

Computer Graphics

Texture mapping

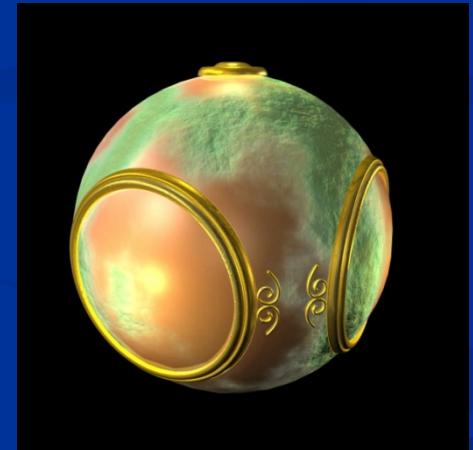
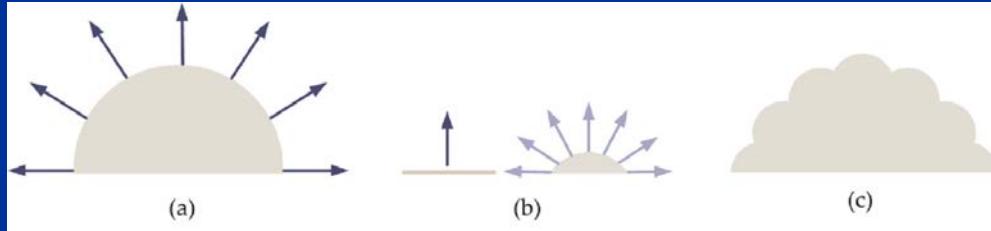
Hyewon Seo

Objectives

- Texture mapping
 - Definitions, classifications
- Texture mapping on polyhedral surfaces
- Texture mapping on parametric surfaces
- Aliasing and antialiasing

Definition

- Method for adding detail
 - Originally from bump map
 - Emulates altering normal vectors during the rendering process



Bump mapping - limitation

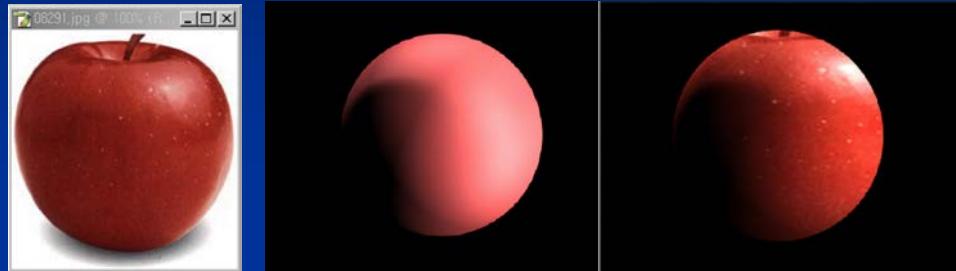


Types of mapping

- **Texture Mapping**
 - Uses images to fill inside of polygons
- **Light mapping**
 - Combine precomputed light effect and texture image
- **Environmental (reflection mapping)**
 - Uses a picture of the environment for texture maps
- **Bump mapping**
 - Emulates altering normal vectors during the rendering process

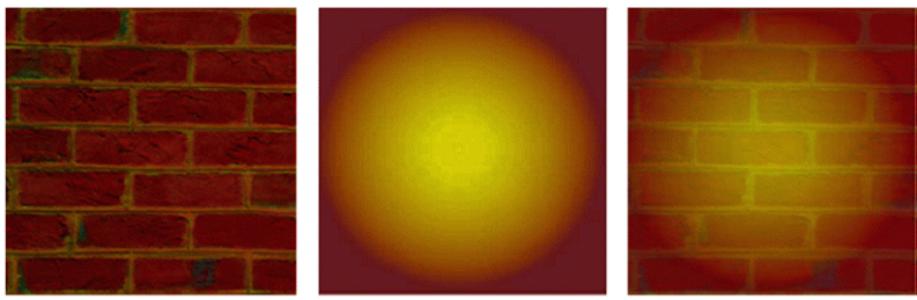
Types of mapping

- General texture mapping



- Light Mapping

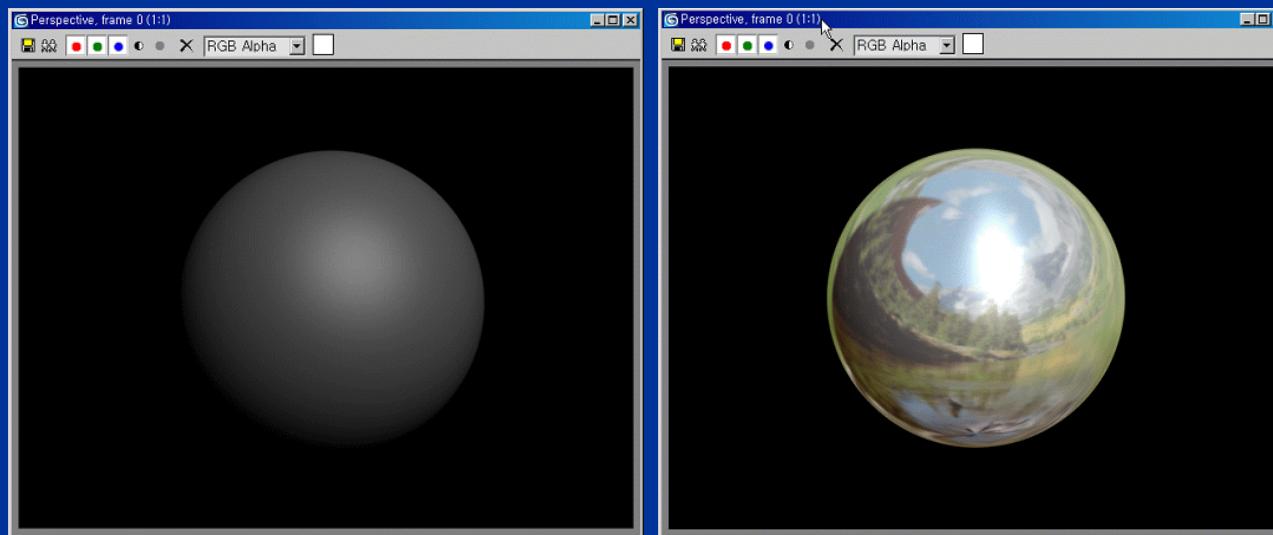
- Instead of computing the light intensity on the surface, combine the texture and the light map
- The result combined image is mapped on the surface



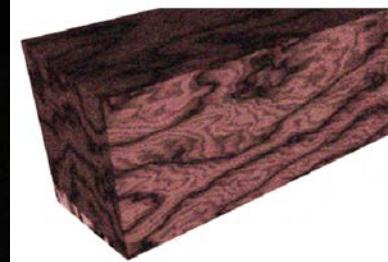
Types of texture map

- **Environmental Mapping**

- Surrounding environment is reflected on the object
- Shiny objects



Why texture mapping?

