From ACM SIGGRAPH 2013 Animation Festival Program

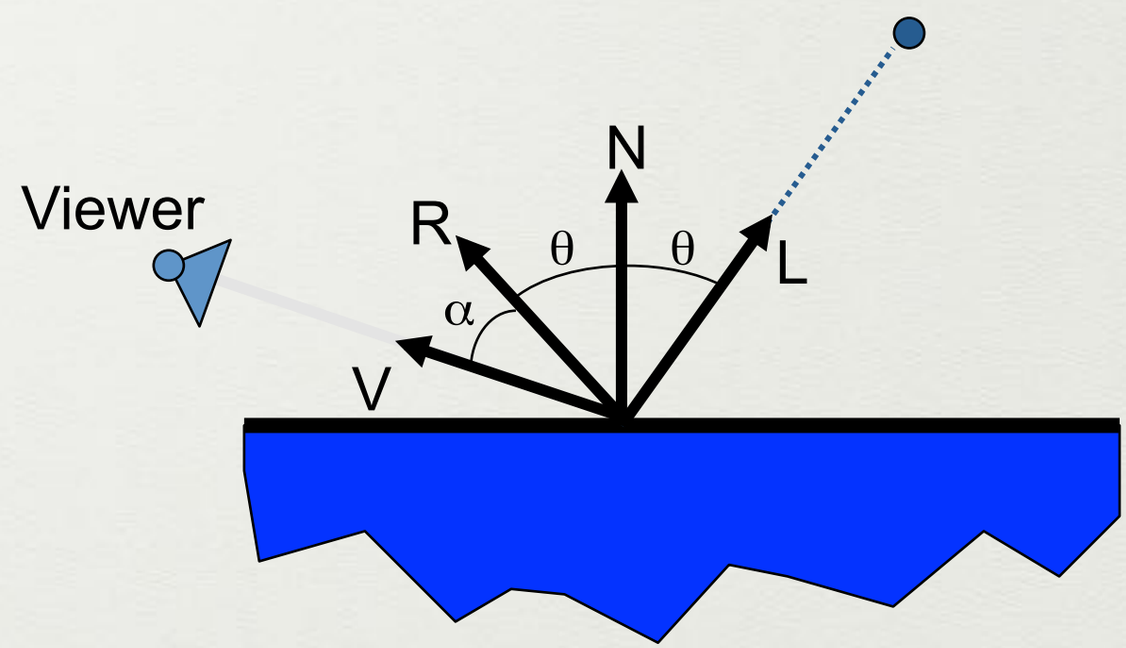
COMPUTER GRAPHICS

Class 22 - Texturing

Recap

$$I = k_{ambient} I + \sum_{i=1}^{light\#} \left(k_{diffuse} I (n \cdot l) + k_{specular} I (v \cdot r)^{n_{shiny}} \right)$$

- Phong Lighting Model
  - Ambient Reflection
  - Diffuse Reflection
  - Specular Reflection
- Light Source Model
- Point lights vs. Area lights



Review

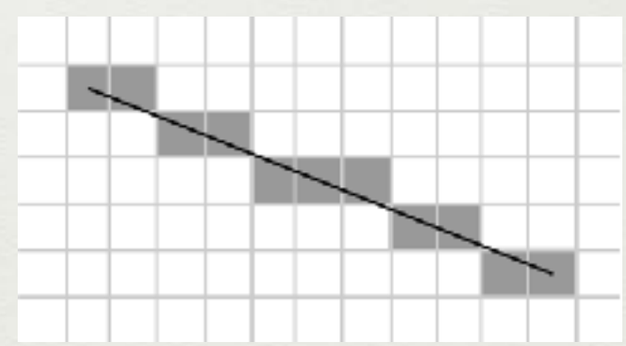
Lighting Model Computation - Flat Shading

Points in (x,y,z)

World -> View -> Projected -> Normalized

A Line

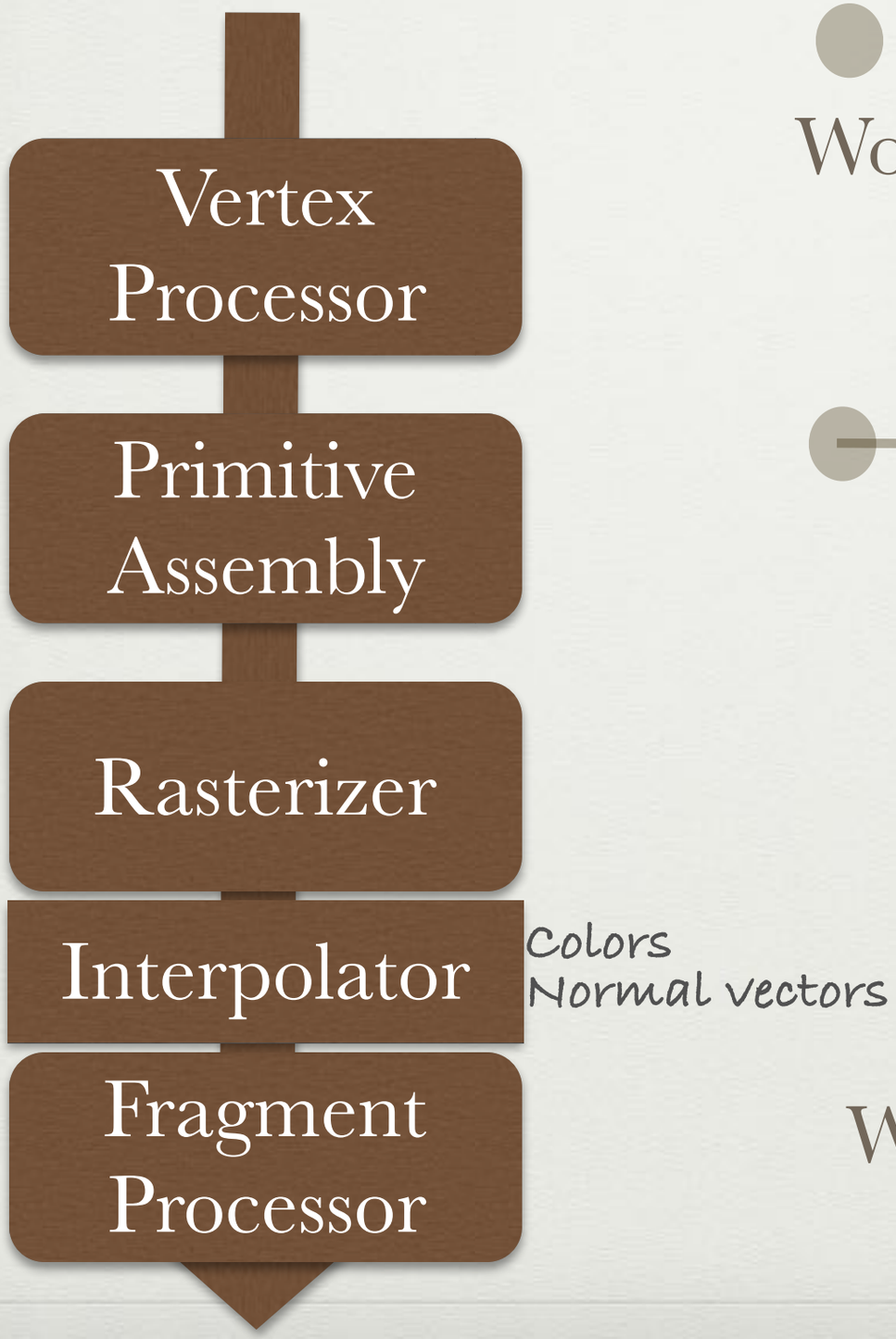
Backface Culling



Z-Buffer/Z-Test

Write to the Frame Buffer

Lighting Model Computation

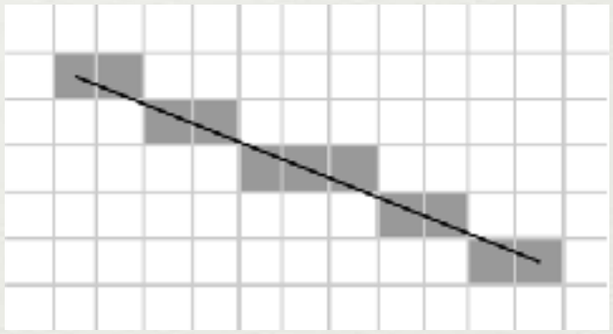


Points in (x,y,z)

World -> View -> Projected -> Normalized

A Line

Backface Culling



Z-Buffer/Z-Test

Write to the Frame Buffer

Introduction

- To give a color on a surface
  - Material
    - Colors for ambient/diffuse/specular reflection
    - Why?
  - Interpolation based coloring

Introduction

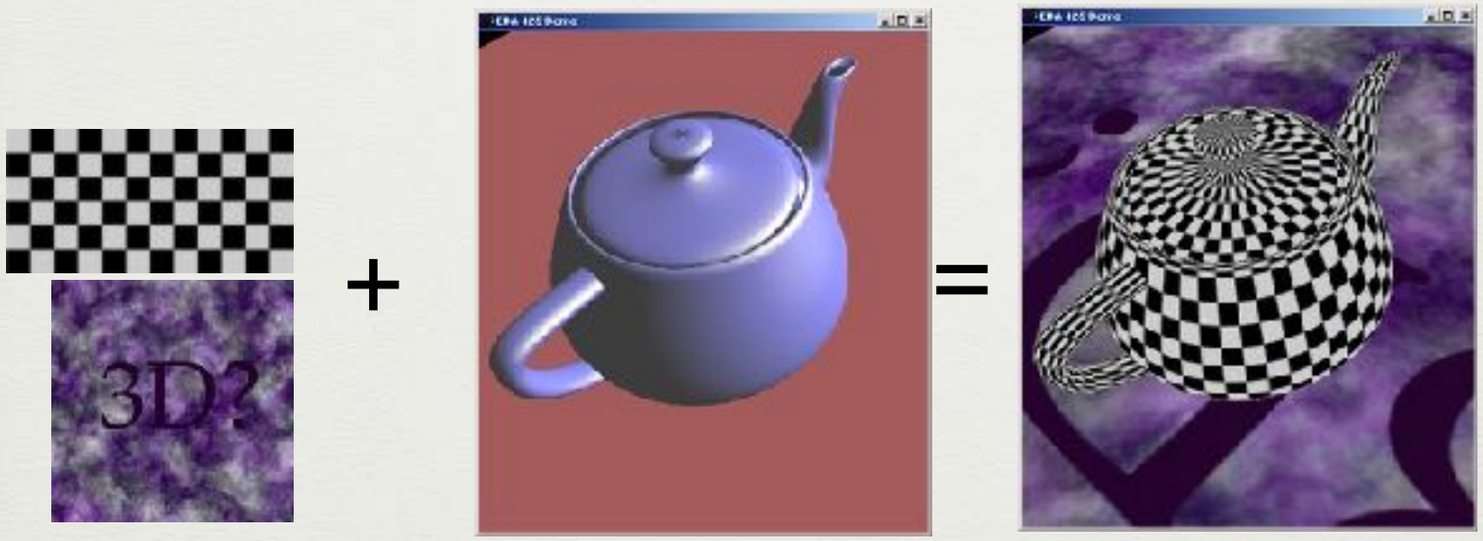
- How to represent complex color?

