CSE 167:
Introduction to Computer Graphics
Lecture #7: Textures

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Announcements

- Project 2 due Friday, Oct. 24^{th}
- Midterm Exam Thursday, Oct. 30^{th}
- After class: solar eclipse!

Example

Rendered by Byungil Jeong, EVL

Video

- **OpenGL – Texture**
  - http://www.youtube.com/watch?v=zBF0dxEuIKE

Lecture Overview

- Texture Mapping
  - Wrapping
  - Texture coordinates
  - Anti-aliasing

Texture Coordinates

What if texture extends across multiple polygons?

→ Surface parameterization

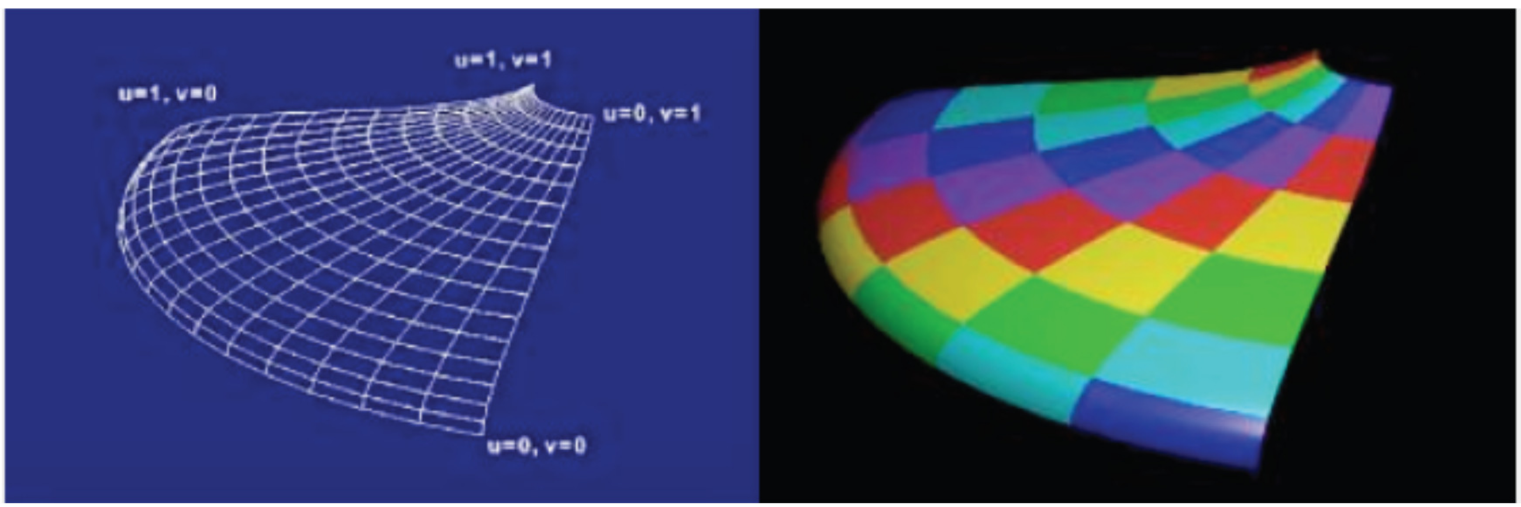
- Mapping between 3D positions on surface and 2D texture coordinates
  - Defined by texture coordinates of triangle vertices
- Options for mapping:
  - Parametric
  - Orthographic
  - Projective
  - Spherical
  - Cylindrical
  - Skin

Parametric Mapping

- Surface given by parametric functions

$$x = f(u, v) \quad y = f(u, v) \quad z = f(u, v)$$

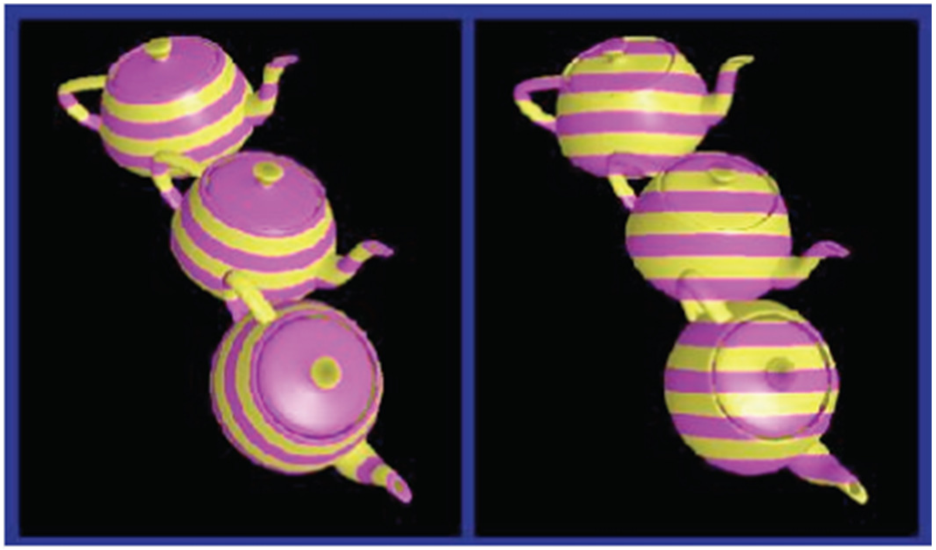
- Very common in CAD
- Clamp (u,v) parameters to [0..1] and use as texture coordinates (s,t)



Orthographic Mapping

- Use linear transformation of object's xyz coordinates
- Example:

