The Digital Image



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The Image as a Digital Signal

- Both computer graphics and photography create a discretized representation of a continuous light signal:
  - Photography: Continuous Incident light →Sensor→Raster
  - CG: Mathematical geometry representation →Raster

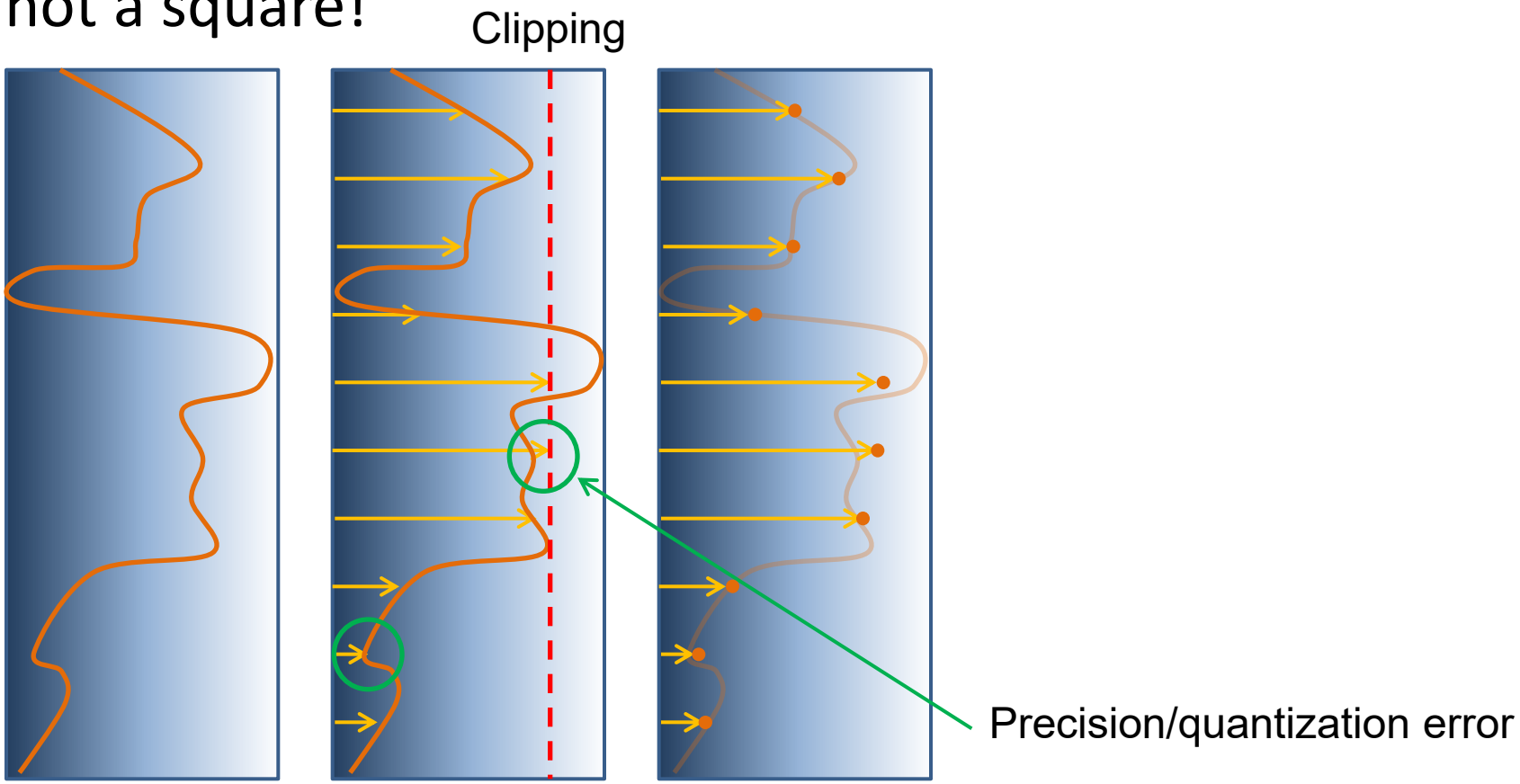


The Image as a Digital Signal

- The digital image signal generation suffers from all digitization problems:
  - Aliasing
  - Quantization errors
- Both digital photography and photorealistic rendering can also suffer from noise
  - Different in nature: statistical vs thermal

The Pixel

- The pixel represents a single sample in the image, not a square!