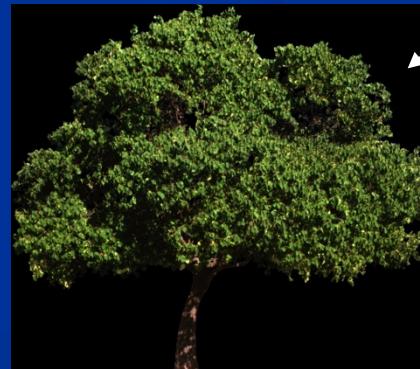


- **Realistic modeling**

- Subdivide each polygon into more
- Or, assign different color and surface normal to each vertex
 - Costly!
- Directly map 2D images on the surface
 - Texture, Texture Image, Texture Map)



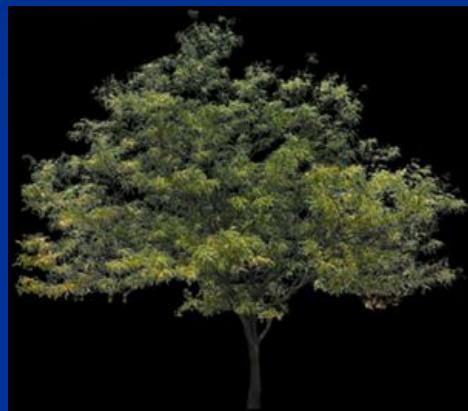
Tree,
higher resolution model
45,992 polygons.



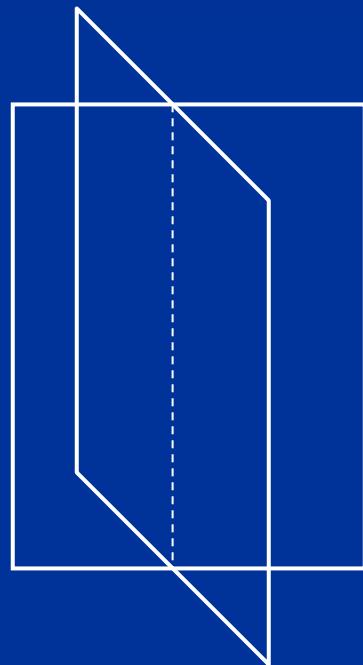
Alpha channel = 0

Tree represented as a texture
1 polygon, 1246x1280 pixels

Billboarding



+



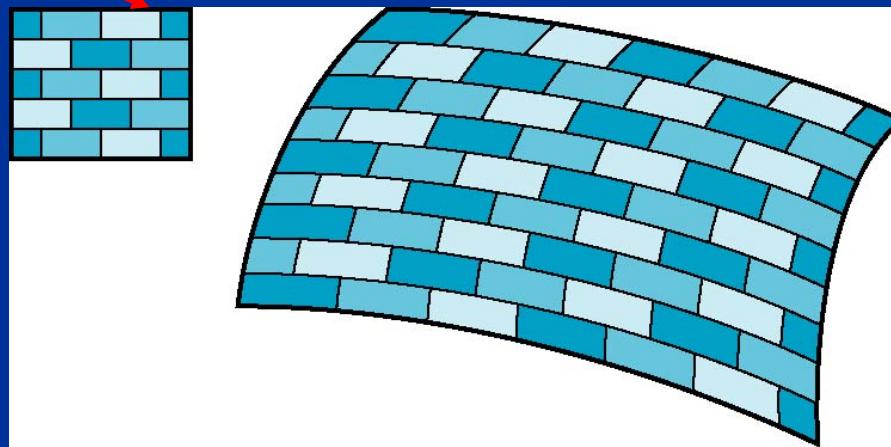
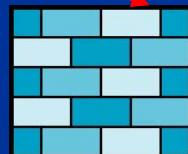
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Is it simple?

- Although the idea is simple---map an image to a surface---there are 3 or 4 coordinate systems involved