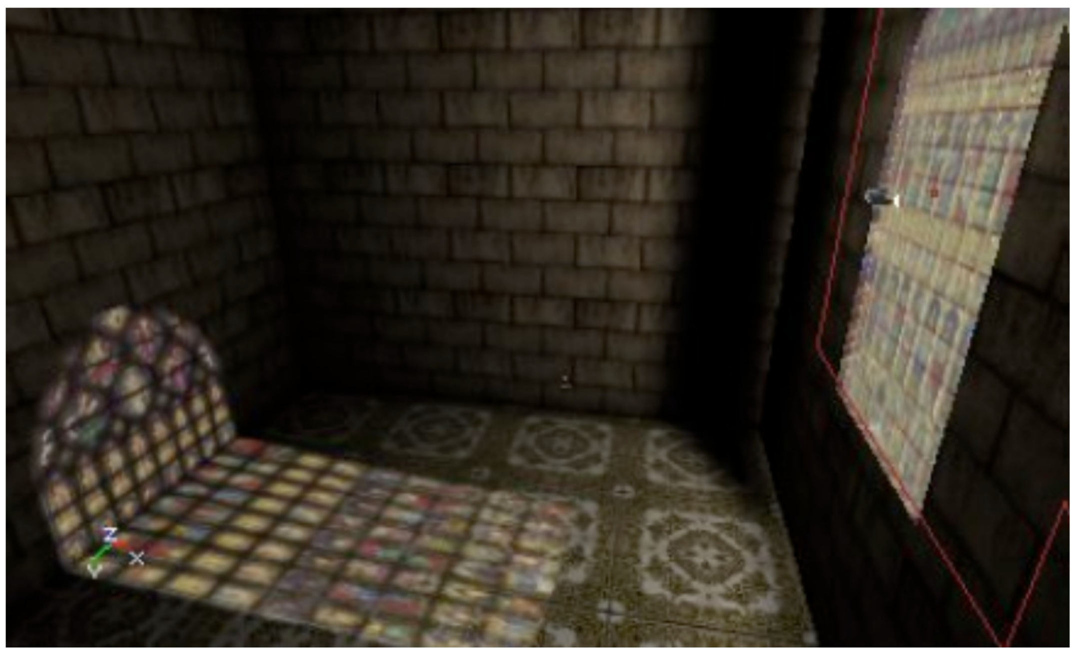
$$\begin{bmatrix} s \\ t \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ w \end{bmatrix}$$



xyz in object space *xyz in camera space*

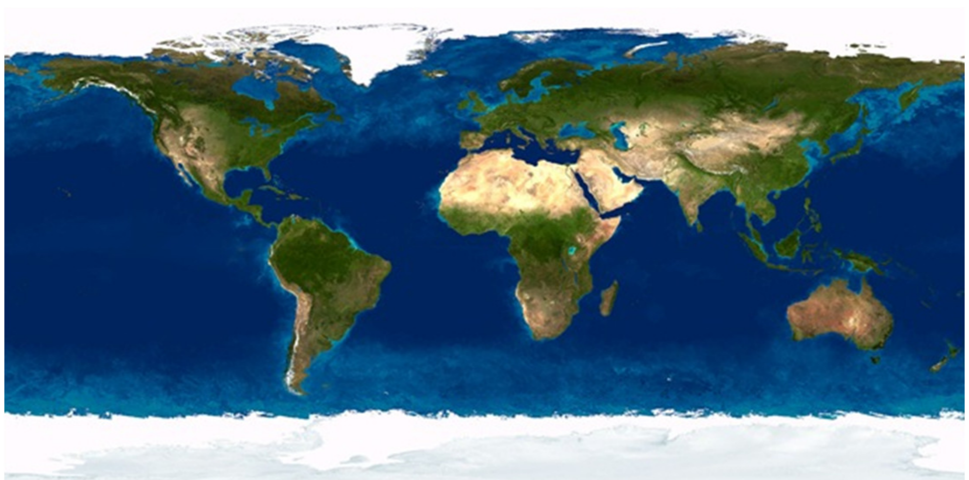
Projective Mapping

- Use perspective projection of xyz coordinates
  - OpenGL provides GL_TEXTURE matrix to apply on texture coordinates
- Can be used for “fake” lighting effects



