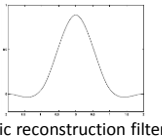
(tent function) performs
bilinear interpolation

Often implemented without cross-correlation

- E.g., http://en.wikipedia.org/wiki/Bilinear_interpolation

Better filters give better resampled images

- **Bicubic** is common choice



Cubic reconstruction filter

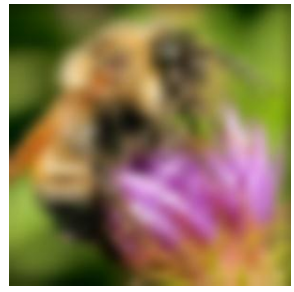
$$r(x) = \frac{1}{6}\begin{cases} (12-9B-6C)|x|^3 + (-18+12B+6C)|x|^2 + (6-2B) & |x|<1 \\ ((-B-6C)|x|^3 + (6B+30C)|x|^2 + (-12B-48C)|x| + (8B+24C) & 1\le|x|<2 \\ 0 & \text{otherwise} \end{cases}$$

Image interpolation

Original image:  x 10

Nearest-neighbor interpolation

Bilinear interpolation



Bicubic interpolation

Image interpolation

Also used for *resampling*

Questions?