2D image

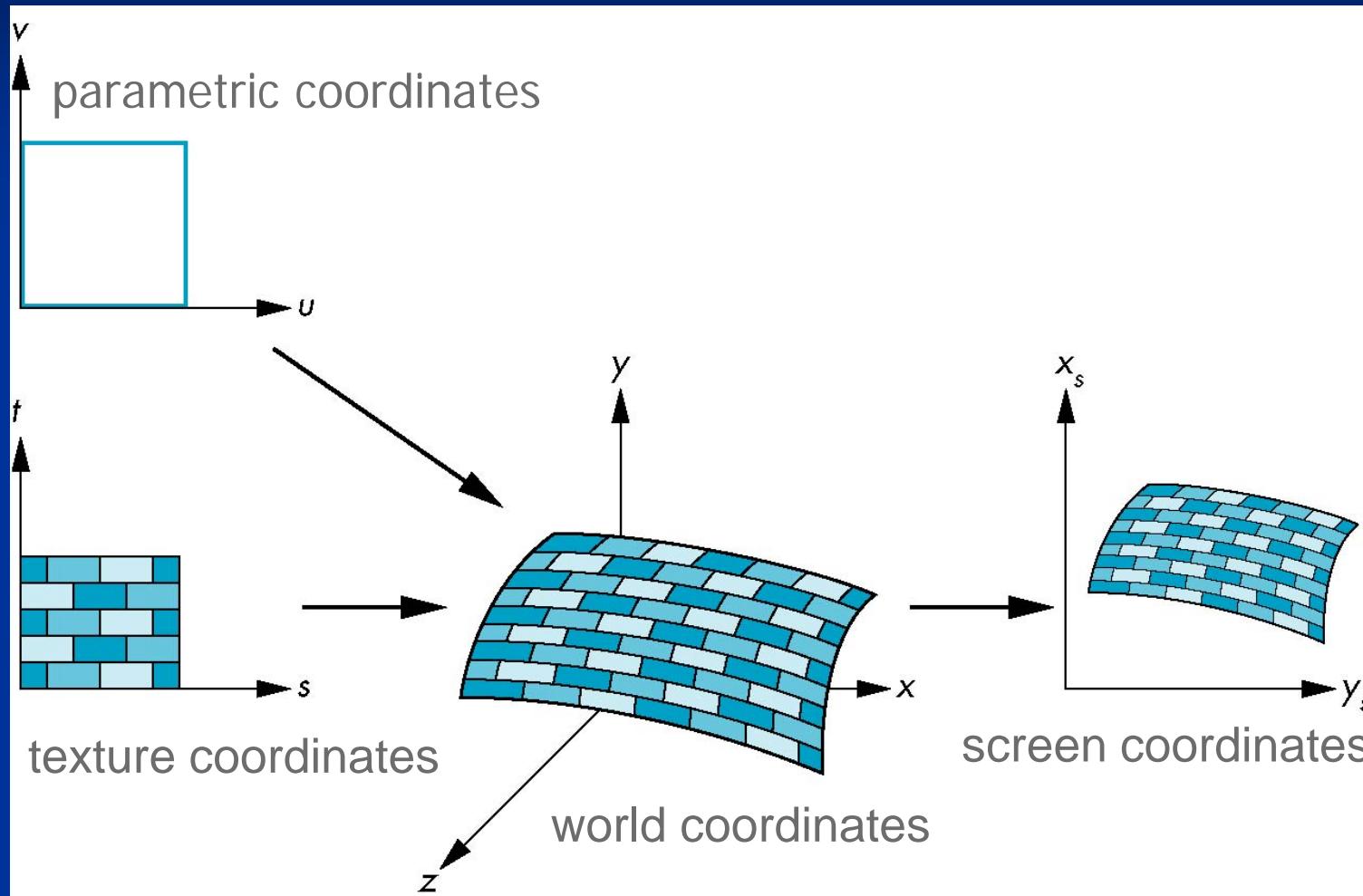


3D surface

Coordinate Systems

- Parametric coordinates
 - May be used to model curved surfaces
- Texture coordinates
 - Used to identify points in the image to be mapped
- World Coordinates
 - Conceptually, where the mapping takes place
- Screen Coordinates
 - Where the final image is really produced

Texture Mapping



Mapping Functions

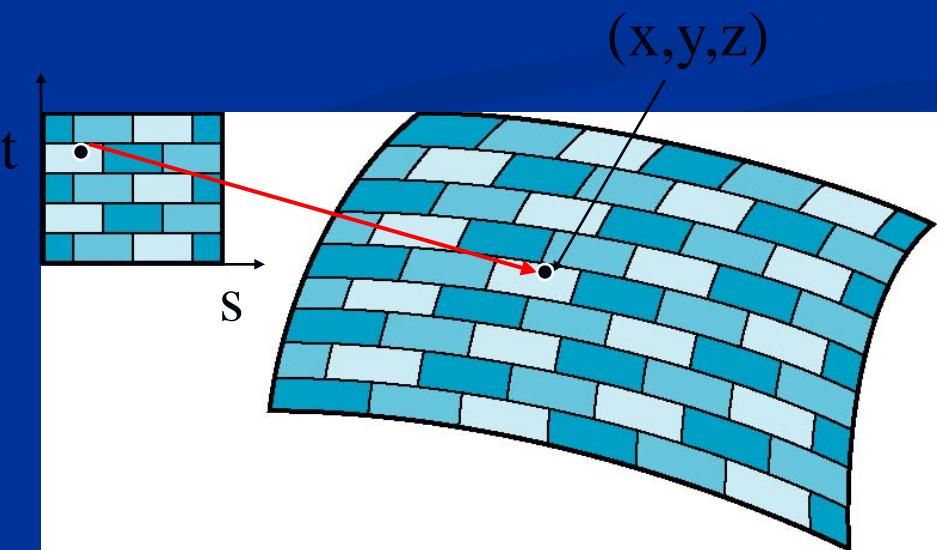
- Basic problem is how to find the maps
- Consider mapping from texture coordinates to a point of a surface
- Appear to need three functions

$$x = x(s, t)$$

$$y = y(s, t)$$

$$z = z(s, t)$$

- But we really want to go the other way

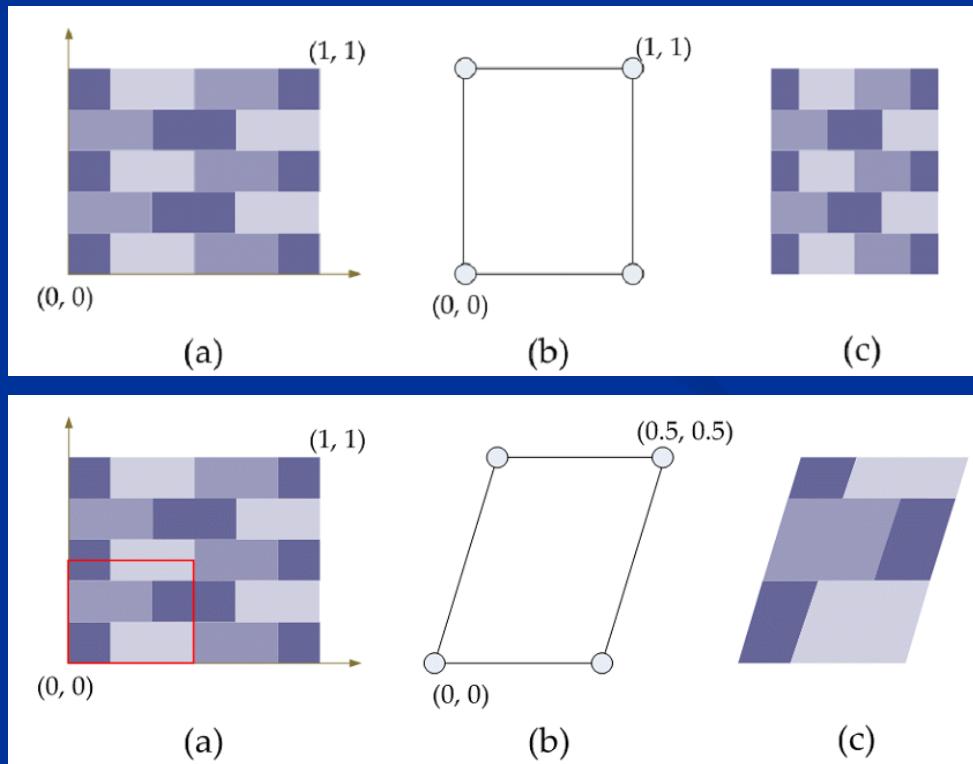


Backward Mapping

- We want to go backwards
 - Given a pixel in the screen, find the corresponding vertex on the object
 - Given a vertex on the object's surface, find the corresponding location on the texture
 - Need a map of the form
 - $s = s(x, y, z)$
 - $t = t(x, y, z)$
- Such functions are difficult to find in general

