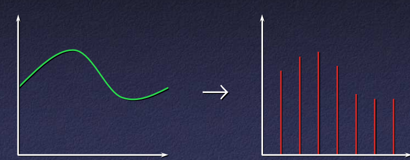
Lightfield Sampling

COS 526, Fall 2006

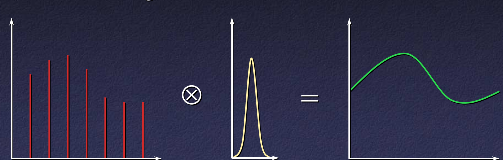
Review of Signal Processing

- Pixels = samples of a continuous function



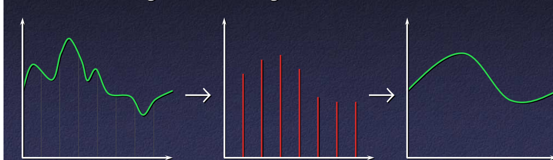
Review of Signal Processing

- Convolve with reconstruction filter to re-create signal



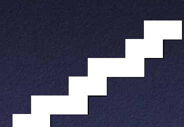
How to Sample?

- Reconstructed signal might be very different from original: “aliasing”



Aliasing in Images

- “Jaggies”



Why Does Aliasing Happen?

- Sampling = multiplication by shah function III(x) (also known as impulse train)

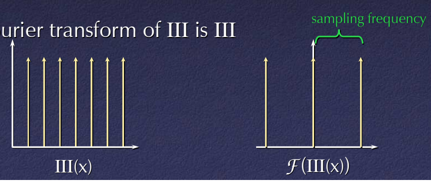
III(x)

Fourier Analysis

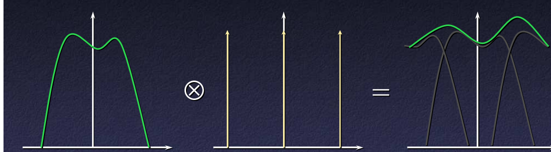
- Multiplication in primal space = convolution in frequency space

$$\mathcal{F}\big(f(x)g(x)\big) = \mathcal{F}\big(f(x)\big) \otimes \mathcal{F}\big(g(x)\big)$$

- Fourier transform of III is III



Fourier Analysis

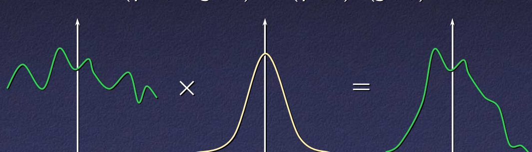


- Result: high frequencies can "alias" into low frequencies

Fourier Analysis

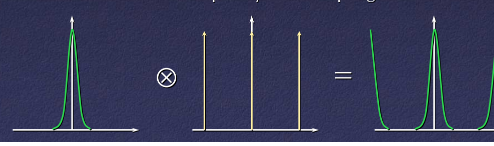
- Convolution with reconstruction filter = multiplication in frequency space

$$\mathcal{F}\big(f(x) \otimes g(x)\big) = \mathcal{F}\big(f(x)\big)\mathcal{F}\big(g(x)\big)$$



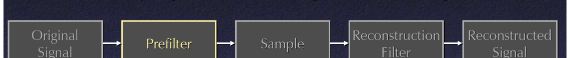
Aliasing in Frequency Space

- Conclusions:
  - High frequencies can alias into low frequencies
  - Can't be cured by a different reconstruction filter: get "blurry jaggies"
  - Nyquist limit: can capture all frequencies iff signal has maximum frequency ≤ ½ sampling rate



Filters for Sampling

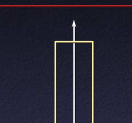
- Solution: insert filter *before* sampling
  - "Sampling" or "bandlimiting" or "antialiasing" filter



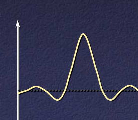
  - Low-pass filter
  - Eliminate frequency content above Nyquist limit
  - Result: aliasing replaced by blur

Ideal Sampling Filter

- "Brick wall" filter: box in frequency

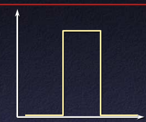


- In space: sinc function
  - sinc(x) = sin(x) / x
  - Infinite support
  - Possibility of "ringing"

