Sampling, Aliasing and Antialiasing

CS475 / 675, Fall 2016

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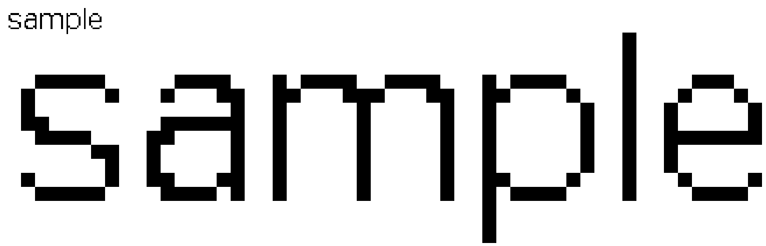
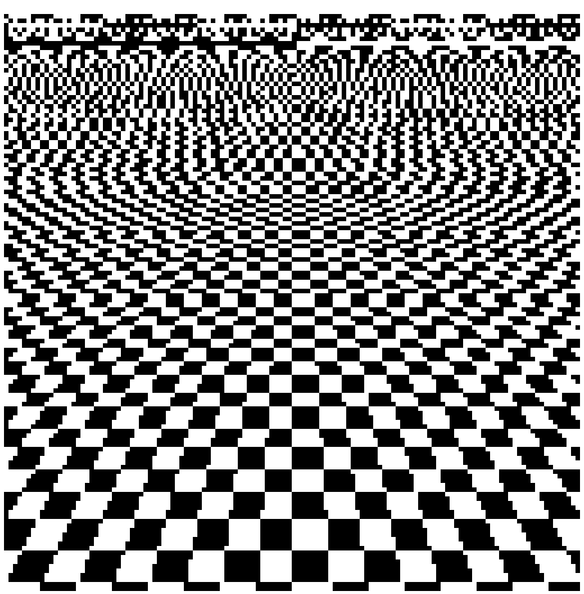
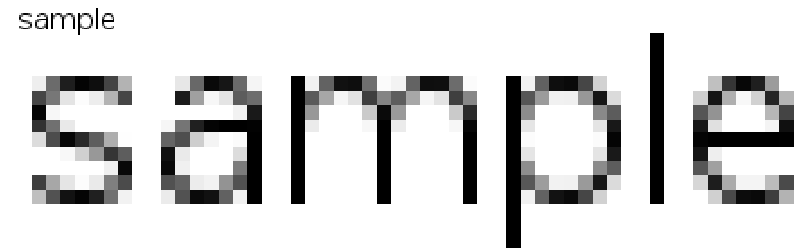
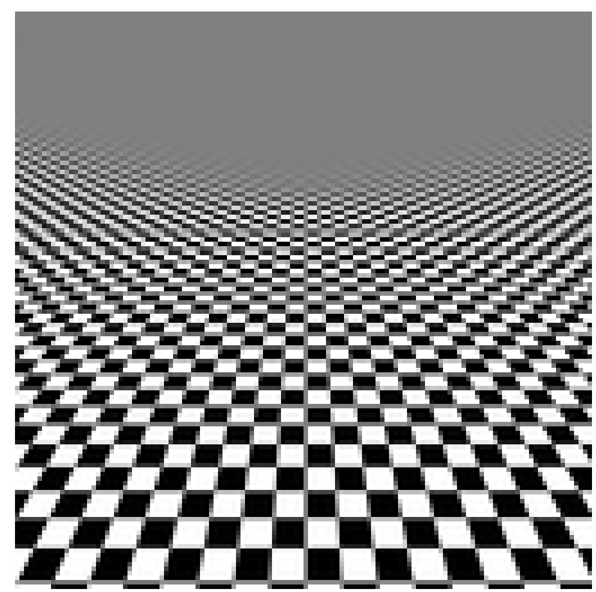
Aliasing