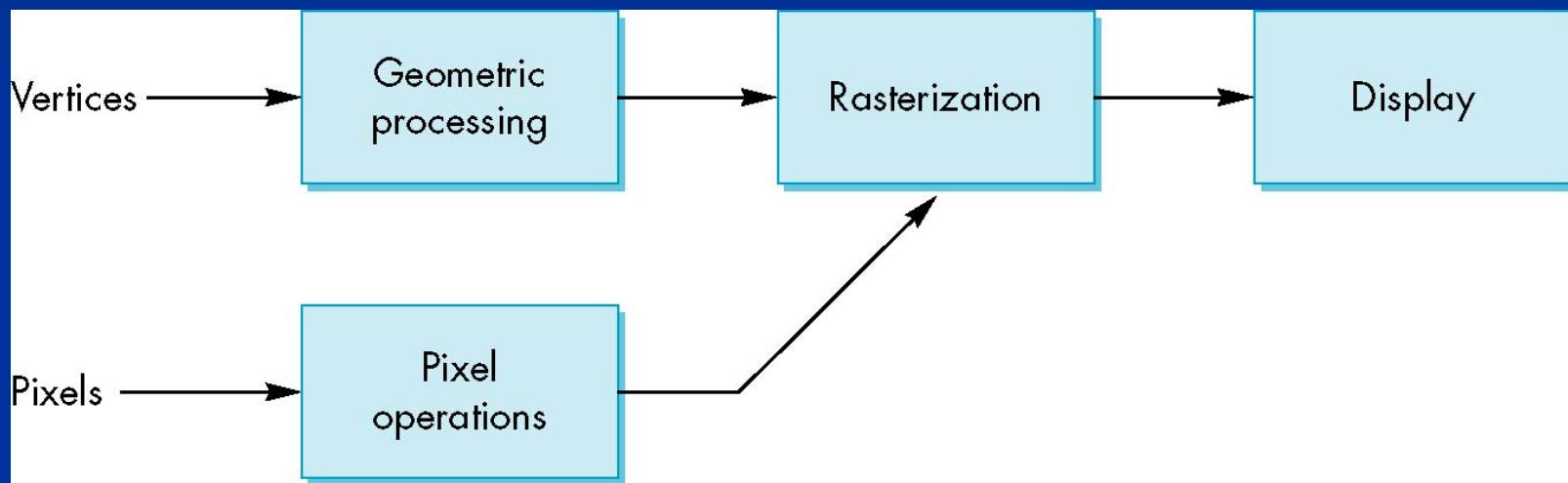
Mapping onto flat polygons

- Reminder: We specify st-coordinates at each vertex



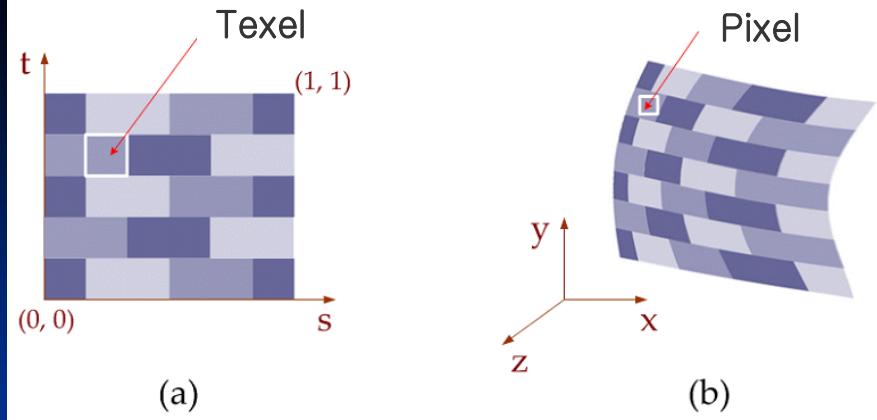
Texture mapping – where in the pipeline?

- After the view projection, at the time of rasterization



- Geometry pipeline vs. Image pipeline
 - Image pipeline is independent from geometry pipeline
 - Merged at the time of rasterization

Texel



- **Texel(Texture Element)**

- Basic unit of texture image
- Specified with (R, G, B, A) values as with pixels
 - Ex: 6X5 2D array. Coordinates are normalized

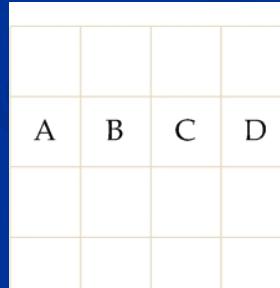
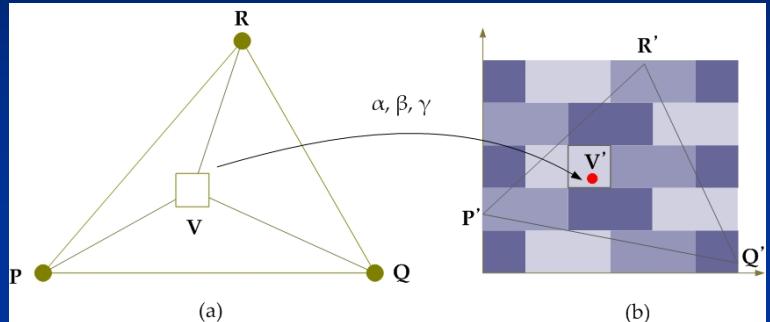
Mapping direction

- Pixel to triangle, & to texture
 - Compute texture color value for each pixel
 - Interpolation

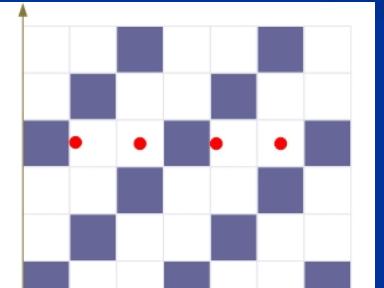
$$V = \alpha P + \beta Q + \gamma R$$

$$V' = \alpha P' + \beta Q' + \gamma R'$$

- aliasing may occur



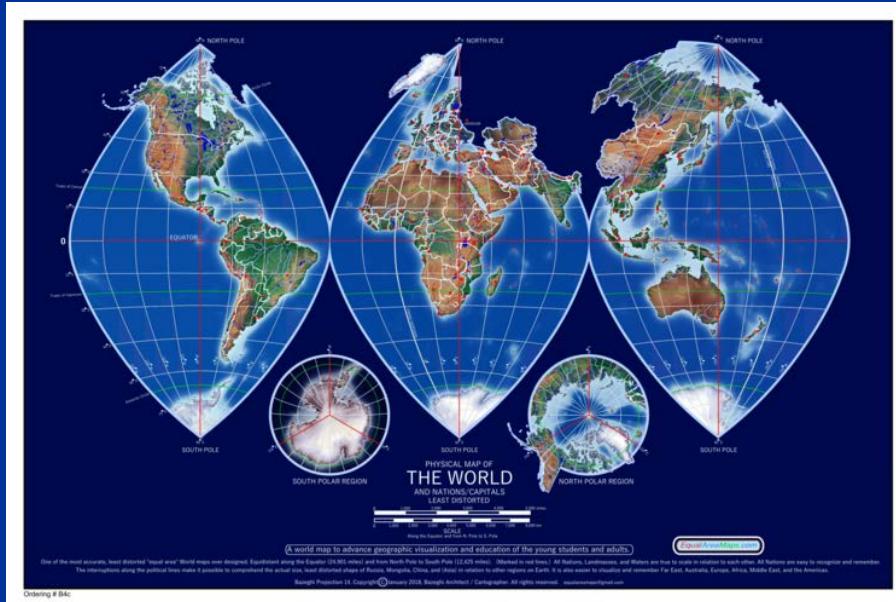
(a)