Introduction

- What to be represented?
  - Complex color distribution - not possible to interpolate
  - Illumination effects

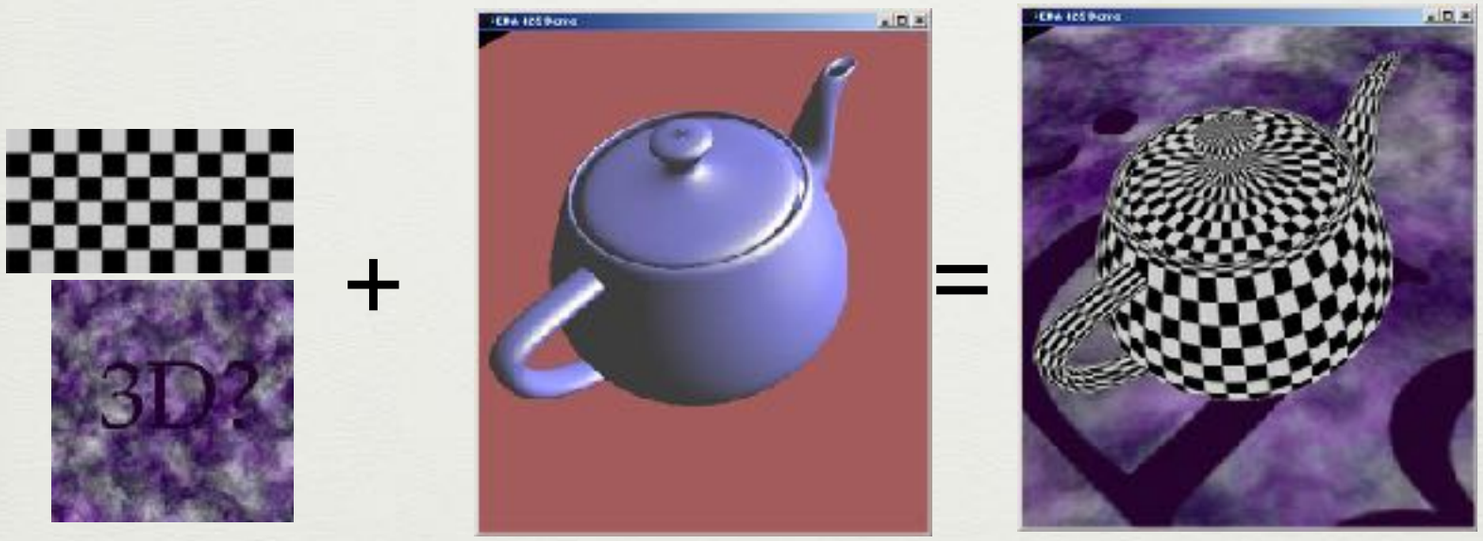
Introduction

- Represent complex color distribution
  - Glueing approach: Texture mapping



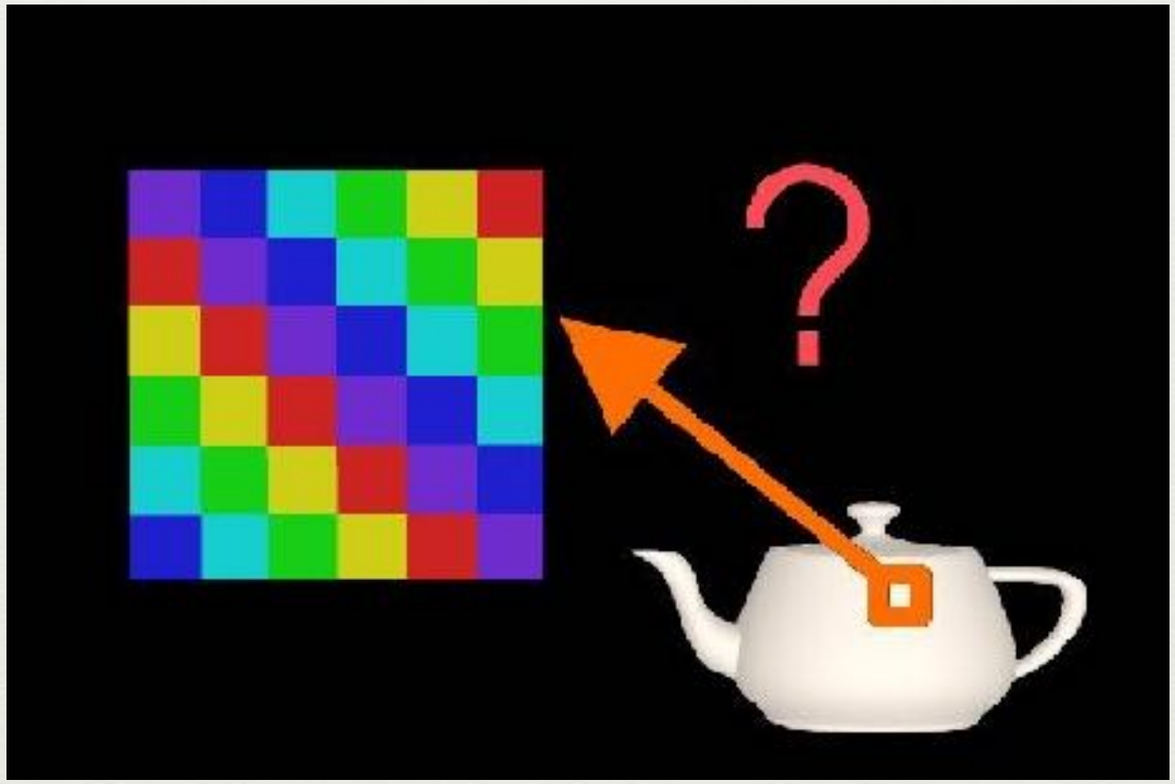
Texture Mapping

- Glueing process of an image to a surface



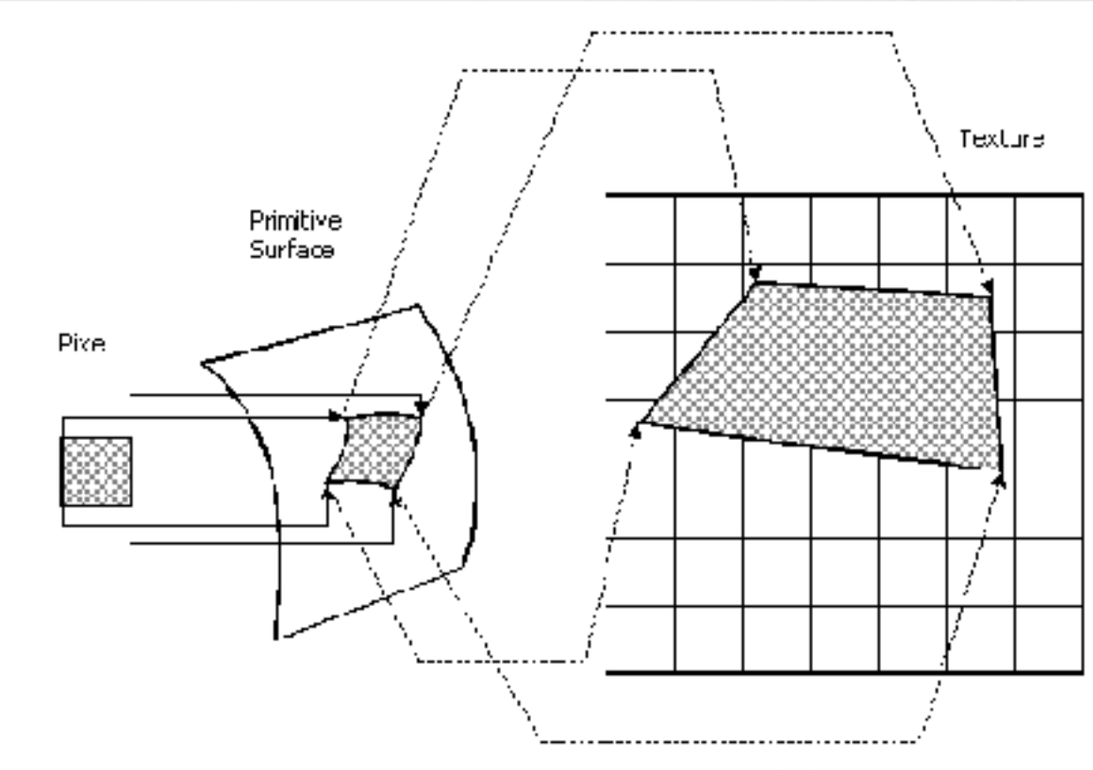
Texture

- An image to be glued
- Defines color distribution on a surface



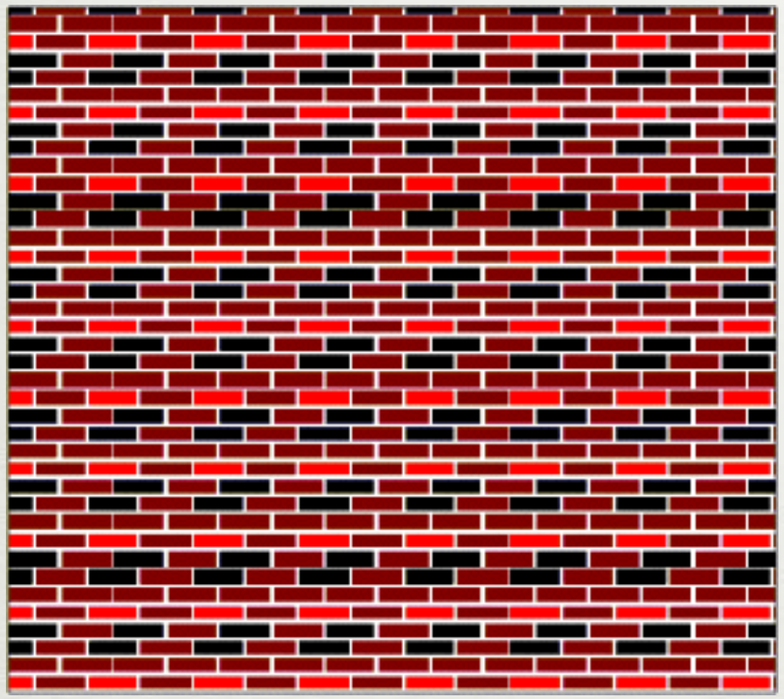
Texture Map

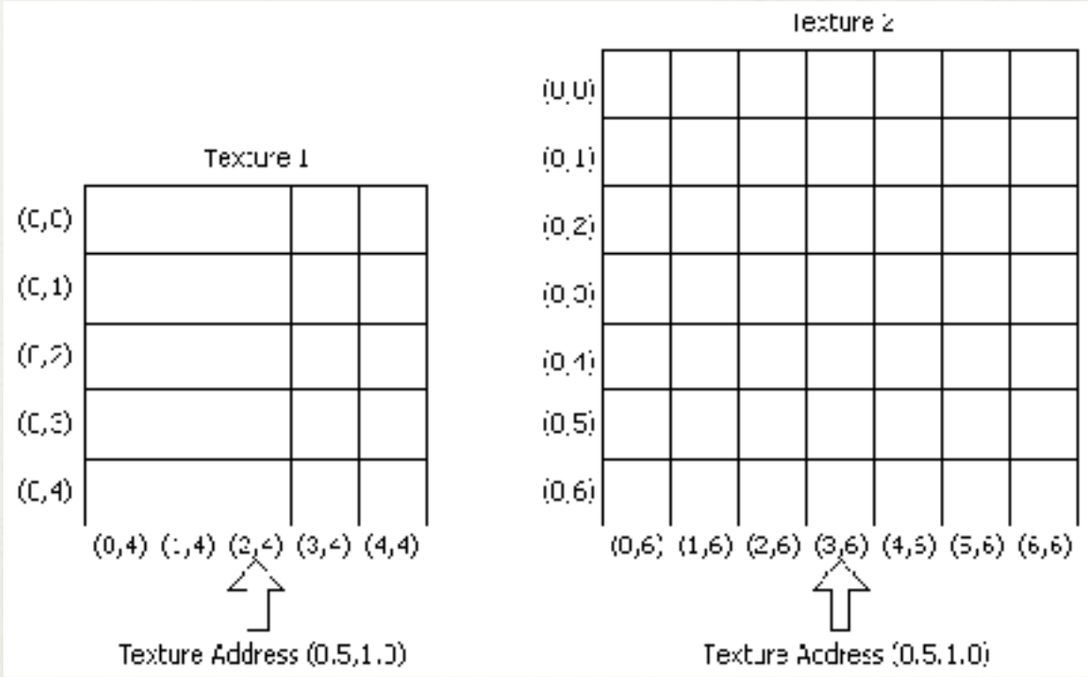