Spherical Mapping

- Use spherical coordinates
- "Shrink-wrap" sphere to object

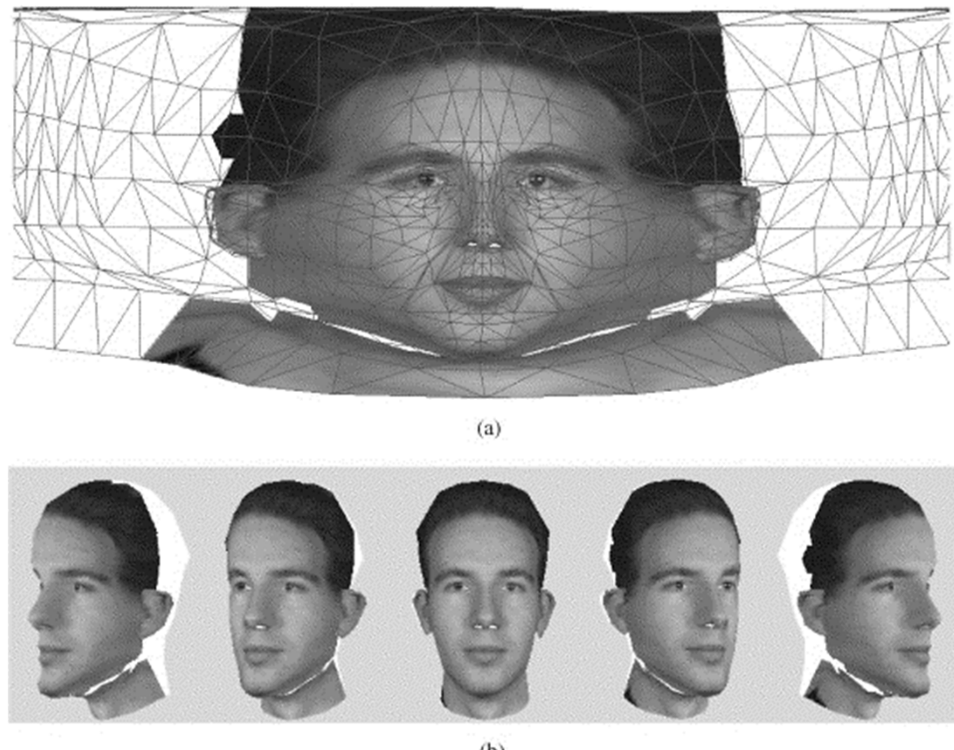


Texture map

Mapping result

Cylindrical Mapping

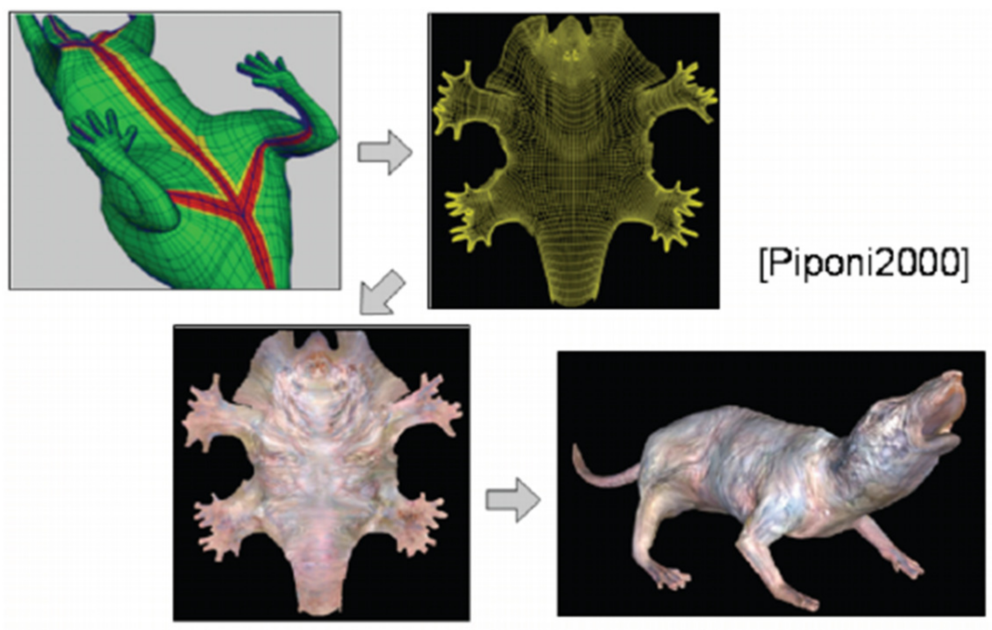
- Similar to spherical mapping, but with cylindrical coordinates
- Useful for faces



Source: "Facial model adaptation from a monocular image sequence using a textured polygonal model", Chang et al. 2002

Skin Mapping

- Complex technique to unfold surface onto plane
- Unfolding mathematics must be done backwards when texture mapping



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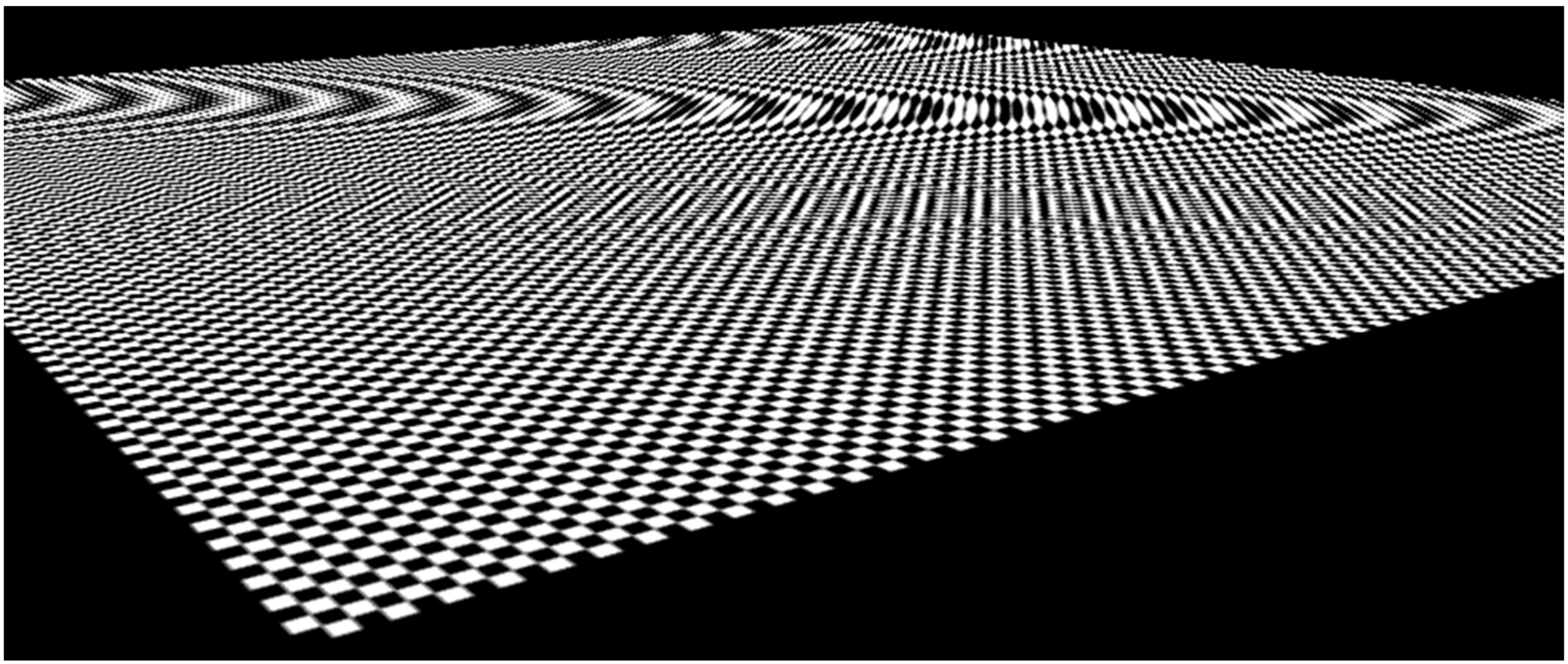
Lecture Overview

- Texture Mapping
  - Wrapping
  - Texture coordinates
  - Anti-aliasing

Aliasing

- What could cause this aliasing effect?