(b)

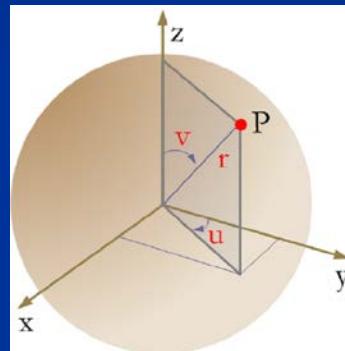
Mapping onto curved surfaces

- Difficult because we wrap curved surface with planes
 - The reverse is also difficult
 - Ex. Distortion on the 2D world map



Case1: Parametric surface

- Example: Sphere

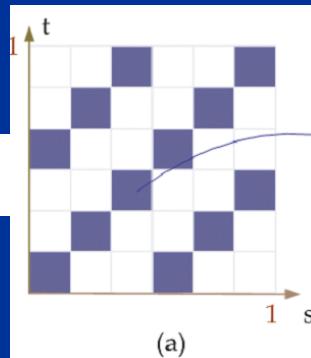


$$z = r \cos v$$

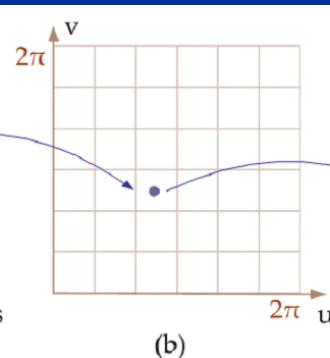
$$y = r \sin v \cos u$$

$$x = r \sin v \sin u$$

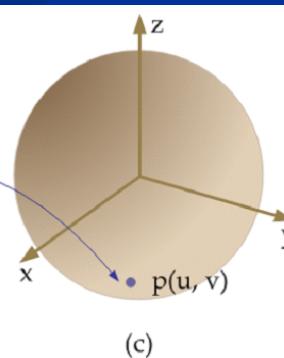
$$u = 2\pi s, \quad v = 2\pi t$$



(a)



(b)



(c)

$$z = r \cos 2\pi t$$

$$y = r \sin 2\pi t \cos 2\pi s$$

$$x = r \sin 2\pi t \sin 2\pi s$$

Case2: Polygonal surface

- 2-Stage Mapping
 - When the surface is not represented as parameters
 - S mapping: texture space -> intermediate surface
 - Intermediate Surface: cylinder, cube, sphere, etc
 - O-mapping: intermediate surface -> real object surface

S Mapping example

: texture space -> intermediate surface

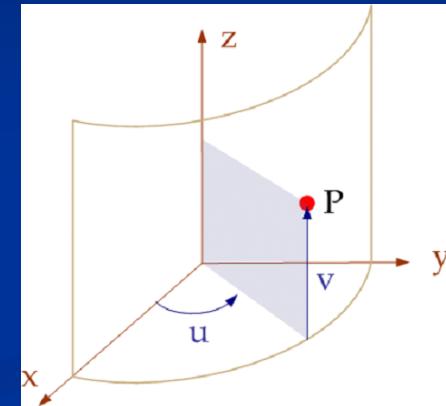


Parametric cylinder: u-v coord.->world coord.

$$x = r \cos 2\pi u$$

$$y = r \sin 2\pi u$$

$$z = v/h$$



Rectangle of the u,v space is mapped to a cylinder (r, h)

texture coord. -> u-v coord.

$$s = u$$

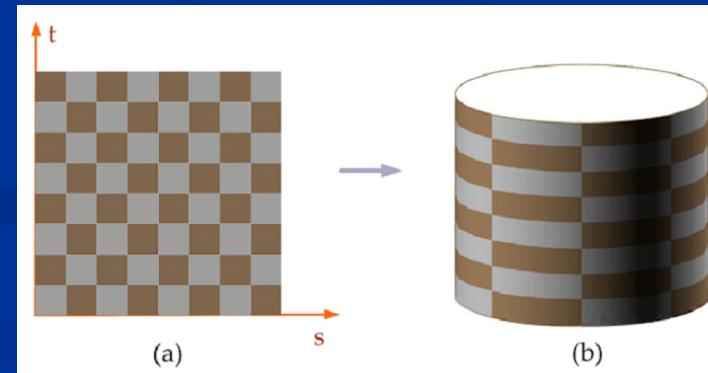
$$t = v$$



$$x = r \cos 2\pi s$$

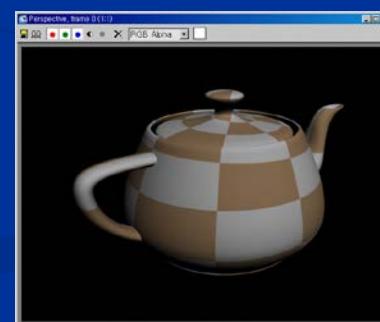
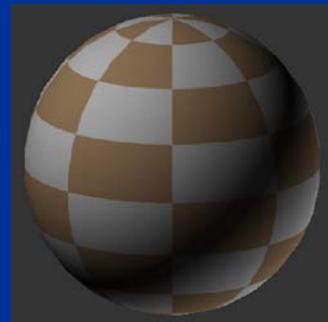
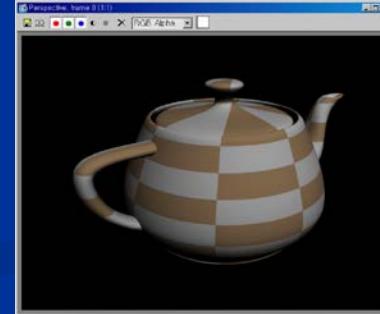
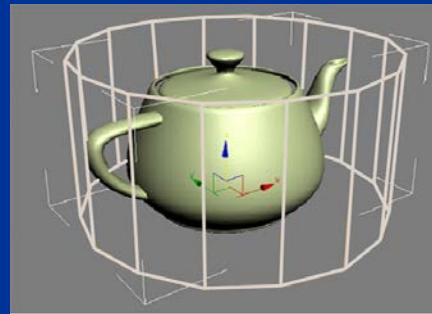
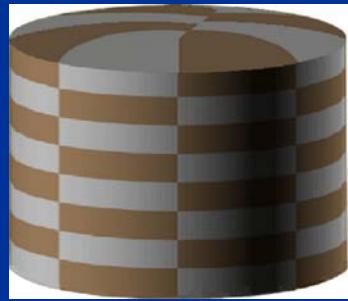
$$y = r \sin 2\pi s$$