- Definition of ‘mapping’ from texture space to surface
- To decide a color of the pixel from the texture
- What to know?



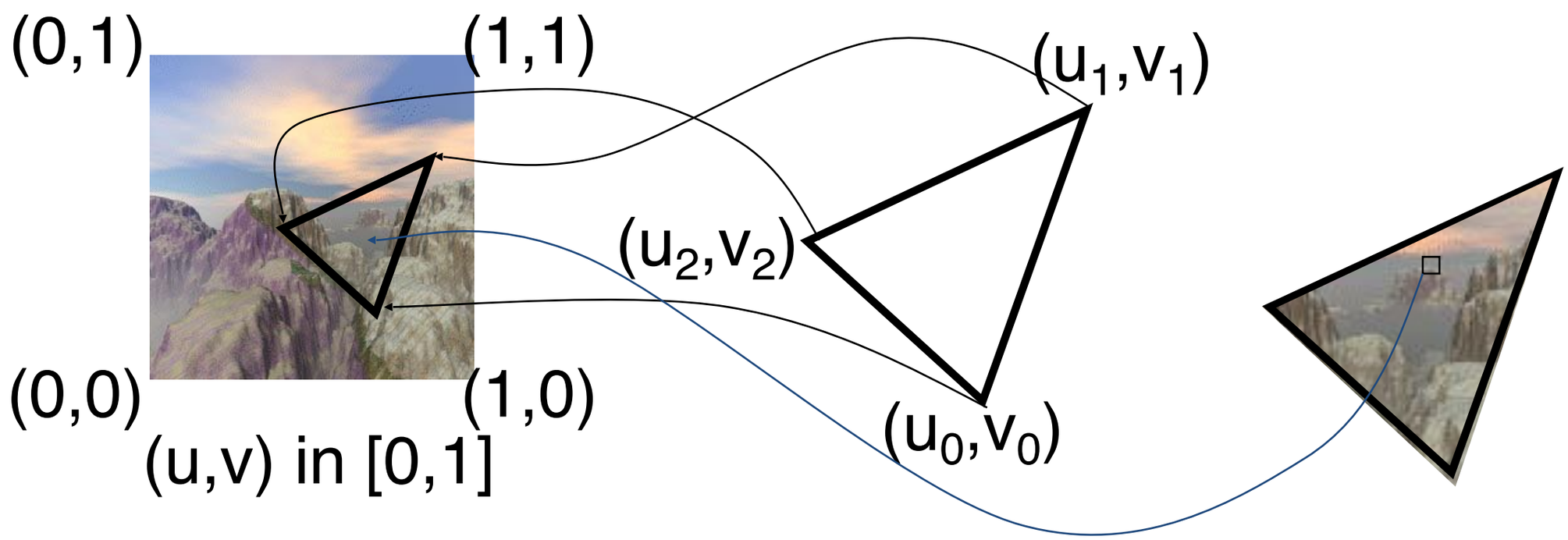
Texture Coordinate

- [0,1] x [0,1] texture space





- Texture Mapping



Summary

- Texture Mapping
  - Texture Image + Mapping Info.
  - Texture Coordinate: (u,v) Coordinate
  - Pixel and Texel

ISSUES IN TEXTURE MAPPING

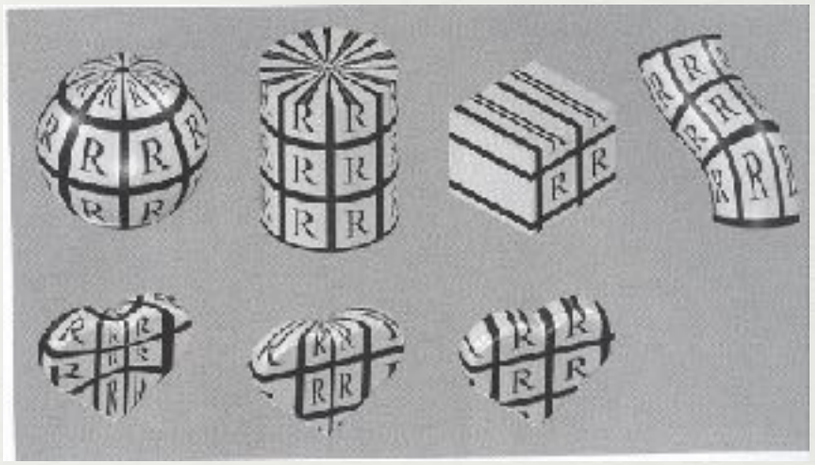
1. Addressing

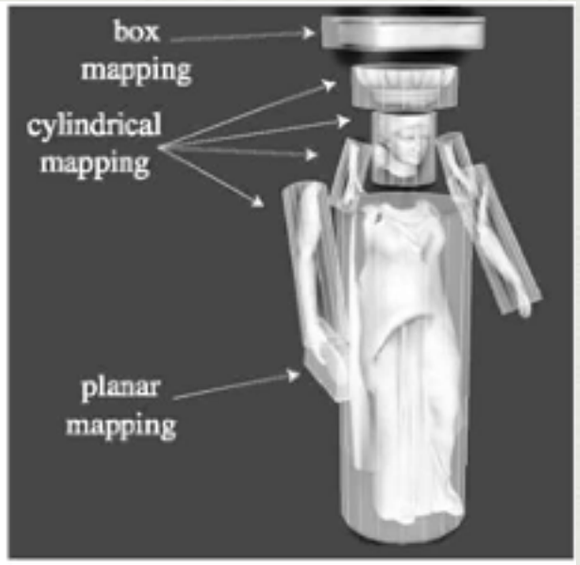
- What if (u,v) > 1.0 or < 0.0?

- Repeat, mirror, clamp, border
  - Repeat:1.3 -> 0.3
  - Mirror:1.3 -> 0.7
  - Clamp: 1.3 -> 1.0
  - Border?

