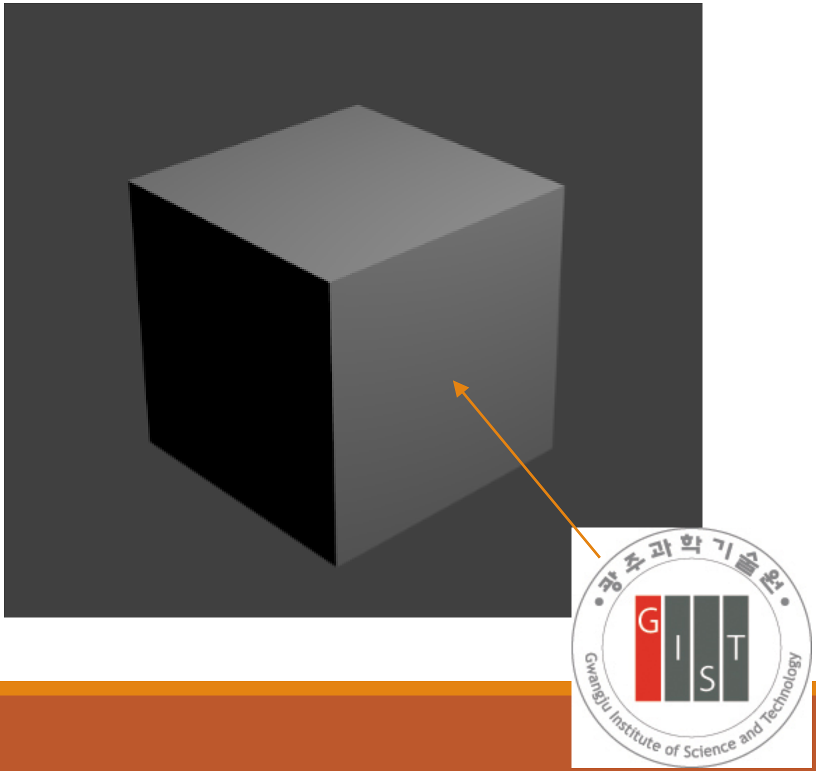
CT4510: Computer Graphics

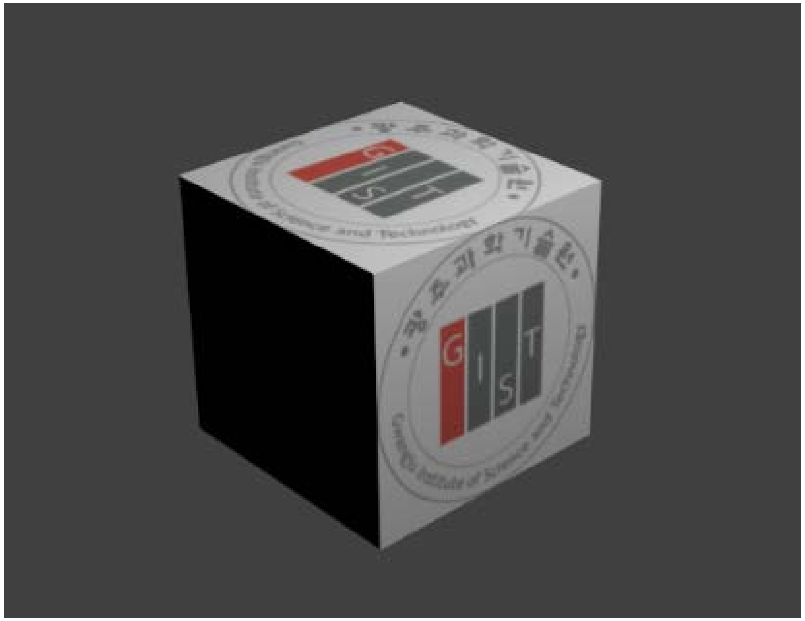
Texture Mapping

BOCHANG MOON

Texture Mapping

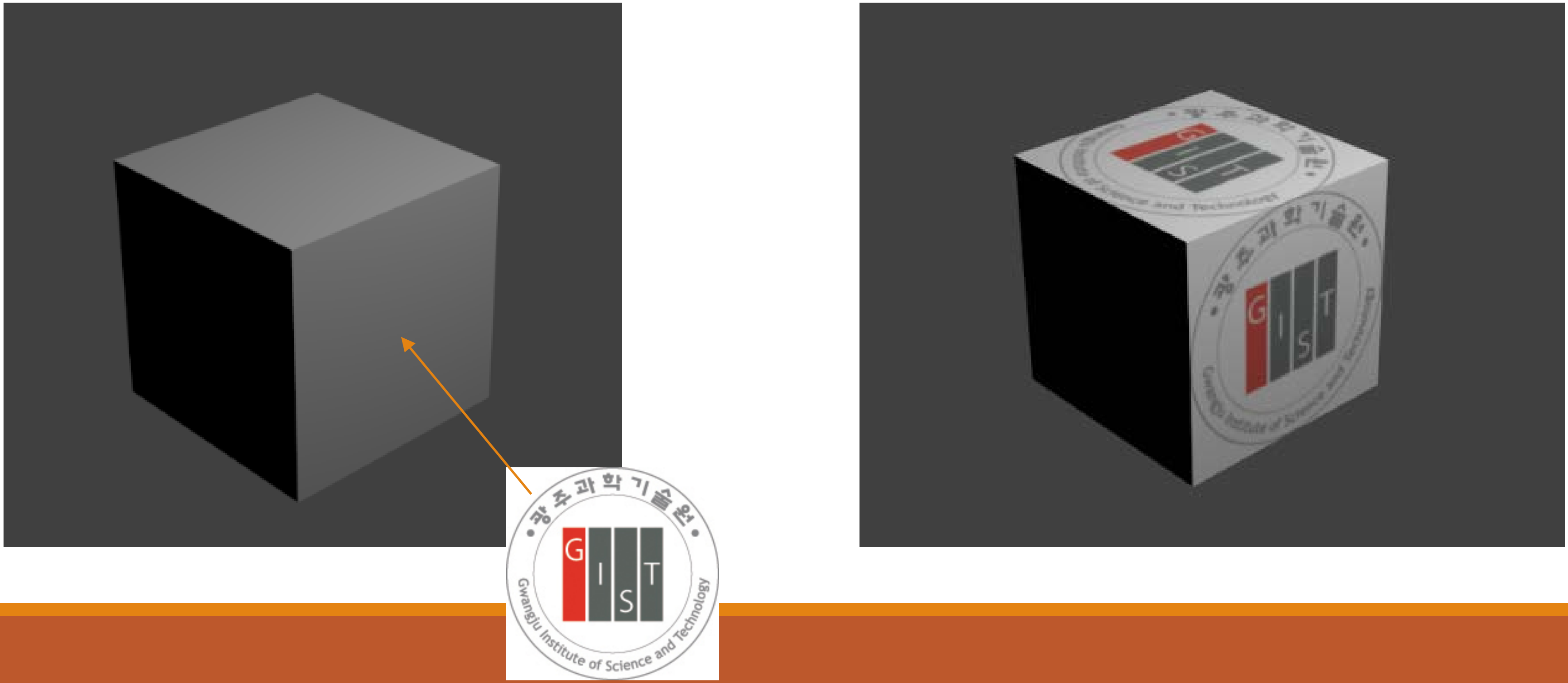
- Simulate spatially varying surface properties
  - Phong illumination model is coupled with a material (e.g., color)