Aliasing

Sufficiently sampled, no aliasing

Insufficiently sampled, aliasing

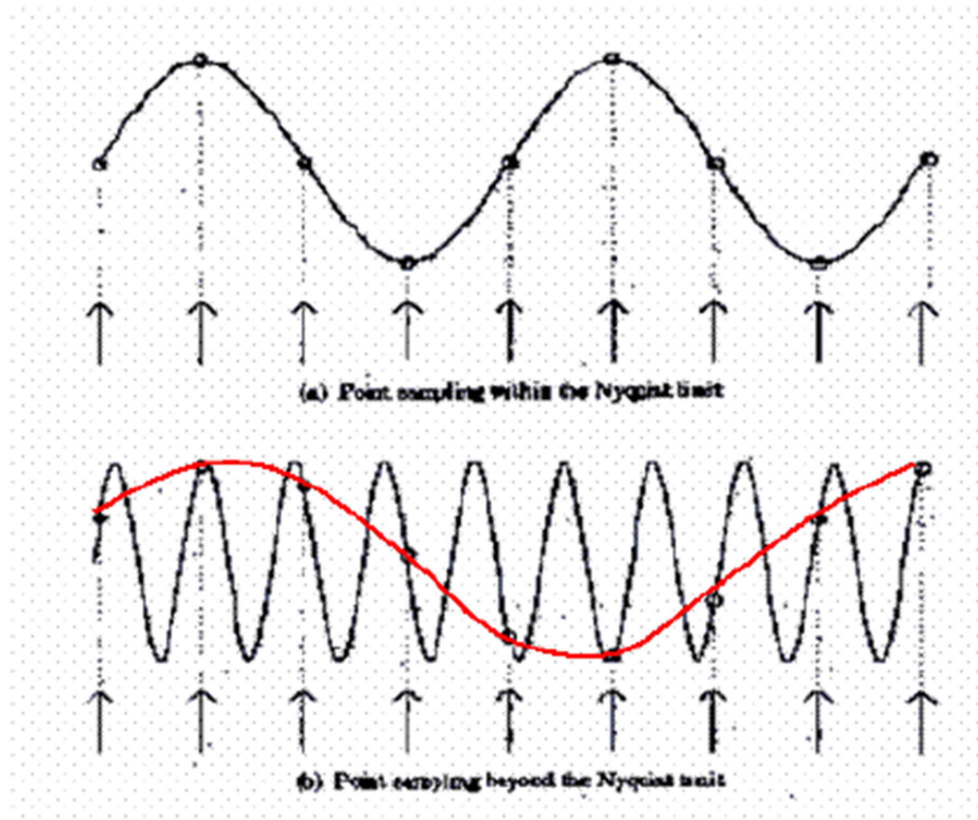
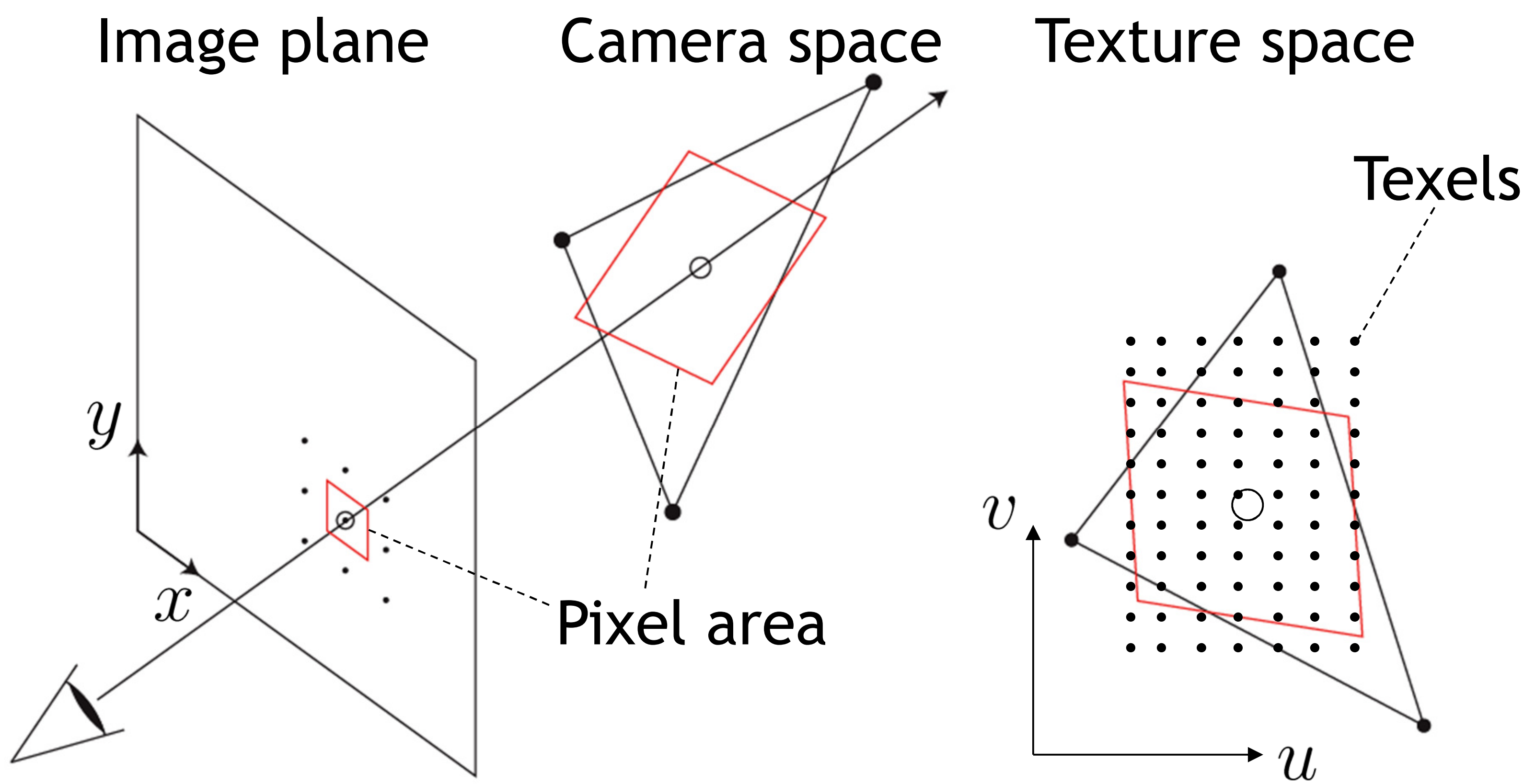