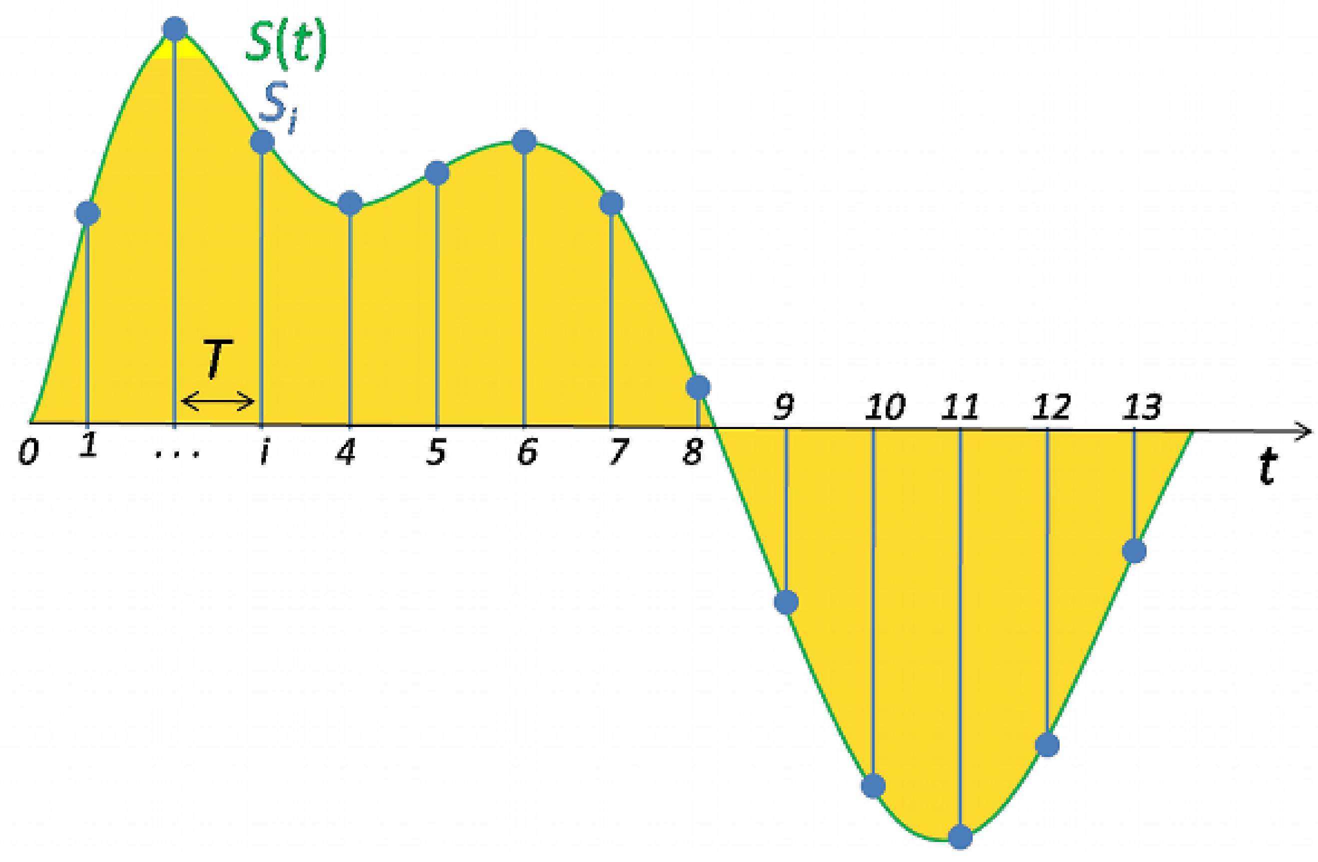
Antialiasing





Basic Ideas in Sampling Theory

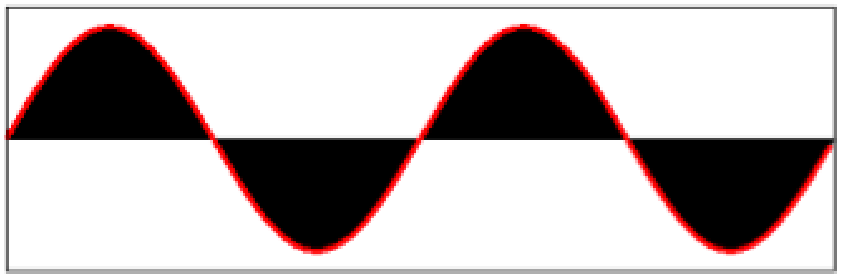
- *Sampling* a signal: Analog → Digital conversion by reading the value at discrete points



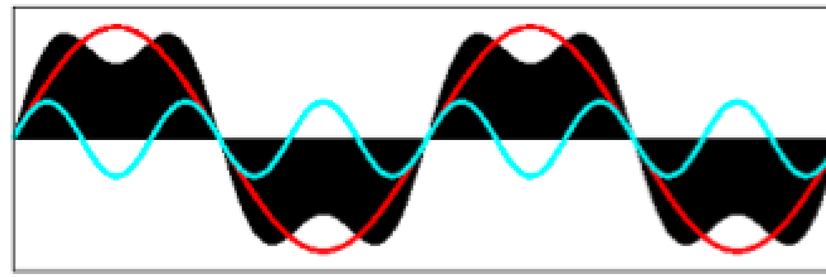
(Wikipedia)