  - Add small polygons with different materials
    - Very expensive





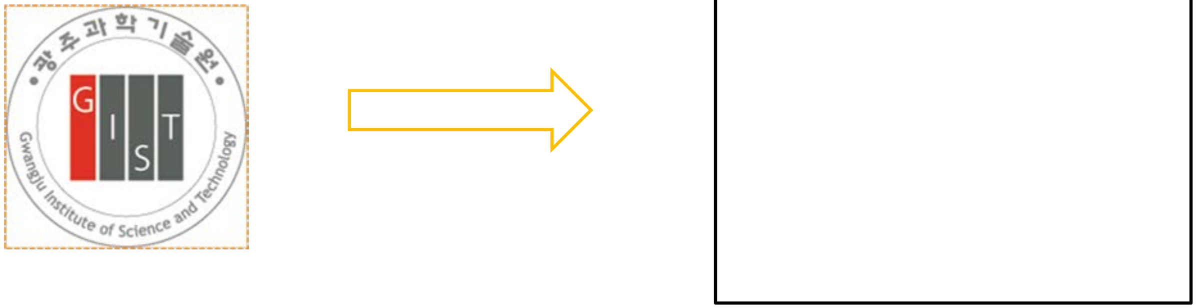
Texture Mapping

- Simulate spatially varying surface properties
  - Geometry of a surface dose not change, but materials need to be changed
  - Add an image onto the surface
  - Need to define a mapping function from the image to the surface