Image: Robert L. Cook

High frequencies in the input data can appear as lower frequencies in the sampled signal

Antialiasing: Intuition

- Pixel may cover large area on triangle in camera space
- Corresponds to many texels in texture space
- Need to compute average



Lecture Overview

- Texture Mapping
  - Mip Mapping

Antialiasing Using Mip-Maps

- Averaging over texels is expensive
  - Many texels as objects get smaller
  - Large memory access and compuation cost
- Precompute filtered (averaged) textures
  - Mip-maps
- Practical solution to aliasing problem
  - Fast and simple
  - Available in OpenGL, implemented in GPUs
  - Reasonable quality

Mipmaps

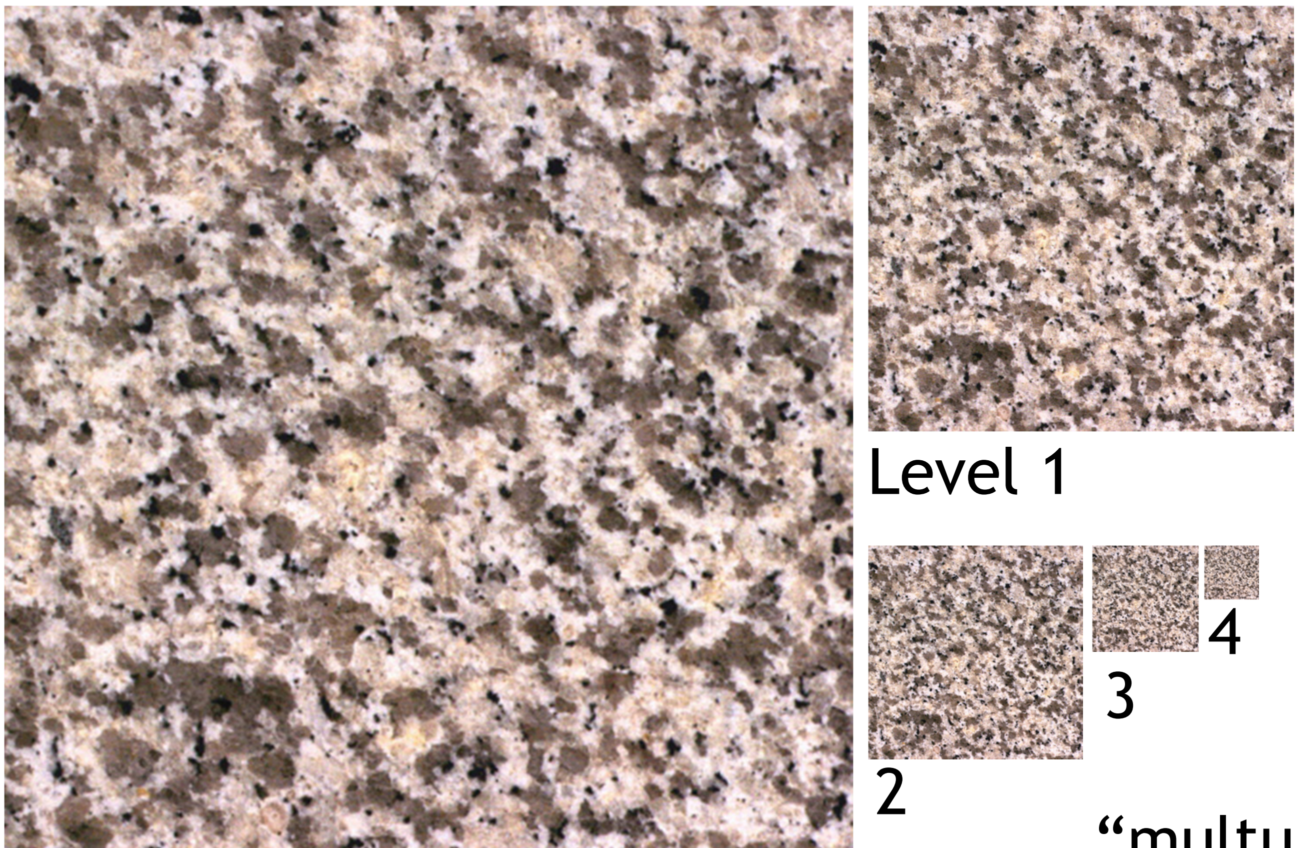
- MIP stands for *multum in parvo* = *"much in little"* (Williams 1983)

Before rendering

- Pre-compute and store down scaled versions of textures
  - Reduce resolution by factors of two successively
  - Use high quality filtering (averaging) scheme
- Increases memory cost by 1/3
  - 1/3 = ¼+1/16+1/64+…
- Width and height of texture should be powers of two (non-power of two supported since OpenGL 2.0)