$$z = t/h$$



Various S mappings

- Embed the object inside the intermediate object and find the map

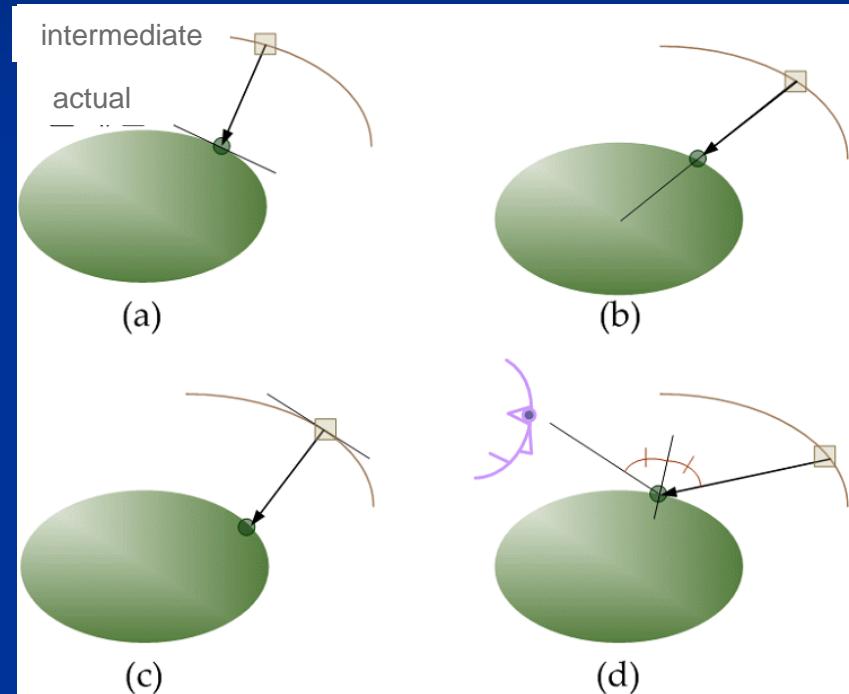


O Mapping

: intermediate surface -> real object surface

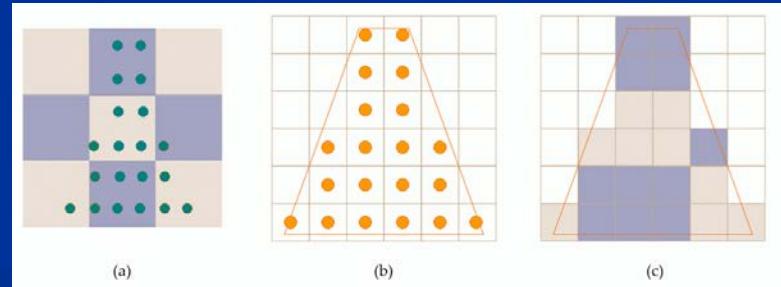
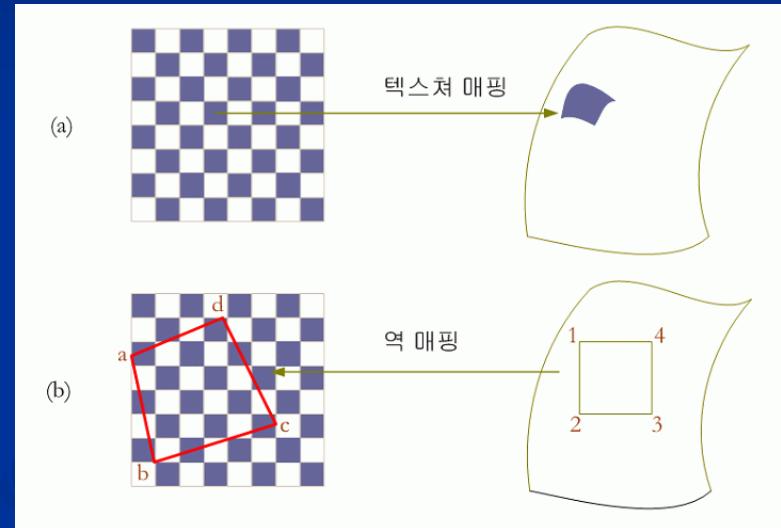
- 4 ways

- Normal vector -> intermediate surface
- Center to surface vector extended
- Normal vector on the intermediate surface -> intermediate surface
- Use reflected view vector



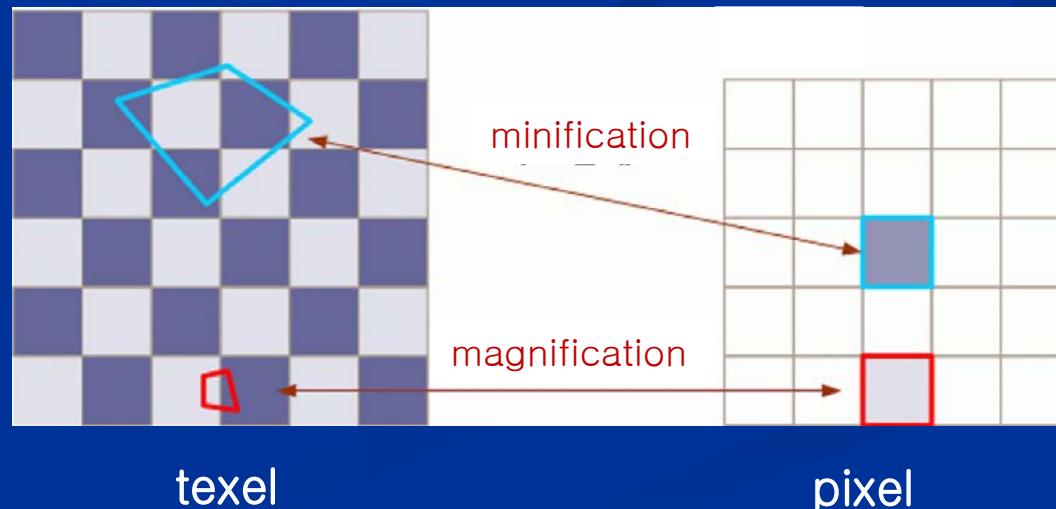
Aliasing

- Texture mapping
 - Non-Linear Mapping): planar square to curvilinear Quadrilateral