Texture Mapping

- Texture lookup
  - Color lookup(Image T, float u, float v) {
    - (x, y) = map_function(u, v)
    - return T(x,y)
  - }
- Note:
  - Each vertex has a texture coordinate (u, v)
  - A point inside a polygon has an interpolated coordinate



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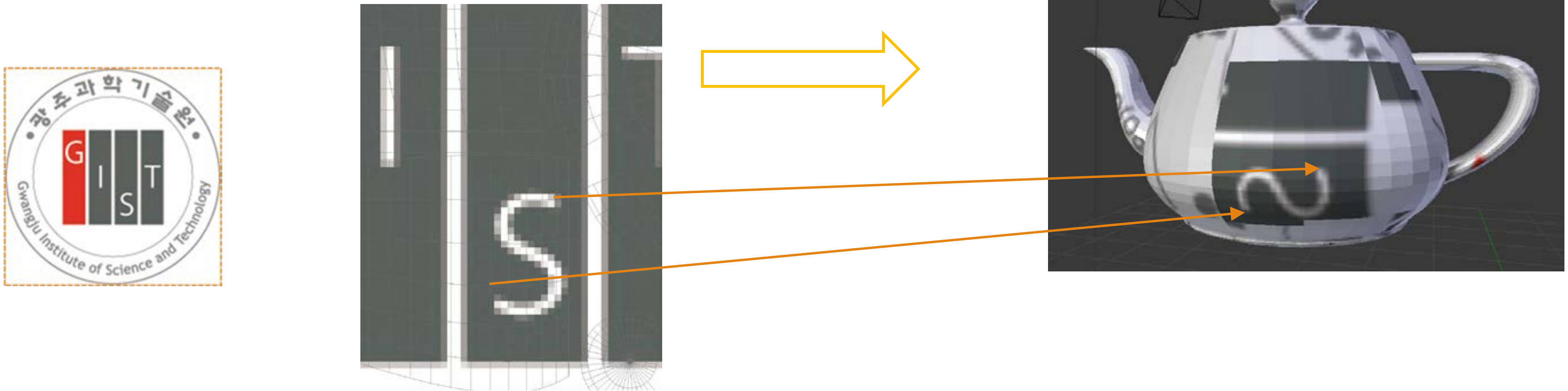
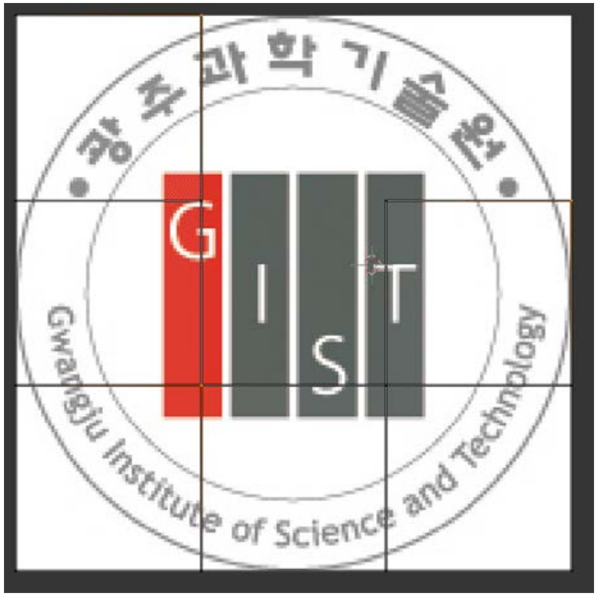
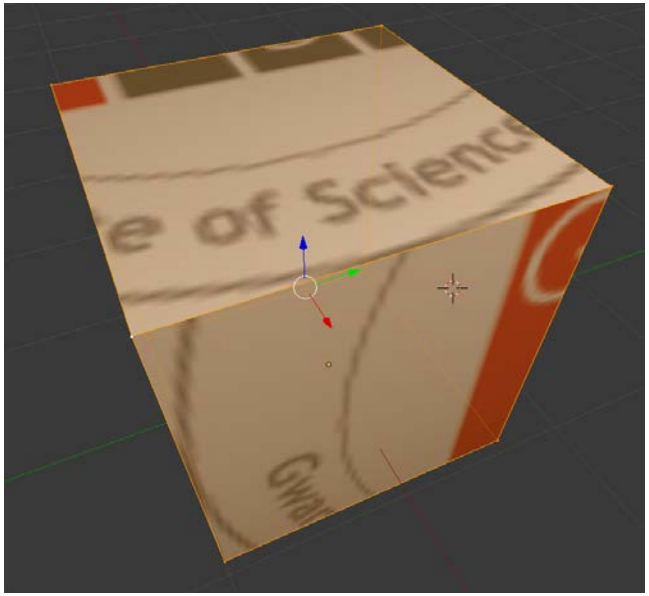