The Pixel (2)

- The sampling rate in an image is determined by the image resolution vs (physical) image size
  - Denser sampling (higher resolution) can correctly capture higher image detail
  - There is **always** a limit of what a specific resolution can correctly represent (see Nyquist criterion next)
  - E.g. doubling the resolution will only mitigate the problem to a higher image frequency

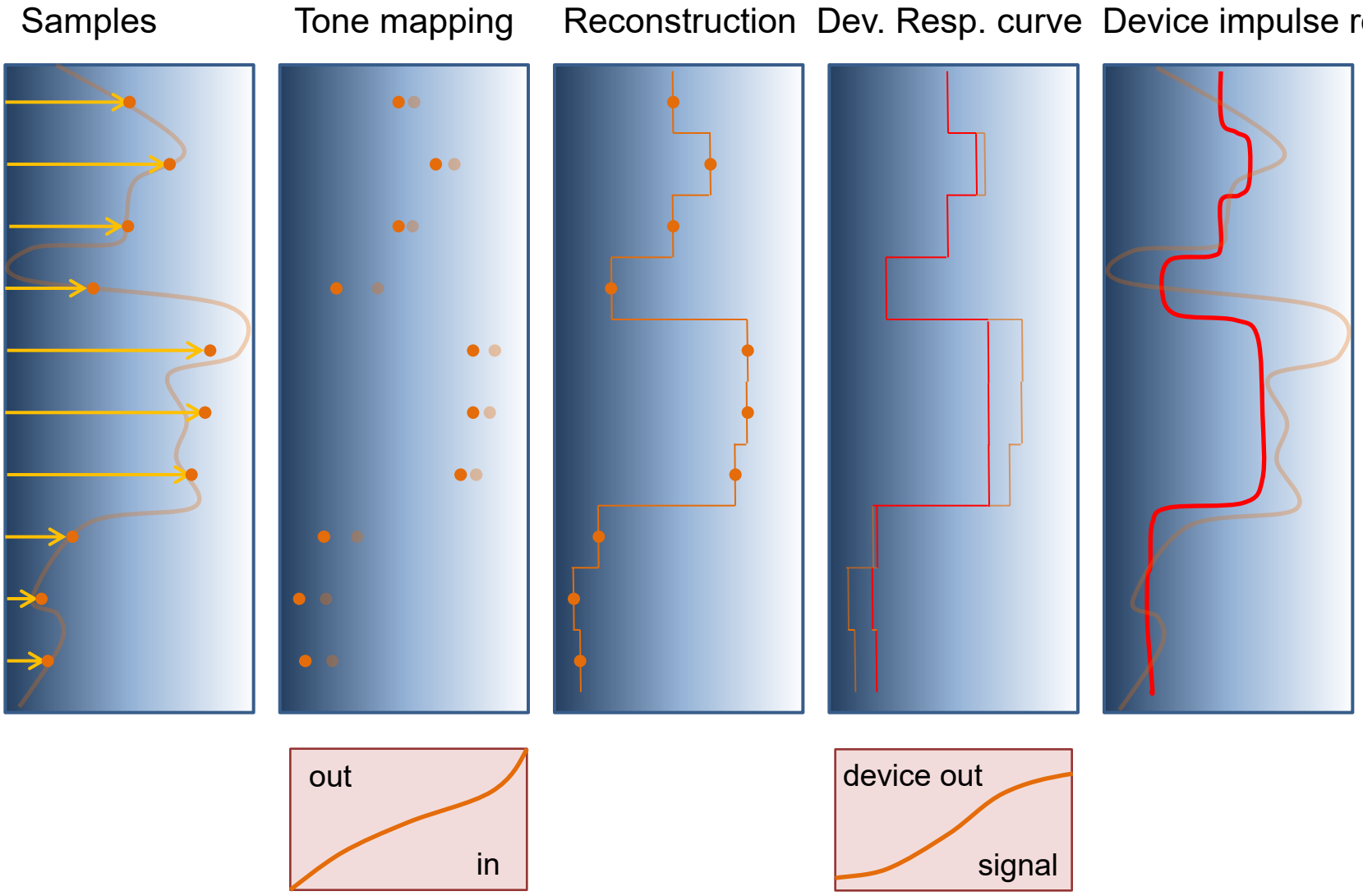
The Pixel (3)

