

CS559 – Lecture 6 Resampling, Color



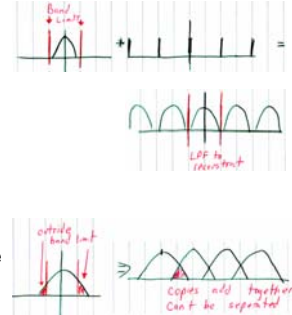
These are course notes (not used as slides)
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With some slides adapted from the notes of Stephen
Chenney

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Sampling Theory



- Sampling is multiply by spike chain in time domain
 - Fourier transform of spike chain is spike chain
 - Fourier transform of multiply is convolution
- Sampling is convolution by spike chain in frequency
- Makes infinite copies of signal
- Reconstruction low-pass filters to remove all but one
- Non-band limited, things "spill"



Sampling / Reconstruction



- Both sampling and reconstruction require Low Pass Filtering
- Sampling:
 - Low pass filter signal to make sure is band-limited
- Reconstruction:
 - Low pass filter spike chain to figure out what happens between samples
- Resampling:
 - Reconstruction followed by sampling

Resizing = Resampling



- Same image – different number of samples
- Issues:
 - New samples are in between old samples
 - Too few new samples to capture all the frequency
- Basic idea (in theory)
 - Reconstruct original signal (LPF the samples)
 - Low-pass filter (so sampling works)
 - Sample at new sampling rate

Resampling – Little Square Model



- Region of source = Region of Dst
- Pixel is a region
 - Dest region might be bigger than pixel in source
 - Average over the region (convolution gives us the weights)
- In-between pixels is piecewise constant
 - Chunky look is what the model says is right

Pre-Filtering



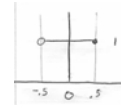
- If SRC is bigger than DST it may have HF
 - If its close, might need it anyway because of imperfect reconstruction
- Need to LPF
- LPF before sampling?
 - Requires you to do a complete reconstruction
 - Only really need to do it at points you will sample
- Pre-Filtering
 - Do LPF before reconstruction / as part of reconstruction
 - Order is OK (convolutions commute)

Reconstruction in Practice



- Sample a sample – no problem!
- Issue is samples between samples
- Theory: LPF a spike chain
 - Convolve “reconstruction kernel” with samples
 - Only really need to evaluate at places where you’ll sample
- Another view: interpolation
 - Different interpolations are different filters

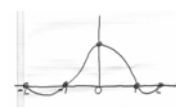
Some reconstruction kernels



Constant



Triangle
(Bartlett)



Interpolating
Cubic
(Catmull-Rom)

Spacing (1 unit = sample distance)

Scaling issues

Interpolating (non-interpolating kernels exist as well)

Approx to Ideal LPF

Reconstruction Example



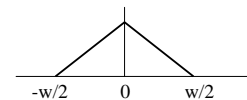
- Could do this as linear interpolation
 - Generalizes nicely this way
- Need to evaluate filter for various values
- Convolve reconstruction kernel with sampling kernel (LPF for frequency limit)
- Easier ways to implement nearest neighbor
- Sample at sample
- Sample between samples
- Bartlett filter
 - Width correct for sample spacing
- See how we get linear interpolation

Functional Form for Filters



- Consider the Bartlett in 1D:

$$H_w(s) = \frac{2}{w} \left(1 - \frac{2|s|}{w} \right)$$



- To apply it at a point x_{orig} and find the contribution from point x where the image has value $I(x)$

$$f(x) = \frac{2}{w} \left(1 - \frac{2|x-x_c|}{w} \right) I(x)$$

- Extends naturally to 2D:

$$f(x, y) = \frac{4}{w^2} \left(1 - \frac{2|x-x_c|}{w} \right) \left(1 - \frac{2|y-y_c|}{w} \right) I(x, y)$$

General Resampling



- Could be any transformation on x, y
- $X', y' = f(x, y)$
- Scale, translate, rotate, something weird
- Kernel should get warped too
 - Little square -> some weird shape
 - Little circle/square (of kernel) -> some weird shape
 - In practice, stick with squares

Reverse Warping



- Note we generally need the INVERSE:
 - $X', y' = f(x, y)$ ($x' = dst, x = src$)
 - Know x' , need to find x is inverse
- Reverse warping is easier (scan over each pixel in the dst, figure out where it comes from)
- Forward warping is trickier
 - Usually can invert function, but if you can't
 - Need to worry about holes
- Lots of fun warps to do!

Shift Gears: Color



- Color
- Quality of Light
 - Has a wavelength – not just an amount
- Can measure the spectrum of light
 - Graph wavelength vs. amount at the measurement
- Different spectra give different “color impressions”

Colors



- One dominant wavelength = pure color
- No dominant wavelength = “white” (or black/gray)
- What do we perceive?
 - Luminance (amount of light)
 - Color (dominant)
 - Purity of Color
- Complications
 - Differences in perception
 - Artist notions vs. physics vs. psychology

Sensing Color



- Different sensors have different sensitivities
 - Spectrum of sensor
 - Convolution with spectrum gives response
- Ideal photo sensor / real photo sensor
- Cameras – wide range sensor
 - Put filters in front of each CCD element
 - Different parts of spectra (R,G,B)
 - Bayer Mosaic (need to interpolate)
 - Foveon

Color Vision in Animals



- Rods = all the same
 - No color vision
- Cones = have different kinds
 - 1-chromat (can't see color) -> Dogs
 - bi-chromat (2 different types) -> large mammals
 - Tri-chromat -> humans ***
 - Color blindness = lack of 1 type
 - Rare genetics condition gives a 4th type
 - Some birds have 4 or 5 types of cones
 - Ducks&Pigeons have 5, European starlings have 4

Distinguishing colors



- 1 sensor
 - All colors look the same
 - Combination of colors looks like any color
- Metamers – perceptually indistinguishable
- 2 sensors
 - Non-overlap case (what differences?)
 - Overlap case
 - Middle vs. combination of sides

Faking Colors



- Metamers allow for faking
- 2 cones = 2 frequencies
- Two different overlapping cones respond
 - Some of each color?
 - Some of the in-between color
- Get either cone, or anything in overlap
- Colors outside of overlap can't be faked
- Can fake responses using N “point” colors