Texture Mapping in OpenGL

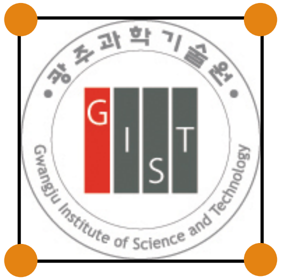
- Assign a texture coordinate, (u, v), to each vertex

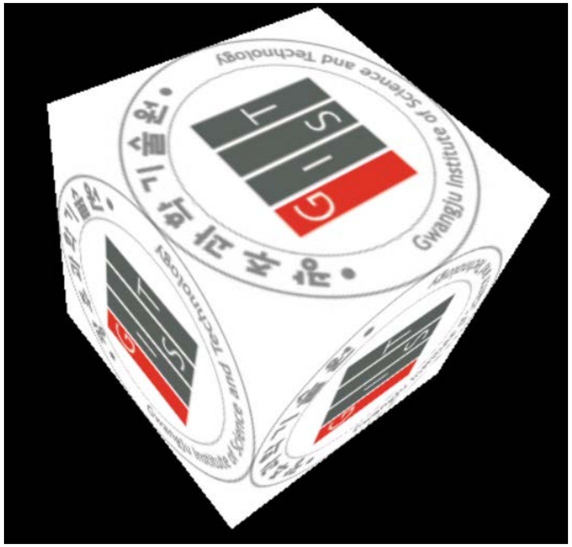




Texture Mapping in OpenGL

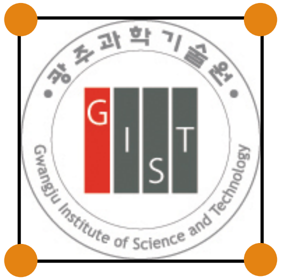
- General procedure for creating a texture map:
  - texImg = Read an image file (jpg, bmp, png, exr, …)
  - Gluint textureID[1];
  - glGenTextures(1, &textureID[0]);// create n texture name(ID) (e.g., n = 1)
  - glBindTexture(GL_TEXTURE_2D, textureID[0]); // bind a texture to the target (e.g., GL_TEXTURE_2D)
  - glTexImage2D(GL_TEXTURE_2D, 0, 3, width of texImg, height of texImg, 0, GL_RGB, GL_UNSIGNED_BYTE, data of texImg);
    - // 0: level-of-detail
    - // 3: number of color components

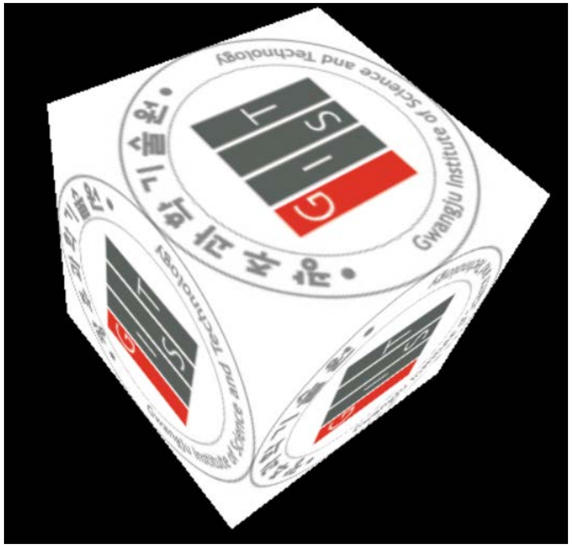




Texture Mapping in OpenGL

- General procedure of using the generated map:
  - glBindTexture(GL_TEXTURE_2D, textureID[0]);
  - glBegin(GL_QUADS);
  - // Front Face
  - glTexCoord2f(0.0f, 0.0f); glVertex3f(-1.0f, -1.0f, 1.0f);
  - glTexCoord2f(1.0f, 0.0f); glVertex3f(1.0f, -1.0f, 1.0f);
  - glTexCoord2f(1.0f, 1.0f); glVertex3f(1.0f, 1.0f, 1.0f);
  - glTexCoord2f(0.0f, 1.0f); glVertex3f(-1.0f, 1.0f, 1.0f);
  - …
  - glEnd();