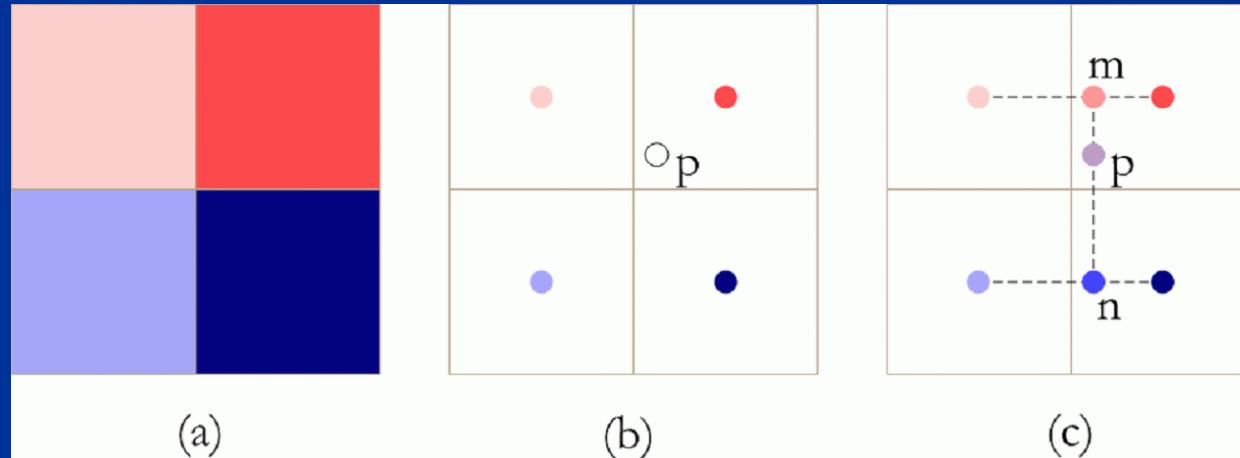
Magnification/Minification

- Minification
 - Many texels to one pixel
- Magnification
 - Small fraction of texel to one pixel
- Aliasing may occur in both cases

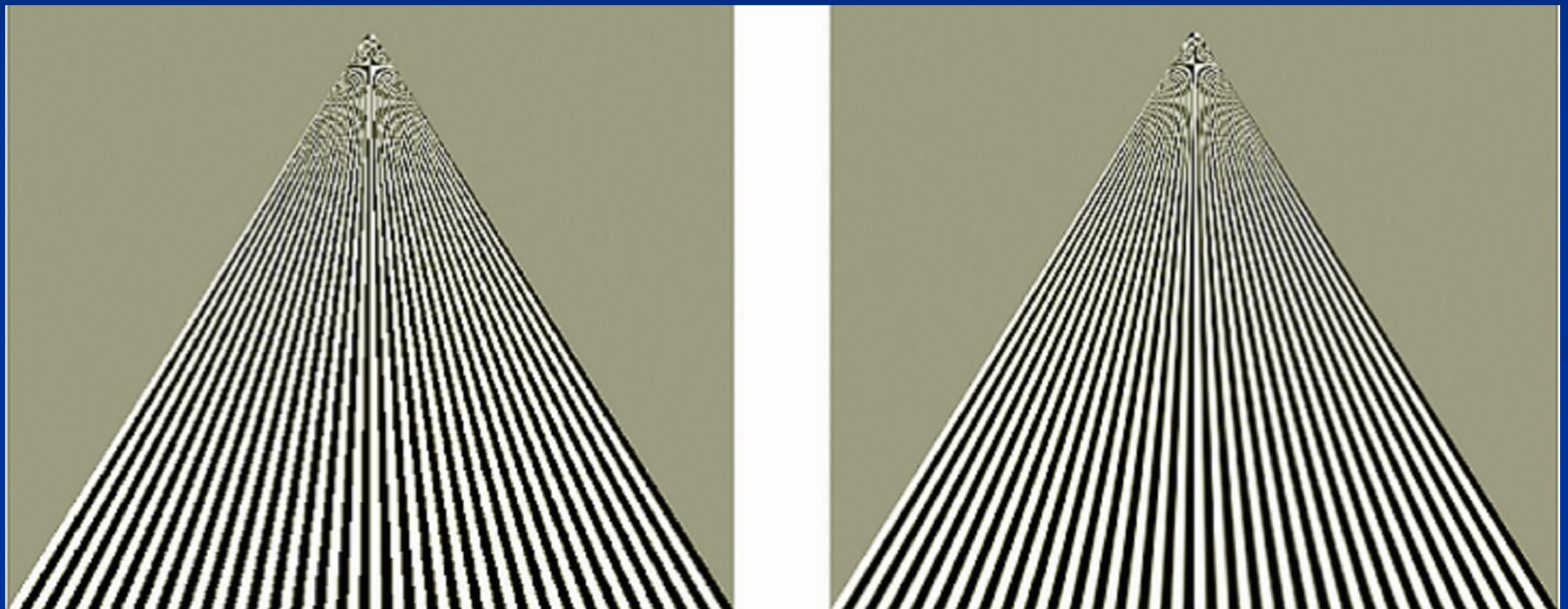


Antialiasing: bilinear interpolation

- Used in magnification
 - Say, a pixel is mapped to p in the texture coord.
- Accepted as standard by most graphics cards
- Boundary of texture becomes blurred