2. Coordinate Generation

- Explicit method
- Projection method
  - Spherical
  - Cylindrical
  - Planar
  - …



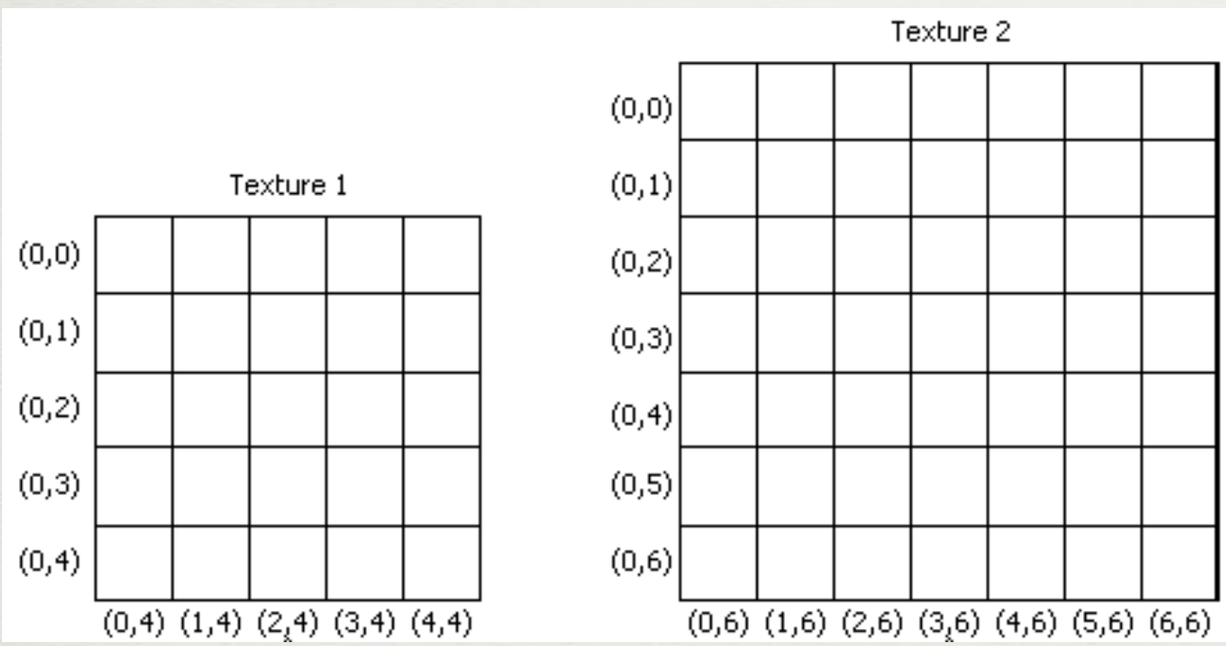


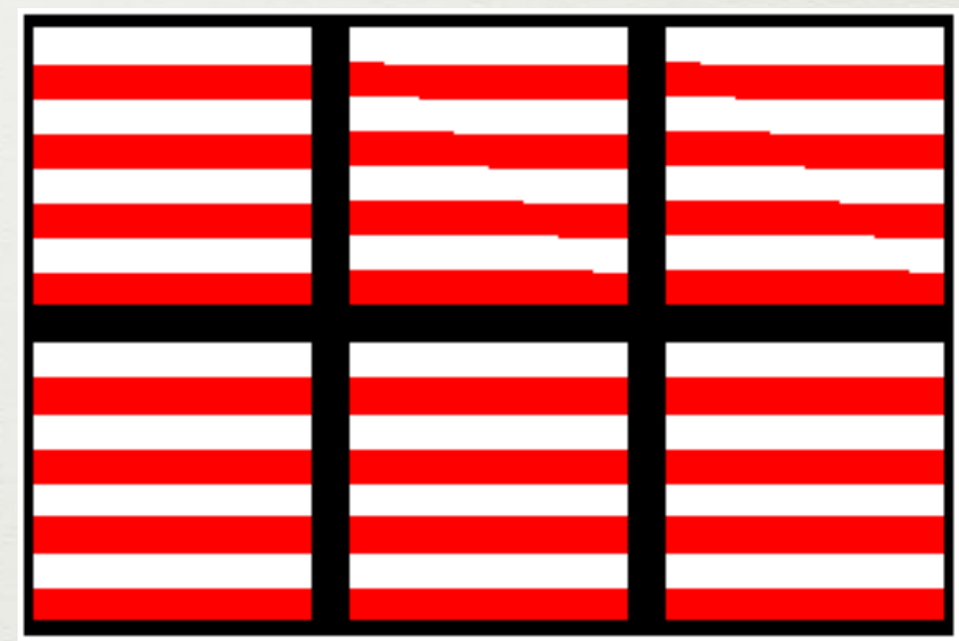
3. Texture Filtering

- Ambiguity in Texture Mapping
  - One ‘texel’ can be mapped onto
    - Part of one pixel
    - Many pixels
  - How to determine which color the pixel will have?

Texture Filtering

- Nearest Neighbor Method
  - Fill the pixel with a color of nearest texel point

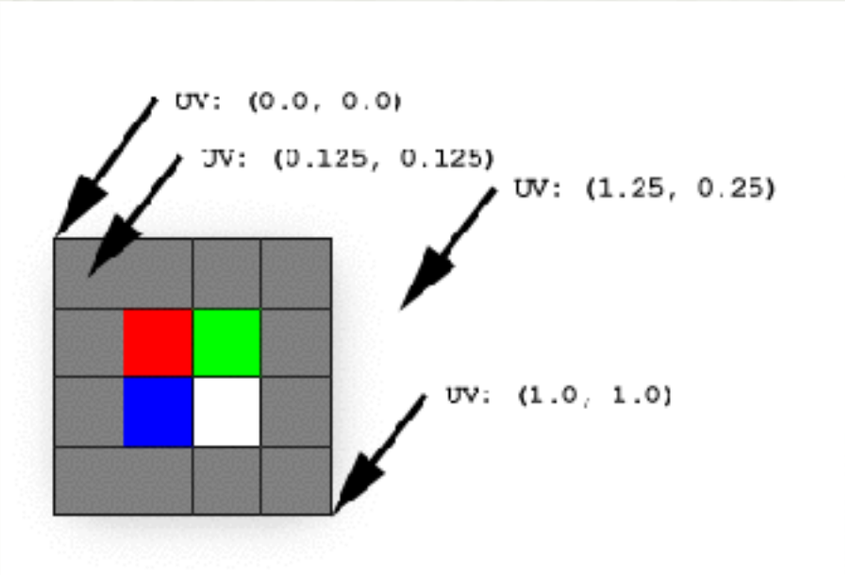


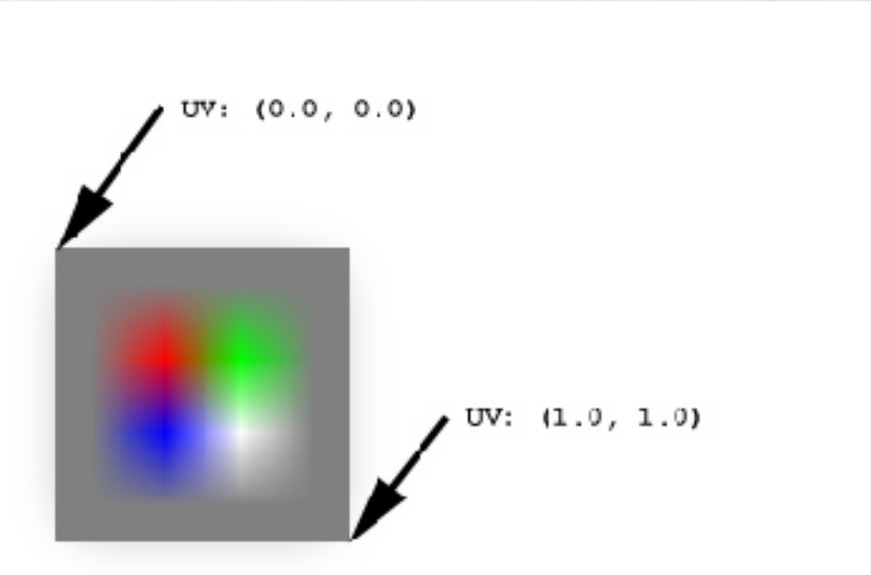


  - Issues on ‘staring effect’

Linear Filtering

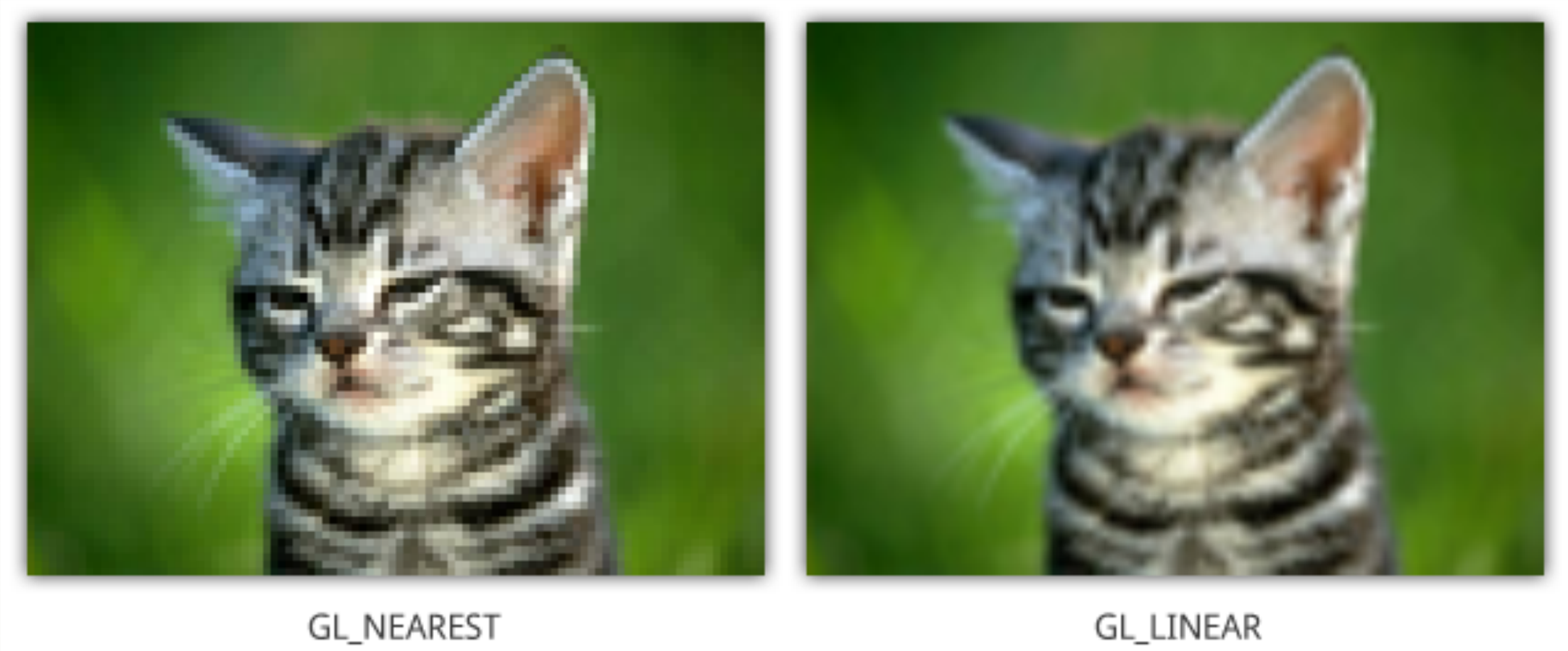
- Sample all neighboring texels
- Calculate linear combination of colors