Basic Ideas in Sampling Theory

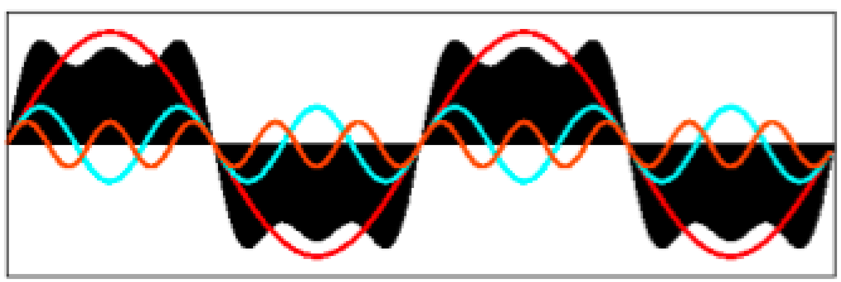
- A signal can be decomposed into components of various *frequencies* (e.g. Fourier Transform)



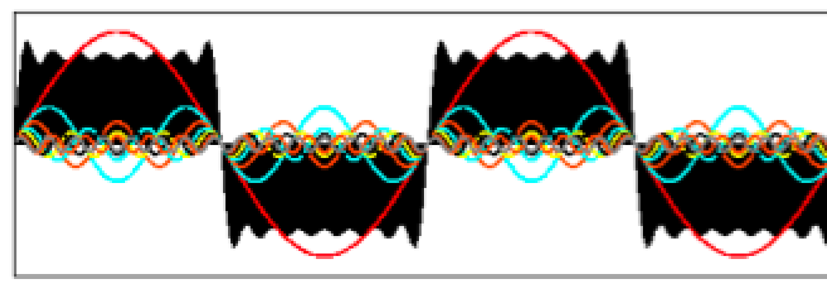
Frequencies: f



Frequencies: $f + 3f$



Frequencies: $f + 3f + 5f$

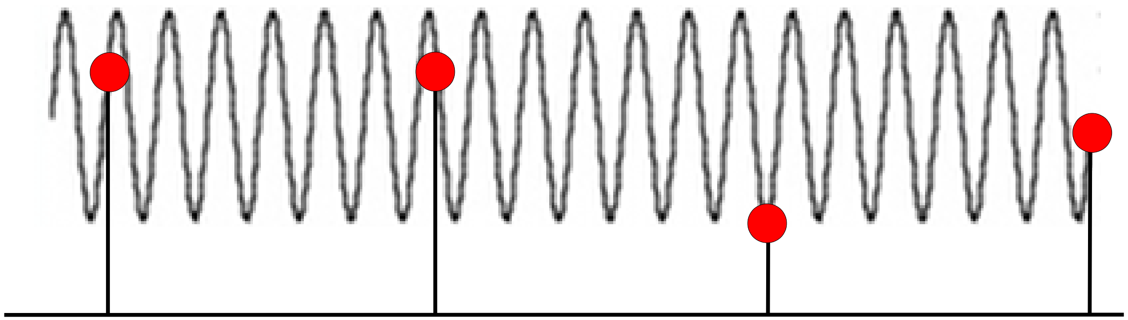


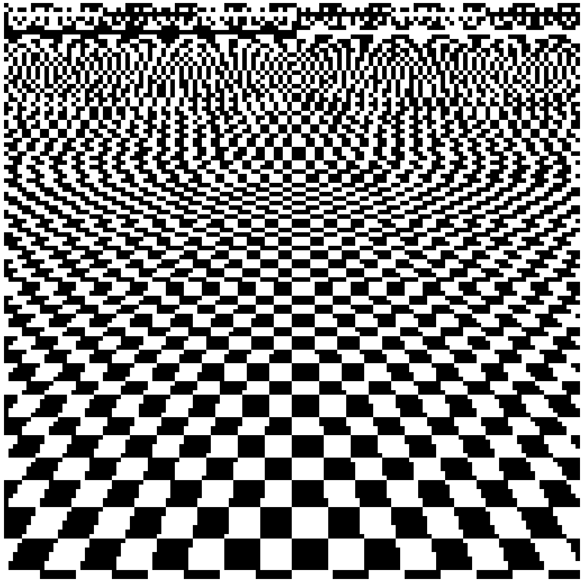
Frequencies: $f + 3f + \ldots + 15f$

Fourier decomposition of square wave (Mark Handley)

What Causes Aliasing?