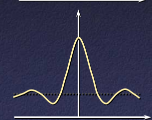


Cheap Sampling Filter

- Box in space
  - Cheap to evaluate
  - Finite support

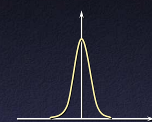


- In frequency: sinc
  - Imperfect bandlimiting



- Even cheaper: precompute for finite number of box sizes – "mipmapping" for textures

Gaussian Sampling Filter



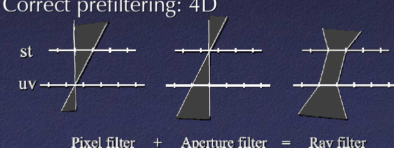
- Fourier transform of Gaussian = Gaussian
- Good compromise as sampling filter:
  - Well approximated by function w. finite support
  - Good bandlimiting performance

Light Field Sampling

- How does this apply to light fields?
  - Capturing light field may or may not antialias correctly
  - Explains appearance of undersampled lightfields
  - Once captured, can only do reconstruction: filtering just produces equivalent of "blurry jaggies"
  - But, can filter down to get low-res antialiased lightfield

Light Field Sampling

- Capturing a lightfield:
  - OK bandlimiting within a captured image
  - Point sampling camera positions: potential for aliasing
  - Result: objects fade in and out w. change in viewpoint
- Correct prefiltering: 4D



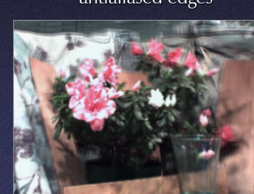
[Levoy & Hanrahan]

Synthetic Aperture

- Acquiring antialiased lightfield:
  - Move camera to dense set of positions on *uv* plane
  - One *uv* "sample" = weighted average of images in some region of *uv* plane

Correct Prefiltering Results

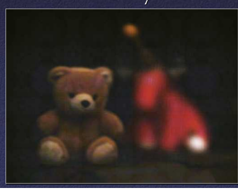
- Fading replaced by blur
  - Analogous to images: jaggy edges replaced by antialiased edges



[Isaksen et al.]

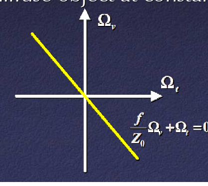
Dynamic Resampling: Isaksen et al., SIGGRAPH 2000

- Can make a (close to) correctly antialiased low-res lightfield from a high-res one
- By choosing filter, can put focal plane wherever you want



Plenoptic Sampling

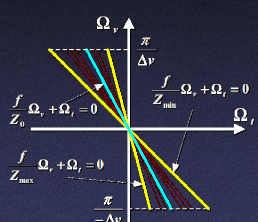
- Chai et al., SIGGRAPH 2000
- Analyze frequency content of lightfields, state equivalent of Nyquist theorem
- Light field of diffuse object at constant depth:



[Chai et al.]

Plenoptic Sampling

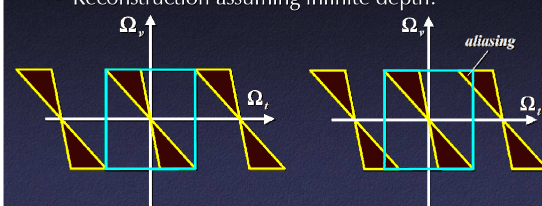
- Light field with bounded depths



[Chai et al.]

Plenoptic Sampling

- Reconstruction assuming infinite depth:



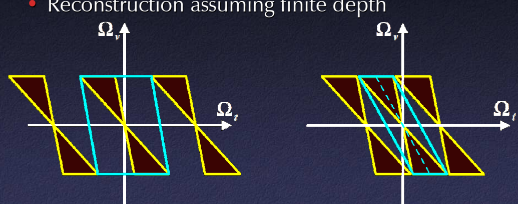
No Aliasing

Aliasing

[Chai et al.]

Plenoptic Sampling

- Reconstruction assuming finite depth



Maximal for this sampling

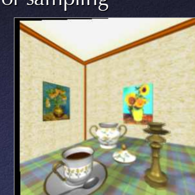
Maximal for this scene

[Chai et al.]

Plenoptic Sampling

- Explains lumigraph performance: local depth estimates good enough for sampling

48×48 images, no depth



16×16 images, 3 bits depth

[Chai et al.]