Linear Filtering

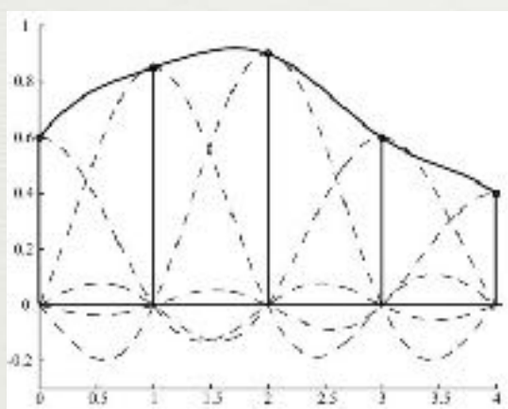
- Good when a texel is mapped onto many pixels

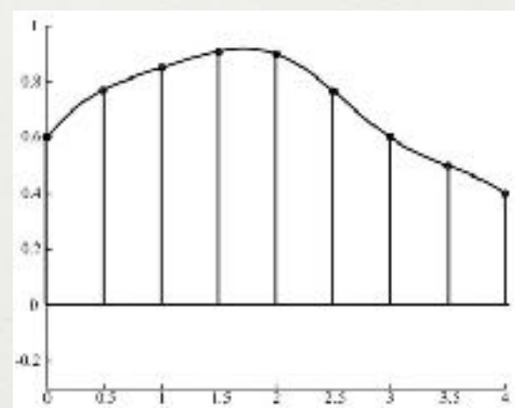


REAL EXAMPLES

Texture Magnification

- When a texel is mapped onto many pixels
  - We need to approximate internal curves on color





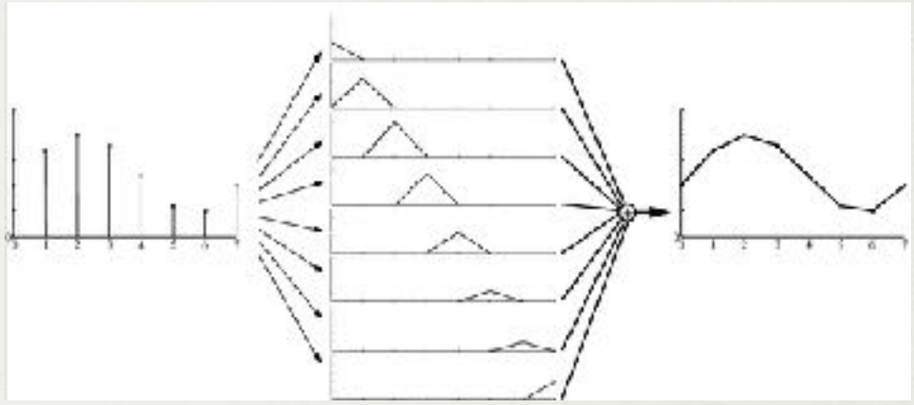
Texture Magnification

- Texture coordinates (p_u, p_v) in [0,1]
- Texture images size: n*m texels
- Nearest neighbor would access:
  (floor(n*p_u), floor(m*p_v))

- Gives poor image quality

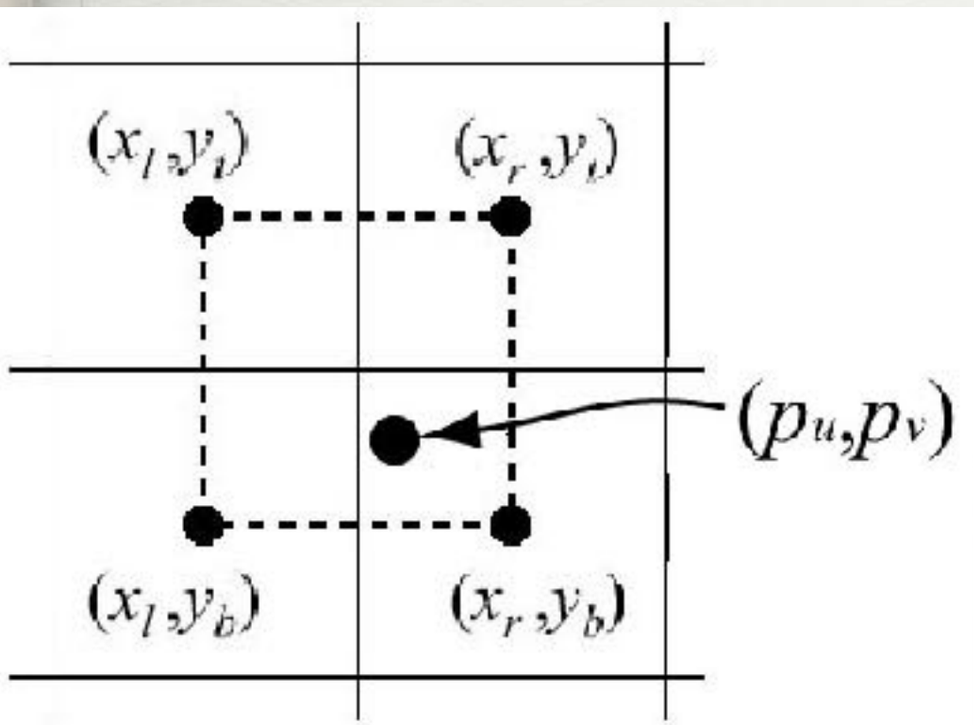
Texture Magnification

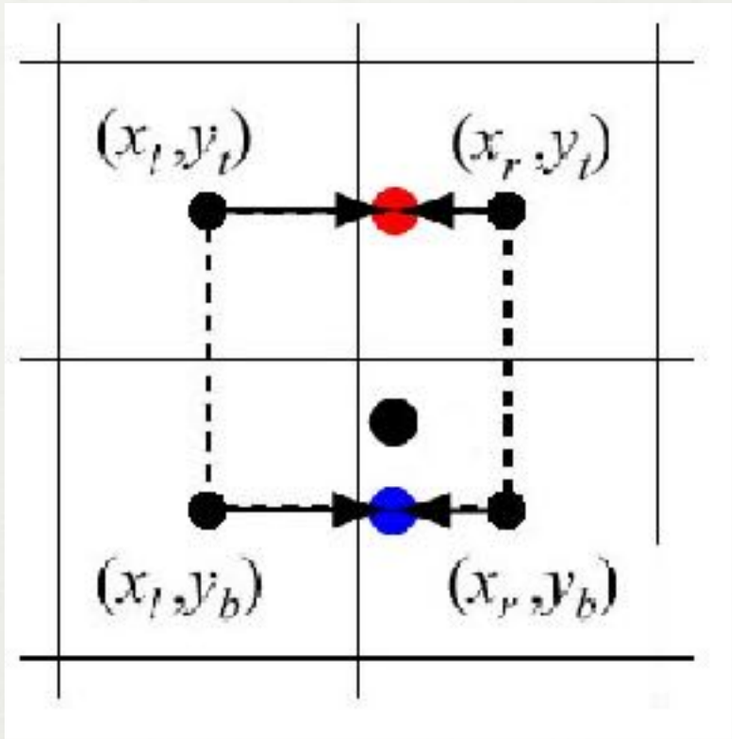
- Use of linear filter

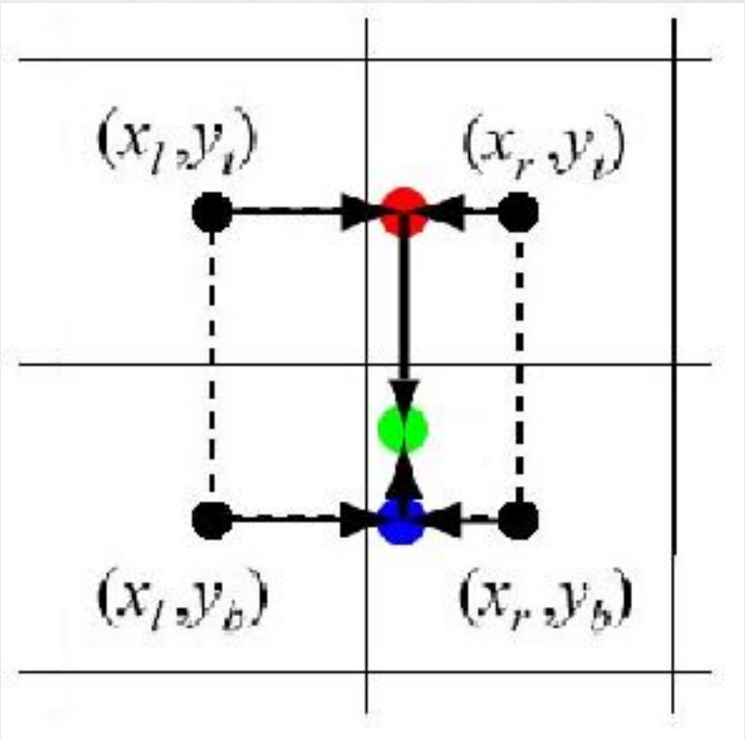


- Equation?
  - In 1D?
  - How about in 2D?