- Roughly speaking, we can correctly reconstruct (see) a repeating variation in intensity with a (sine) period of 2 pixels or more
- Faster intensity changes cannot be systematically and correctly sampled, leading to **aliasing** and noise
- To alleviate this, we purposefully **limit the frequency** (detail) of the input signal to match our sampling capabilities

The Pixels We See

- In order to perceive the color of an image, we have to go through a reconstruction of an analog intensity from the samples. This involves:
  - A reconstruction filter → obtain a continuous signal
  - A tone mapping stage → adjust intensity to actual displayable range
  - The device's response curve → translates nominal intensities to actual light
  - The device's spatiotemporal impulse response → spreads intensity over screen surface and time

The Pixels We See (2)



Reconstruction Filters

- “Spread” isolated discrete samples to form an analog signal
- Try to rectify the original signal



Nearest neighbor
(piecewise constant)



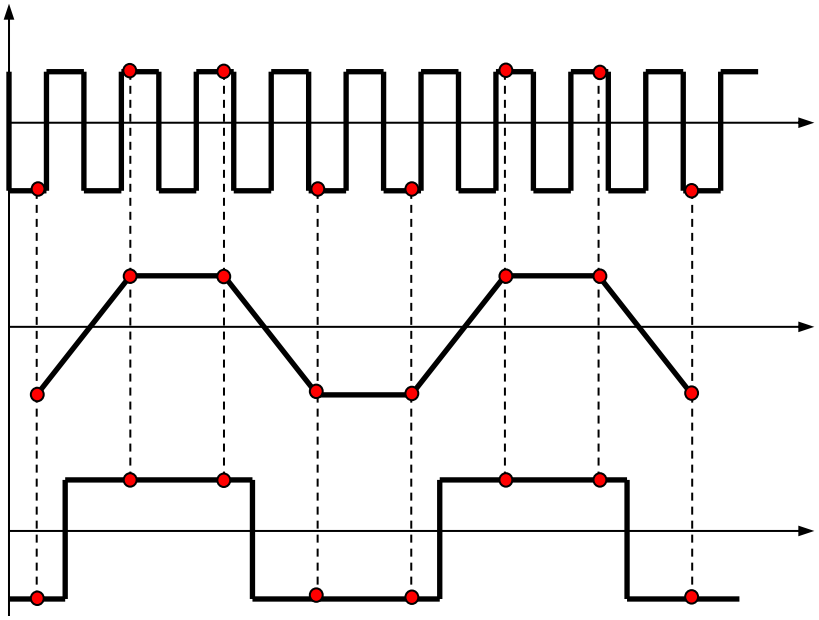
Bilinear



Bicubic

Aliasing

- Aliasing is the miss-interpretation of the samples as a different signal than the original during the reconstruction



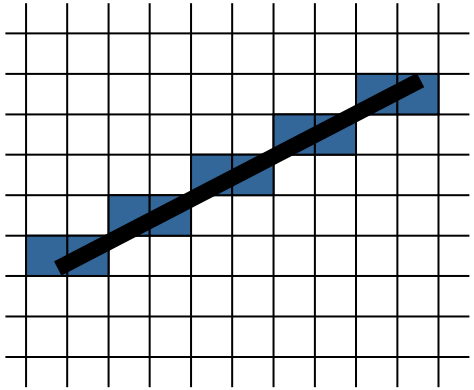
Major Aliasing Cases in Graphics

- Image-space
  - Geometry aliasing
    - Erratic and discontinuous sampling of boundaries and thin structures (“juggies”, holes)
  - Texture aliasing
- Temporal aliasing
  - Unutural apparent motion

Geometric Aliasing

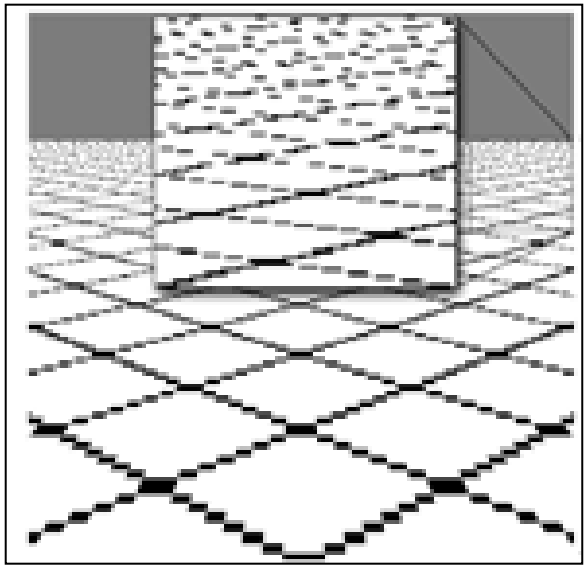
- Erratic and discontinuous sampling of boundaries and thin structures (holes, noise)
- Sampling of smooth structures at regular locations (“juggies”)