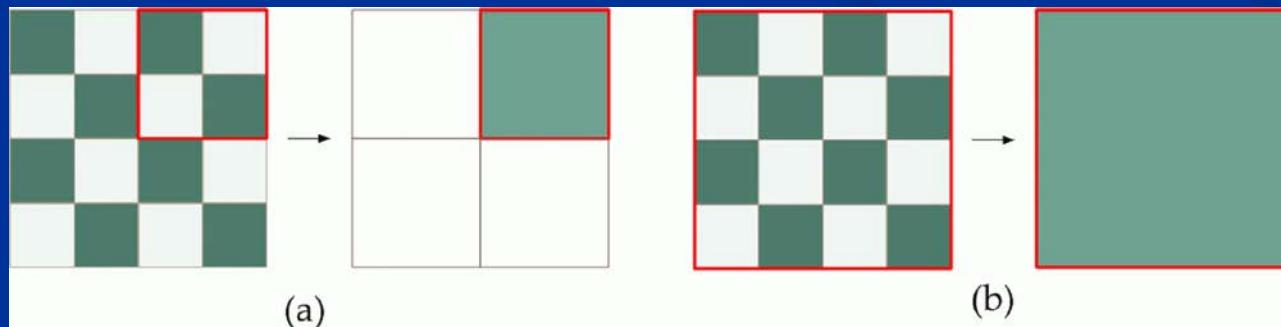


Point sampling & bilinear interpolation

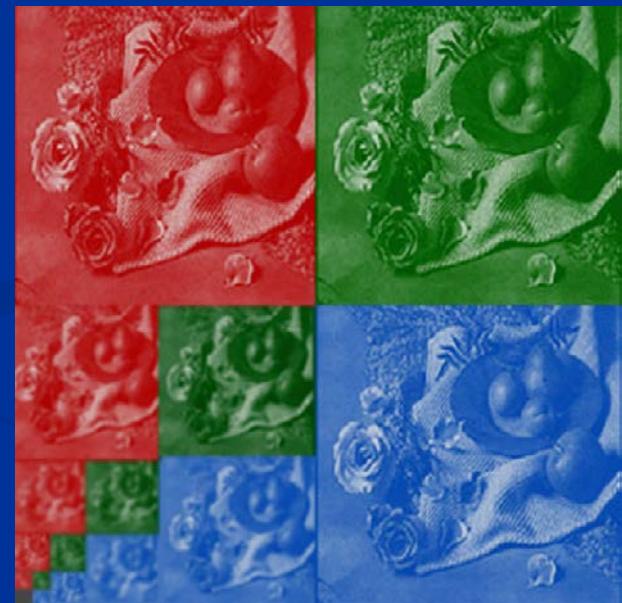
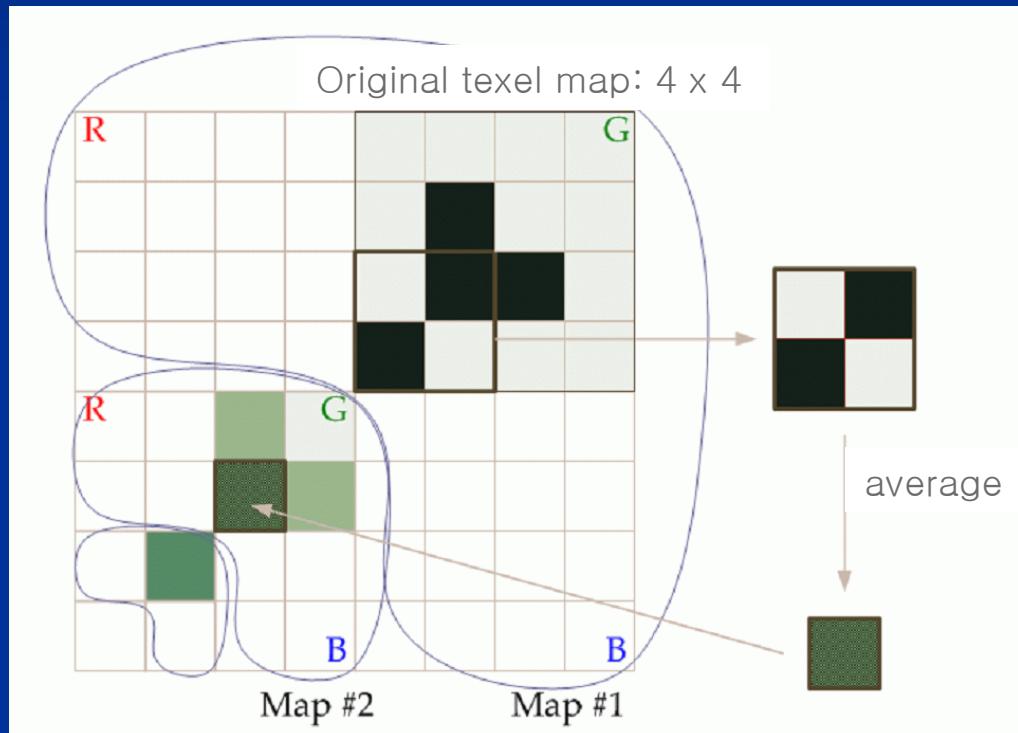


Antialiasing: Mip map

- Used in minification: 1 pixel to many texels
- MIP Mapping: Multum in Parvo, Many Things in a Small Place
 - Average texel colors at each level of resolution and store them
 - Pre-Filtering, Multi-Resolution Texture



Mip map

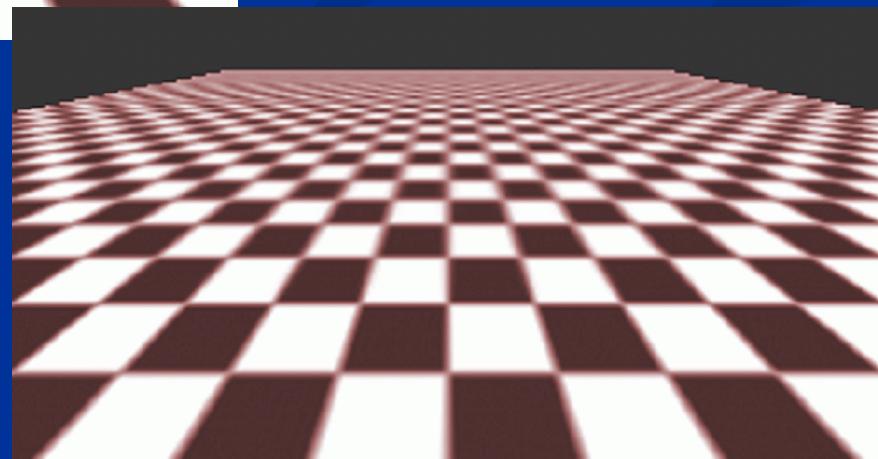
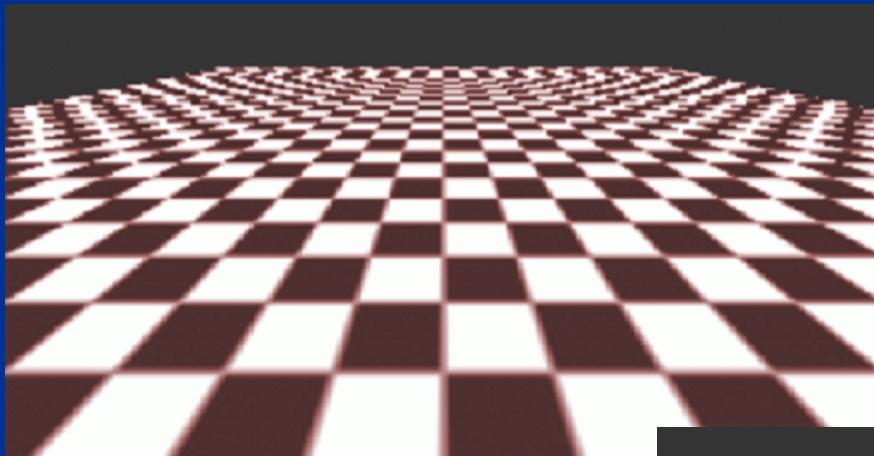


Tri-linear Interpolation

- As a result of MIP map
 - Resolutions of the screen and texture become similar
- Tri-linear Interpolation
 - Mapping of 1 pixel to 2 texels:
 - Generate a new map by blending Map #1 and Map #2
 - Apply bilinear interpolation

Antialiasing example

- Point sampling vs. Point sampling using mipmap



Antialiasing example

- Point sampling using mipmap vs. +bilinear interpolation