Bilinear Interpolation







Bilinear Interpolation

- $\mathbf{t}(u,v)$ accesses the texture map
- $\mathbf{b}(u,v)$ filtered texel

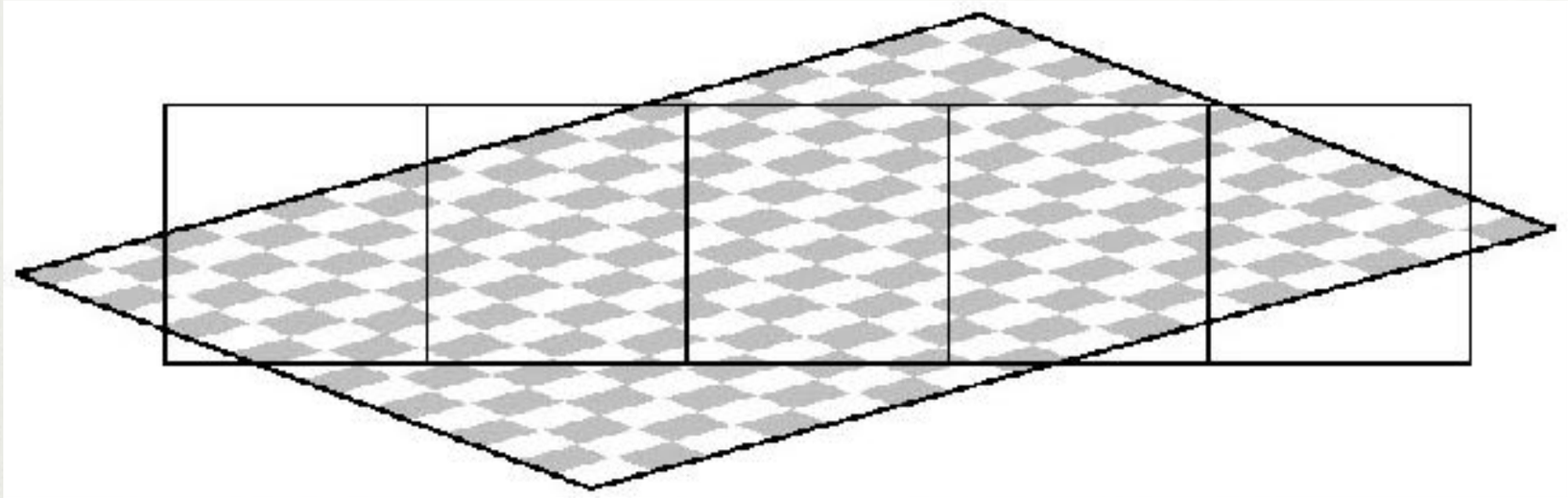
$$(u', v') = (p_u - \lfloor p_u \rfloor, p_v - \lfloor p_v \rfloor).$$

$$\begin{aligned}\mathbf{b}(p_u, p_v) =& (1-u')(1-v')\mathbf{t}(x_l, y_b) + u'(1-v')\mathbf{t}(x_r, y_b) \\ &+ (1-u')v'\mathbf{t}(x_l, y_t) + u'v'\mathbf{t}(x_r, y_t).\end{aligned}$$

- HW5
  - Devise bilinear interpolation method and check the equation is in the same form with above
  - Due 20/Nov.

Texture Minification

- What does a pixel ‘see’?

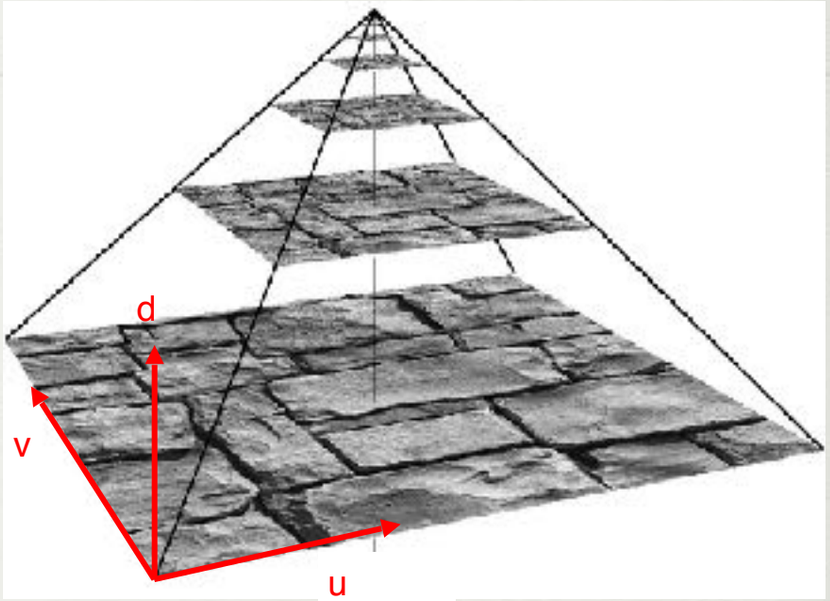


- Getting average of all texels for a pixel?
  - How?
  - Too complex!

Texture Minification

- Averaging is too complex
- How about pre-generate average colors?
  - Pre-generate average colors
  - Use averaged colors instead of original ones
  - Mipmaps

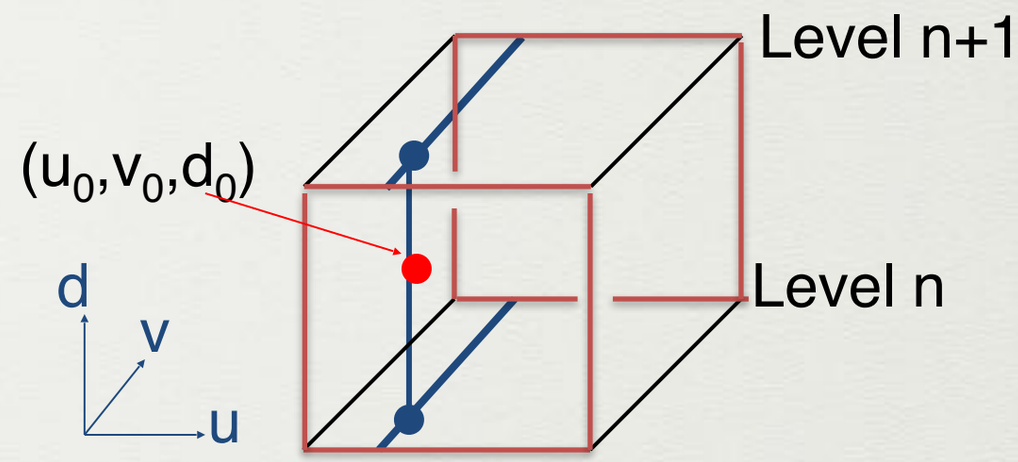
Mipmapping



- Image pyramid
- Construction
  - Averaging over 4 children texels to form one parent texel
- Usage
  - Compute d first
  - Compute colors from two neighboring images

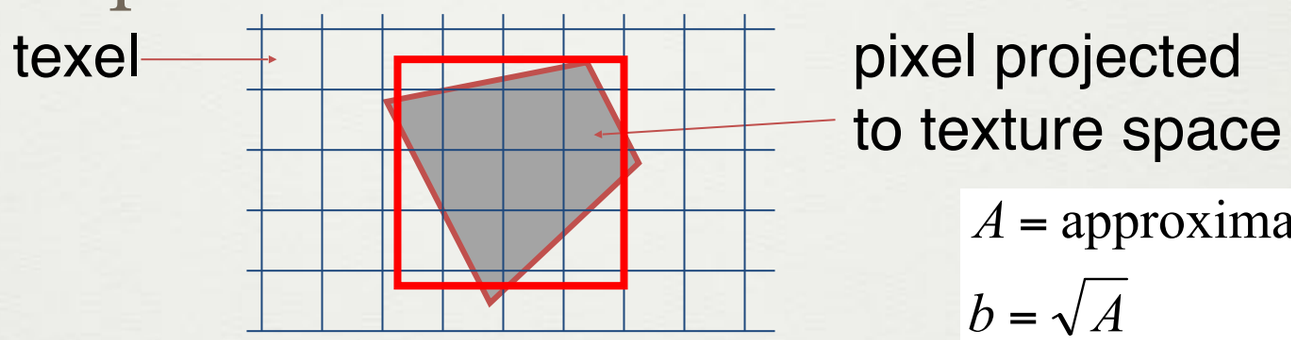
Mipmapping

- Compute colors
  - Nearest neighbor
  - Linear filtering
    - Trilinear interpolation
  - Combination of both?



Mipmapping

- How to compute d?