- Sampling rate is too low to capture high-frequency variation





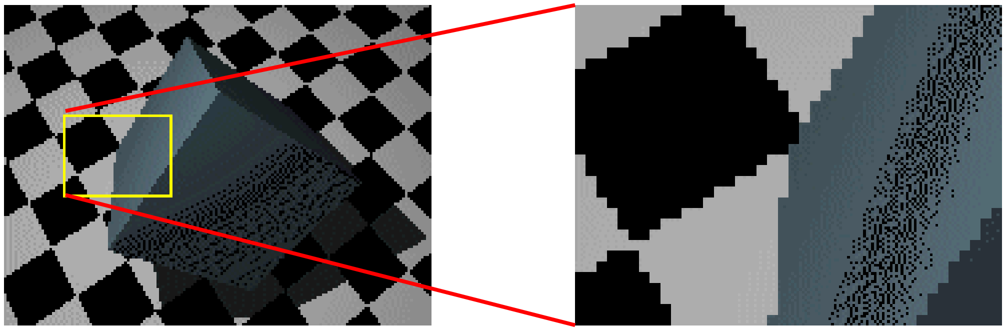
Nyquist-Shannon Sampling Theorem

- If a signal
  - has no component with frequency higher than B, and
  - is discretely sampled with frequency at least $2B$
- … then it can (in theory) be perfectly reconstructed!

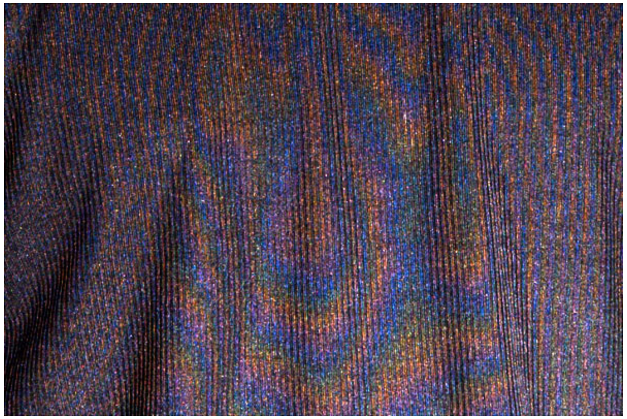
- Given a system that takes discrete samples at frequency v (e.g. the pixels on a display), the *Nyquist frequency* of the system is $v / 2$
  - = highest frequency detail the system can resolve

Manifestations of Aliasing

- Jagged edges on rendered shapes



- Moiré in digital cameras

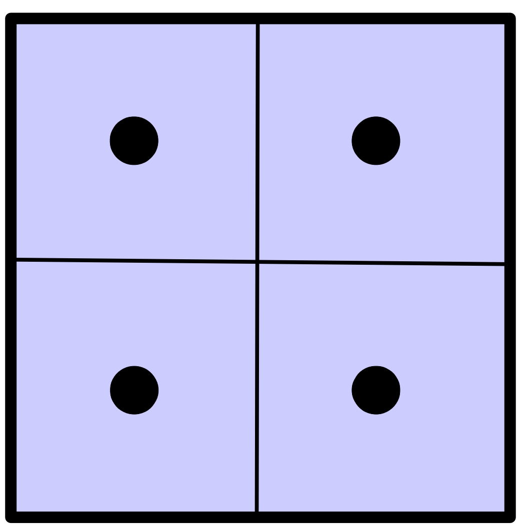

(Wikipedia, dpreview.com, dpanswers.com)

Removing Aliasing (Antialiasing)

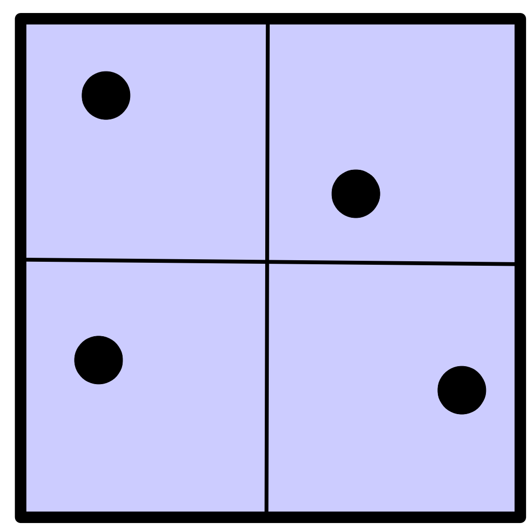
- *Prefiltering:* Compute low-frequency version from continuous representation, then discretize
  - e.g. compute amount of pixel coverage from geometric equation of shape
  - e.g. antialiasing filter in front of digital camera sensors, to reduce moiré etc.
- *Postfiltering:* Oversample continuous signal, then filter to remove high-frequency components
  - e.g. supersampling in a raytracer
- Lots of tradeoffs, beyond scope of course

Supersampling

- Render multiple samples for each pixel
  - For a raytracer, this is a particular case of distribution raytracing
- Compute (weighted) average of samples



Regular grid



Jittered grid

No Antialiasing

(nhancer.com)

Antialiasing with 16 Samples Per Pixel

(nhancer.com)