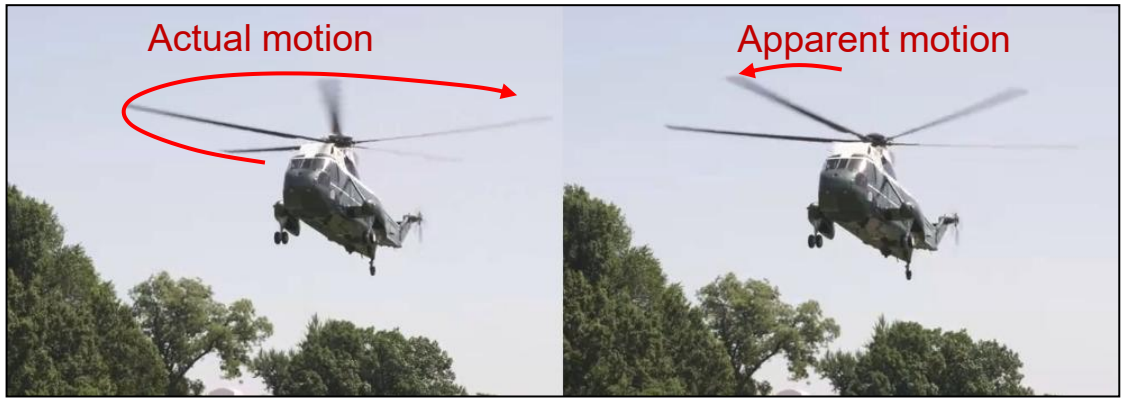
Texture Aliasing

- Textures are images themselves or procedural patterns for modifying the appearance of geometry
- These are signals, too
- Sampling them at an inadequate rate in image space, produces significant aliasing
- Manifested as:
  - Noise
  - Irregular patterns
  - Both change erratically with motion



Temporal Aliasing

- Temporal aliasing occurs usually in fast motion
- Frame rate is inadequate to capture the motion frequency (happens to the HVS as well)
- We usually confuse the motion with another



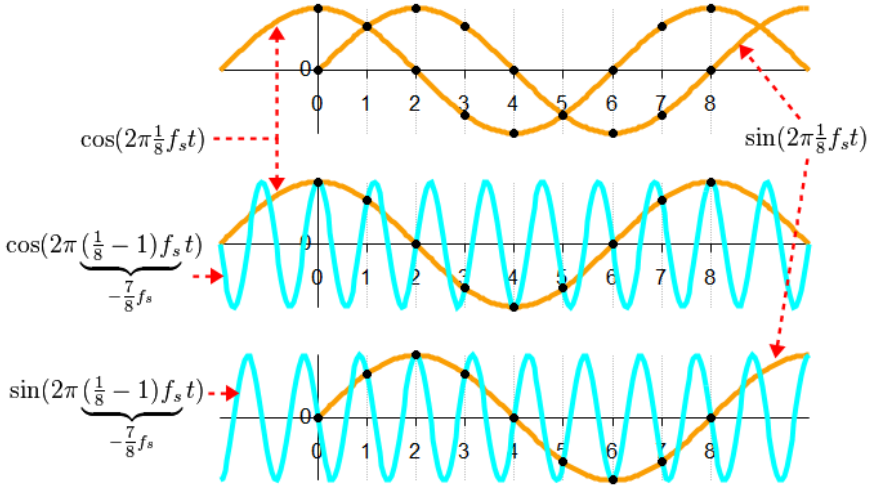




Image source: Wikipedia

Contributors

- Georgios Papaioannou

- Sources:
  - Wikipedia
  - T. Theoharis, G. Papaioannou, N. Platis, N. M. Patrikalakis, Graphics & Visualization: Principles and Algorithms, CRC Press