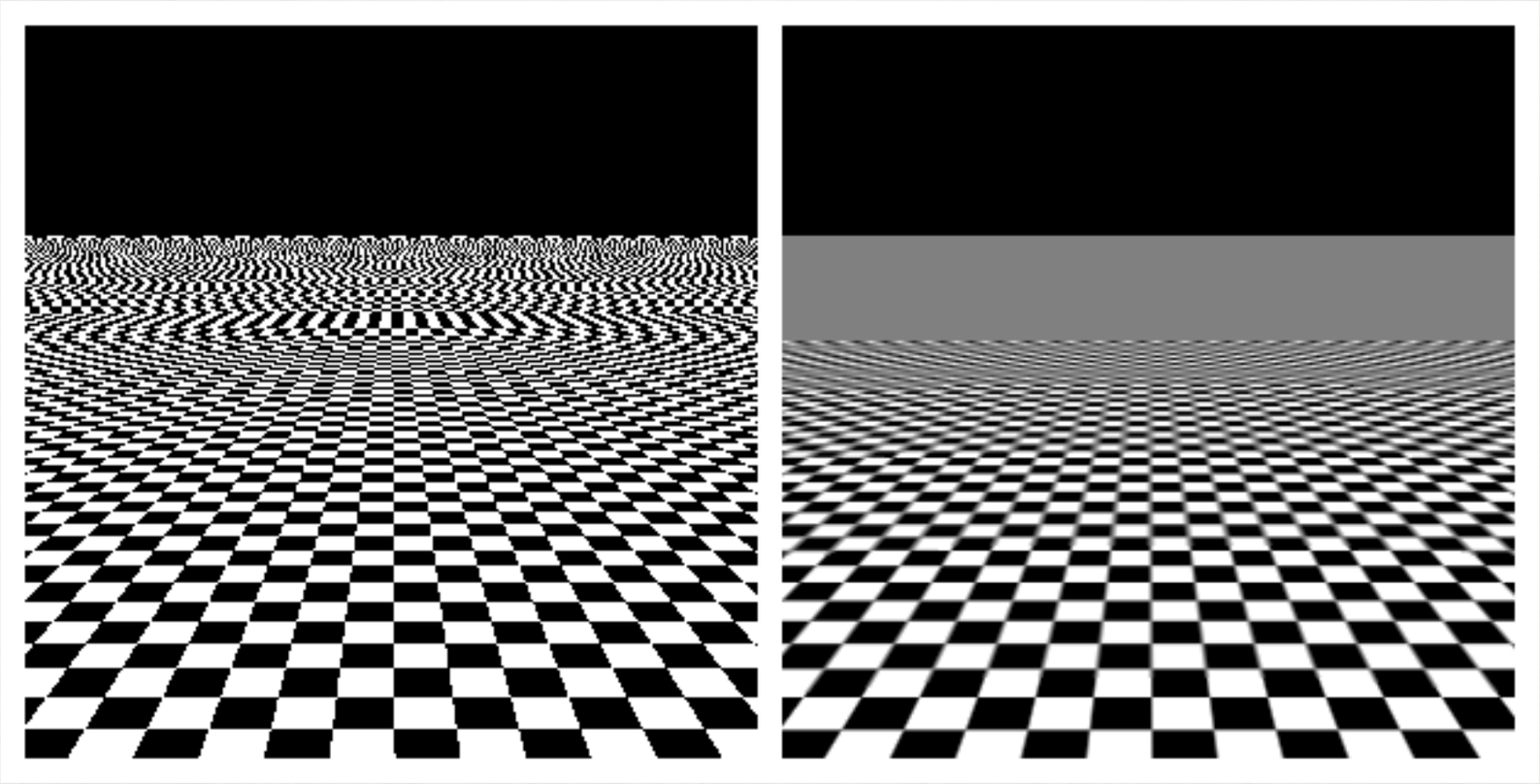
$$A = \text{approximative area of quadrilateral}$$
$$b = \sqrt{A}$$
$$d = \log_2 b$$

- Approximate quad with square

-

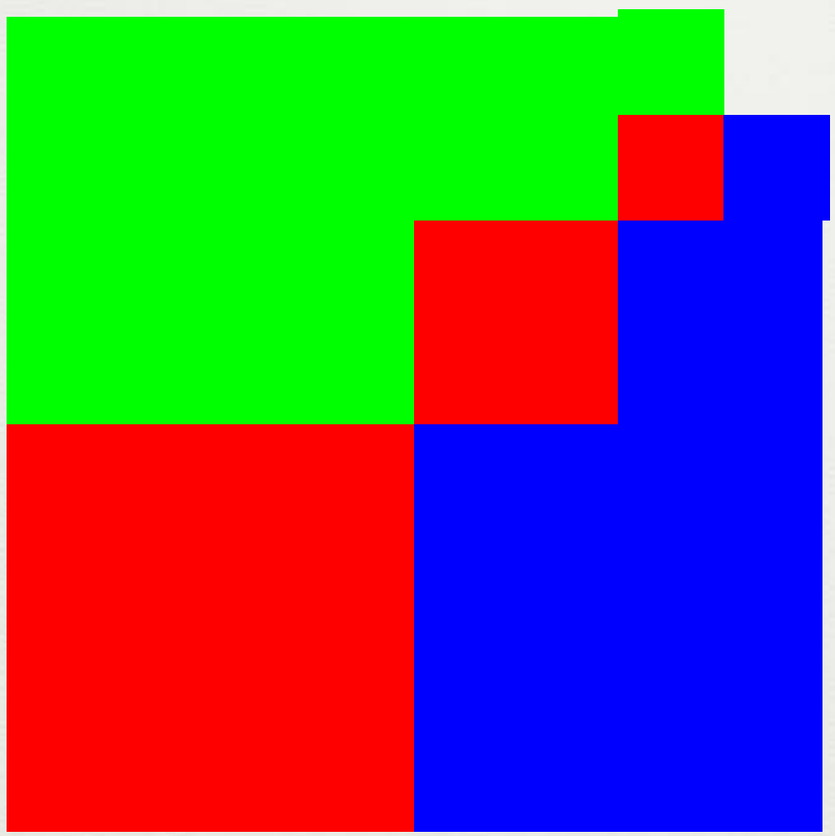
Mipmapping

- Mipmapping usually gives over blur



Mipmapping

- How about the memory requirements?

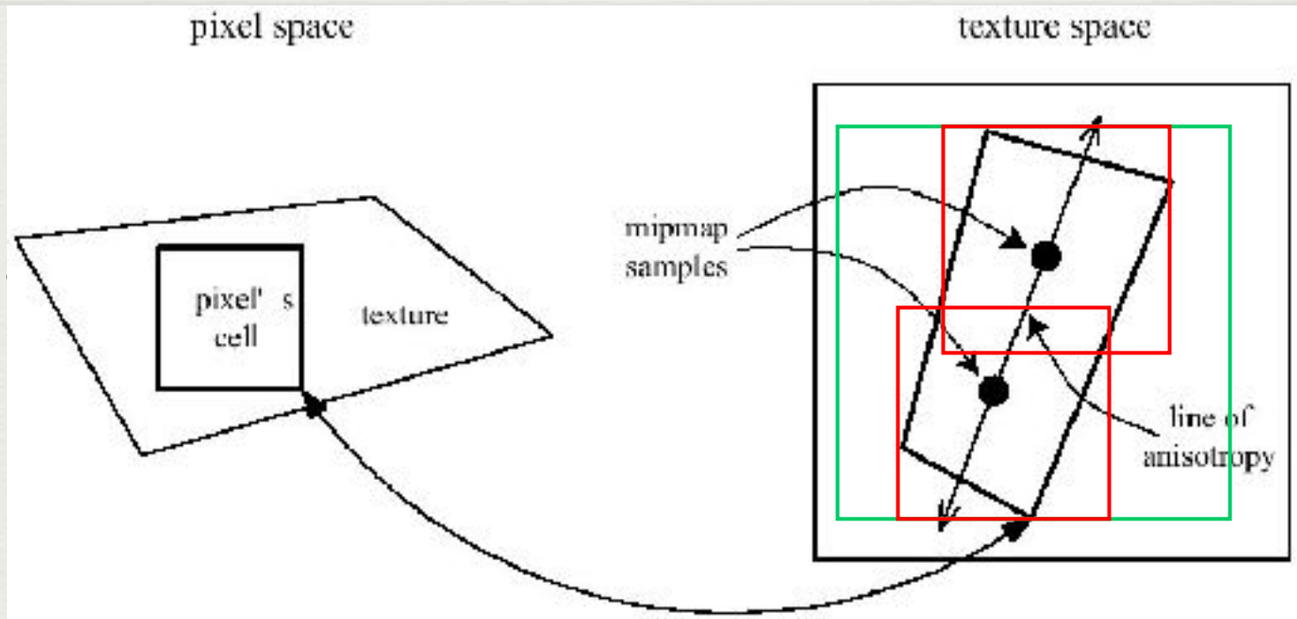


- No more than 33% more

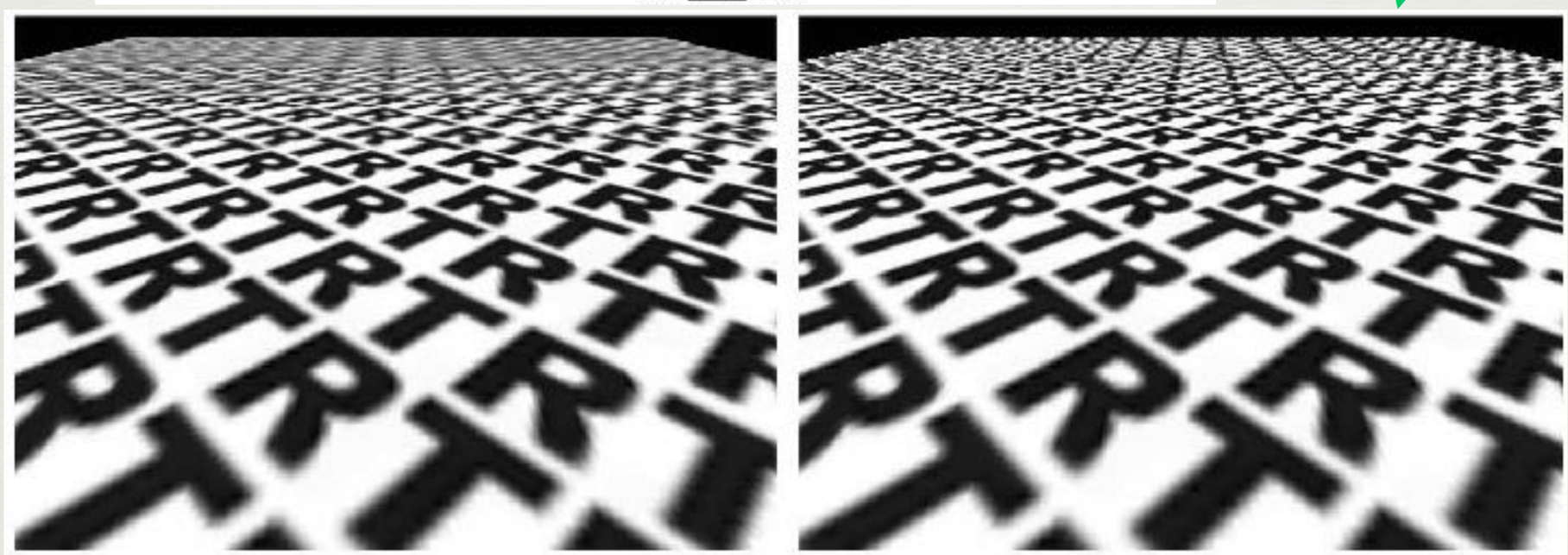
Mipmapping

- Why over-blur happens?
  - Approximating long pixels into a square
- Can we reduce the effect?
- How?