Mipmaps

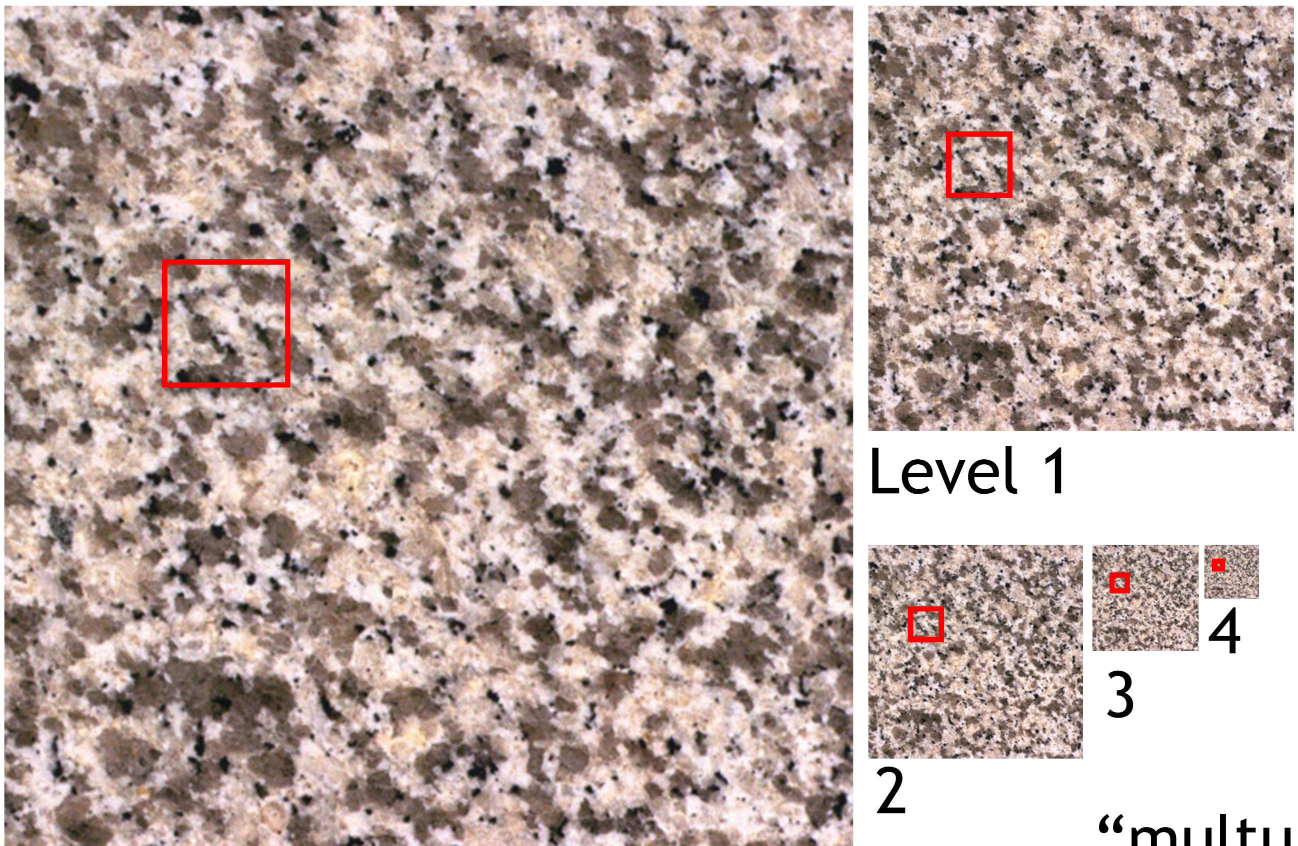
- Example: resolutions 512x512, 256x256, 128x128, 64x64, 32x32 pixels



"multum in parvo"

Mipmaps

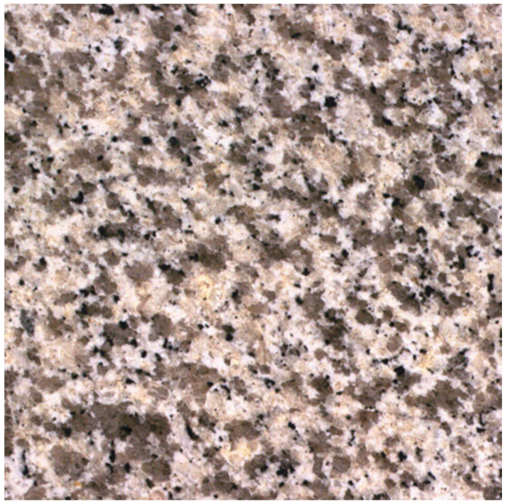
- One texel in level 4 is the average of 4^4=256 texels in level 0



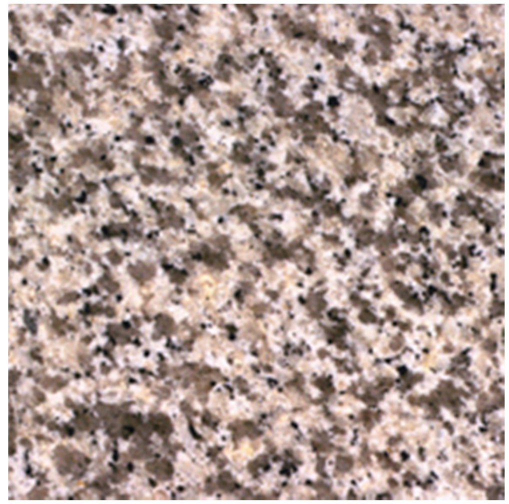
Level 0

"multum in parvo"