Anisotropic Texture Filtering



16 samples




tom's hardware guide
No Mipmaping Point Sampling
No Mipmaping Linear
Mipmaping Bilinear
Mipmaping Trilinear
Mipmaping 16x Aniso Tril.

Applying Texture

- Color Computation
  - Illumination Color
  - Texture Color
  - Do we need to combine? Why?

Applying Texture

- Modulate and Replace

  - Modulate: Multiply texture color with Lighting
  - Replace: Use only texture color

Applying Texture

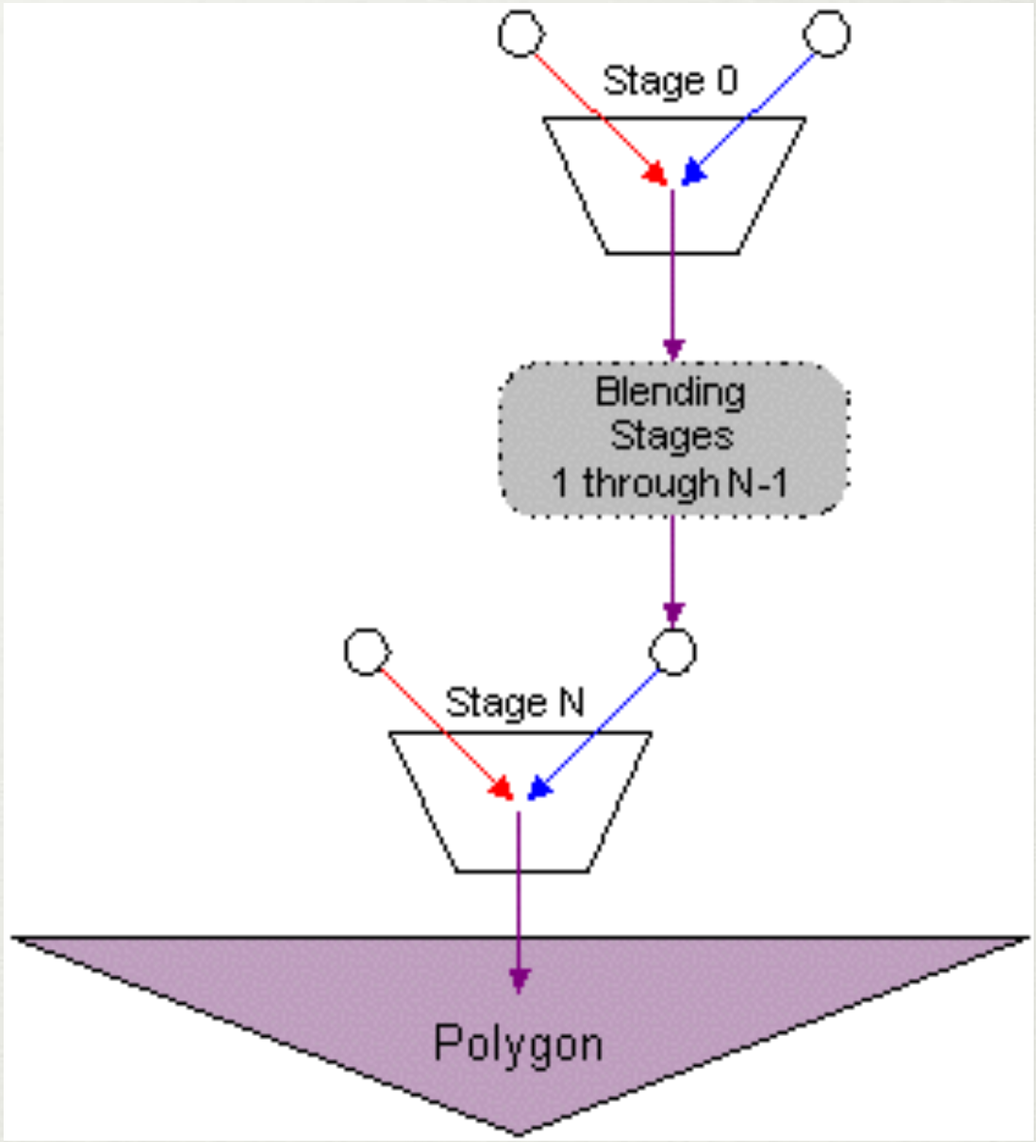
- Other operations
  - Add, sub, …

Multi-texture

- Blending
  - Texture with Lighting
  - Texture and Texture

Multi-Texture

- How?



x

=

whatever times one equals whatever

x

=

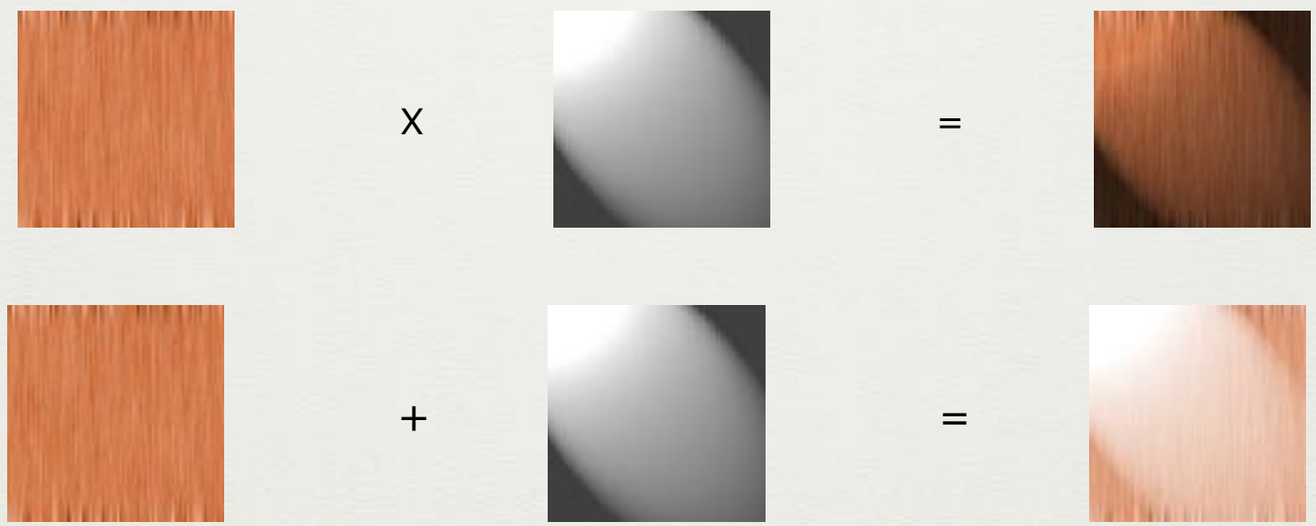
whatever times zero equals zero

x

=

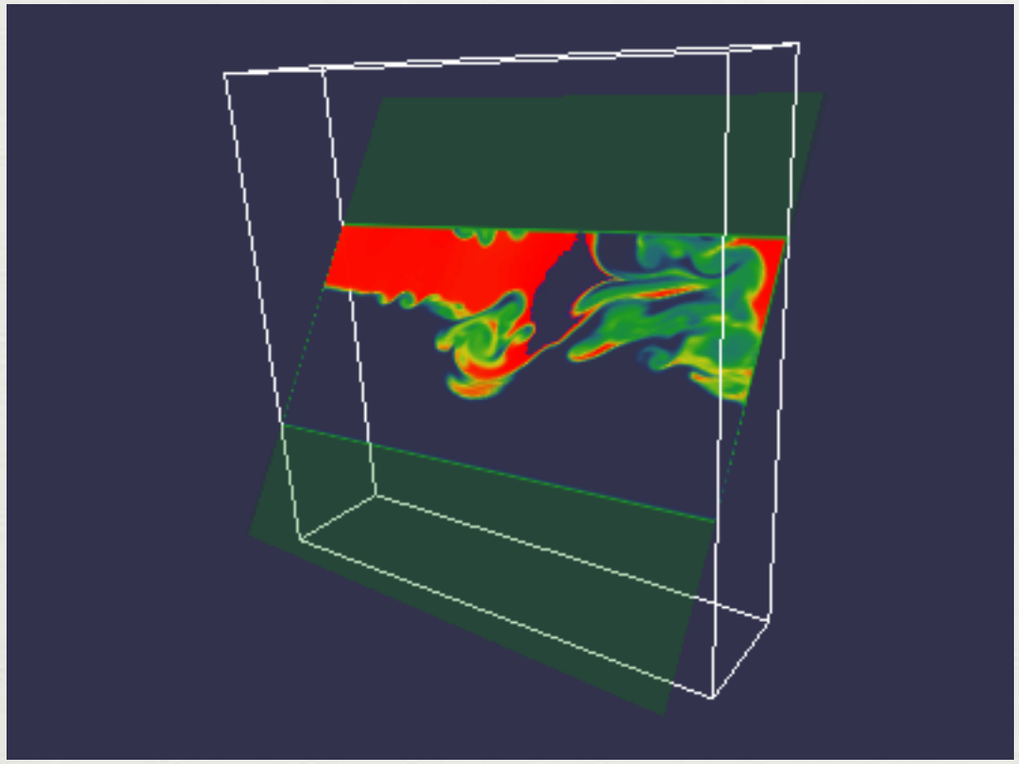
texture map times light map equals shadows

- 텍스트를 입력하세요.



Other Texture

- 3D Texture



Summary

- Texture Mapping
  - Texture Image and Coordinate
  - Texture Addressing
  - Texture Filtering
  - Texture Operation
  - Multi-texture