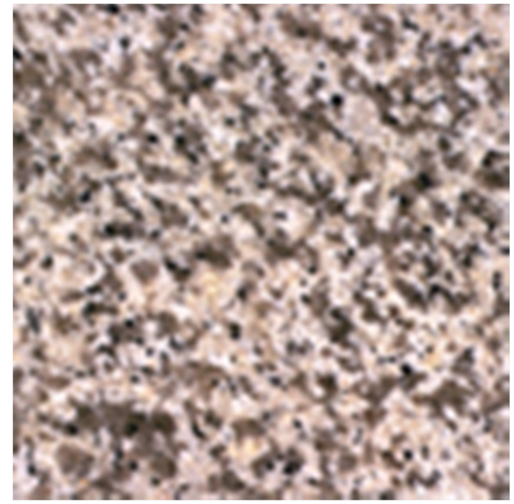
Mipmaps



Level 0



Level 1



Level 2

Level 3

Level 4

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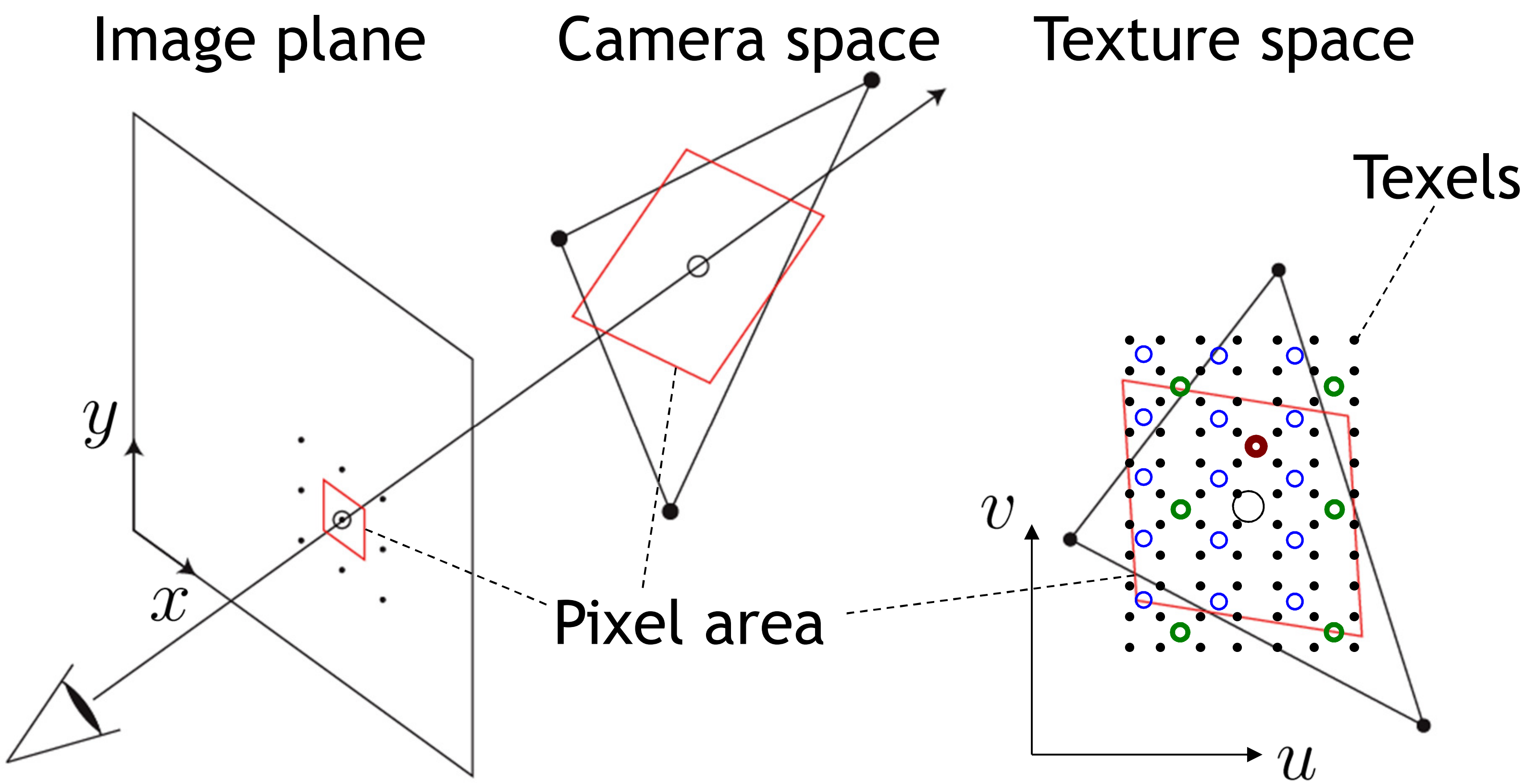
Rendering With Mipmaps

- "Mipmapping"
- Interpolate texture coordinates of each pixel as without mipmapping
- Compute approximate size of pixel in texture space
- Look up color in nearest mipmap
  - E.g., if pixel corresponds to 10x10 texels use mipmap level 3
  - Use nearest neighbor or bilinear interpolation as before

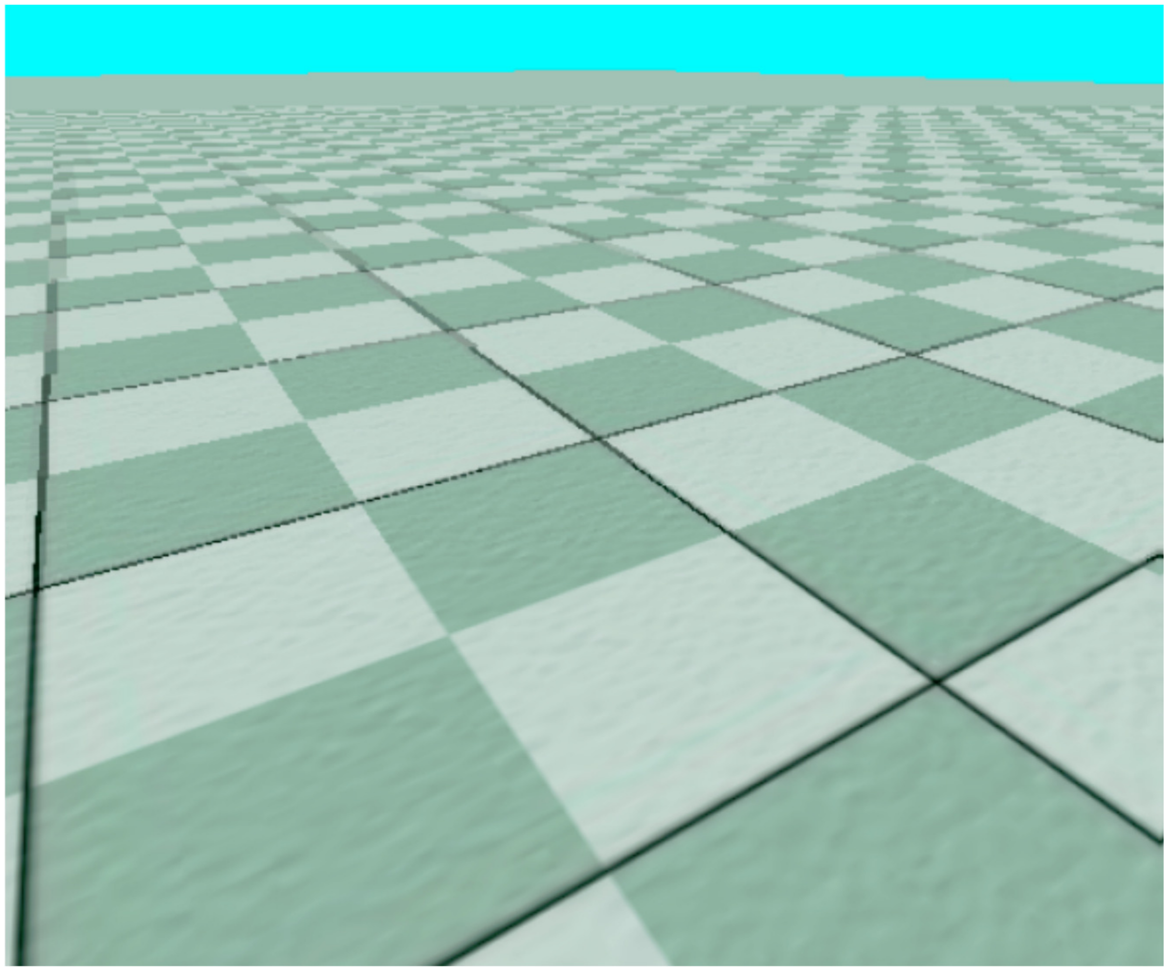
Mipmapping



- Mip-map level 0
- Mip-map level 1
- Mip-map level 2
- Mip-map level 3

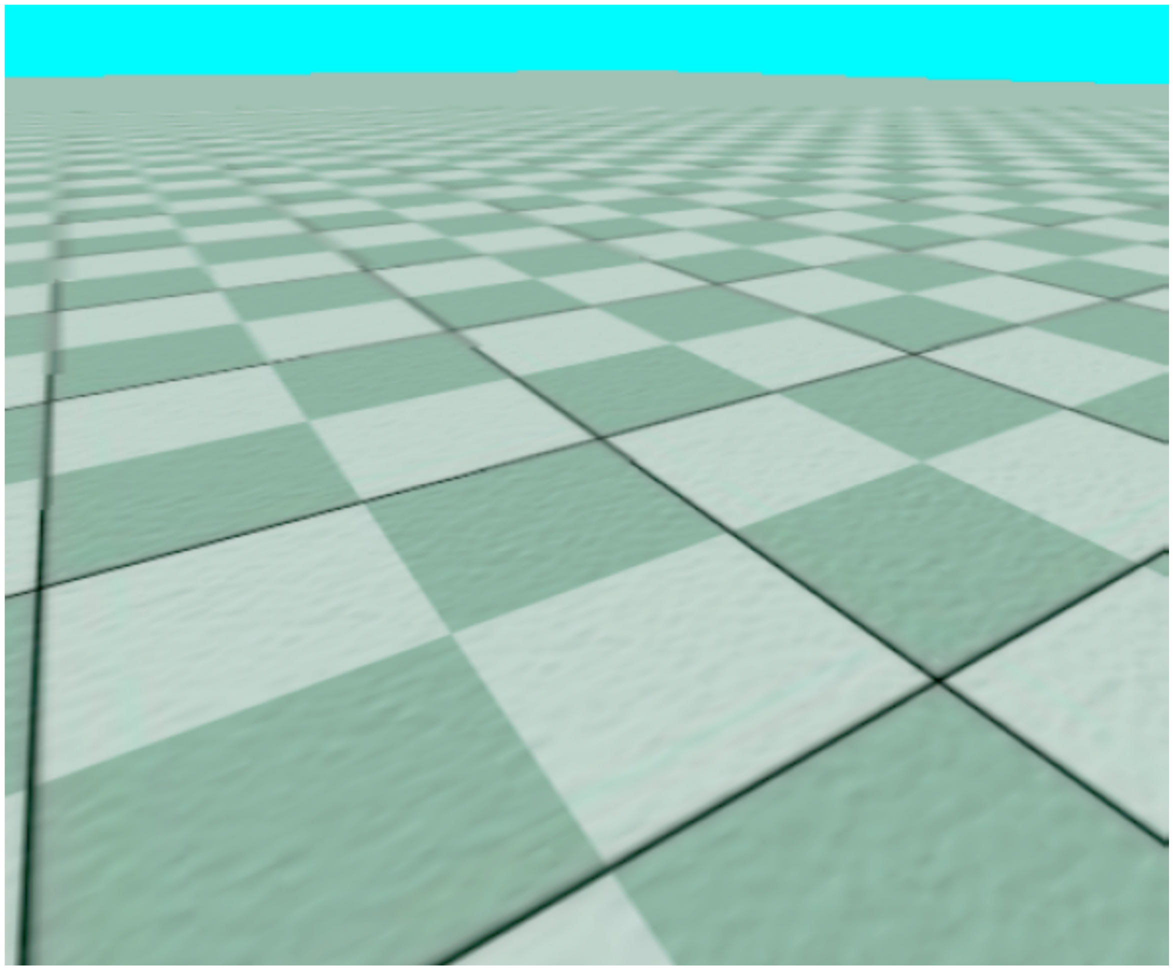
Nearest Mipmap, Nearest Neighbor

- Visible transition between mipmap levels



Nearest Mipmap, Bilinear

- Visible transition between mipmap levels



Trilinear Mipmapping

- Use two nearest mipmap levels
  - E.g., if pixel corresponds to 10x10 texels, use mipmap levels 3 (8x8) and 4 (16x16)
- 2-Step approach:
  - Step 1: perform bilinear interpolation in both mip-maps
  - Step 2: linearly interpolate between the results
- Requires access to 8 texels for each pixel
- Supported by hardware without performance penalty

More Info

- Mipmapping tutorial w/source code:
  - http://www.videotutorialsrock.com/opengl_tutorial/mipmapping/text.php

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