Texture Mapping

- Assign texture coordinates (normalized coordinates) at each vertex
  - (u, v) in the range ([0…1], [0…1])
- Texture pixel (texel) is fetched given a (u, v) coordinate
  - e.g., (u, v) → (u_{tex}, v_{tex}) in the range $([0 \ldots width_{tex}], [0 \ldots height_{tex}])$
  - As a result, $(x, y) \rightarrow (u, v) \rightarrow (u_{tex}, v_{tex})$

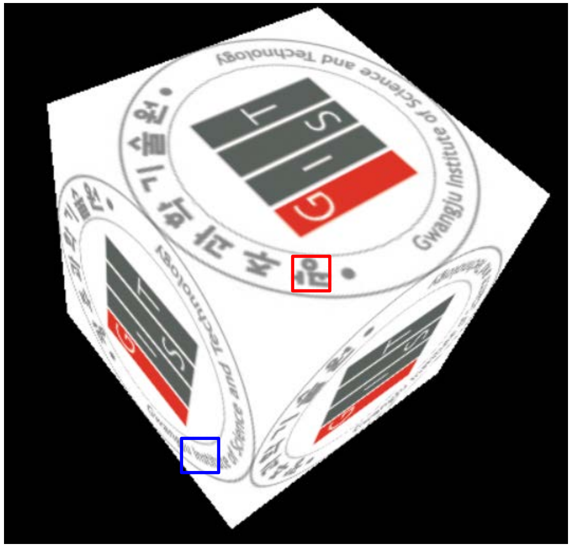
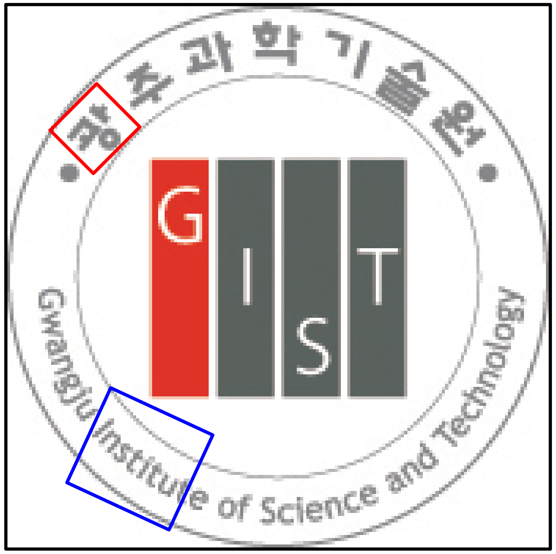


Image space



Texture space

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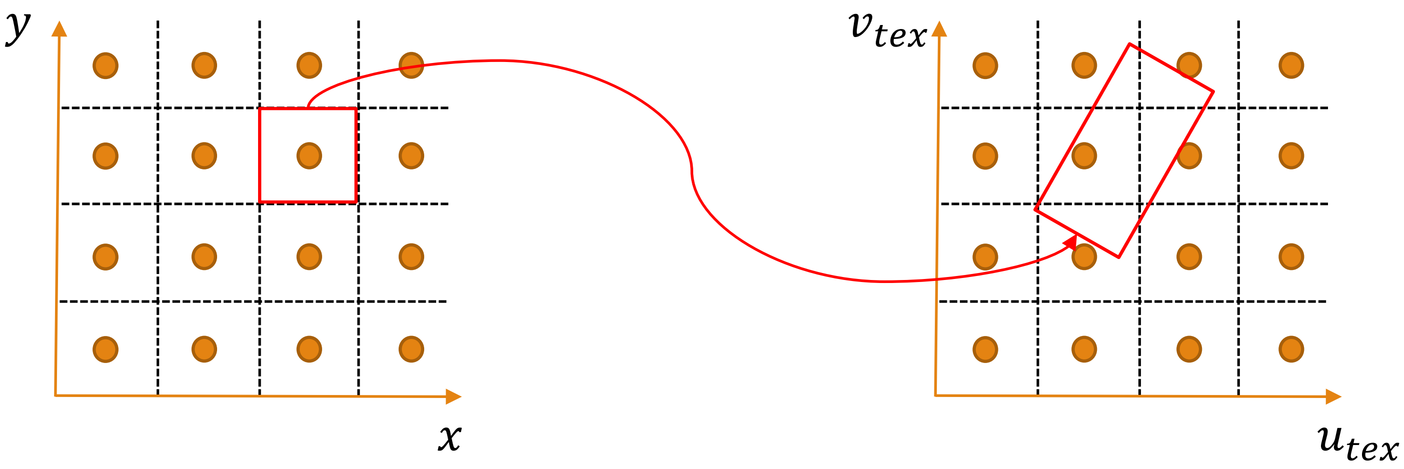
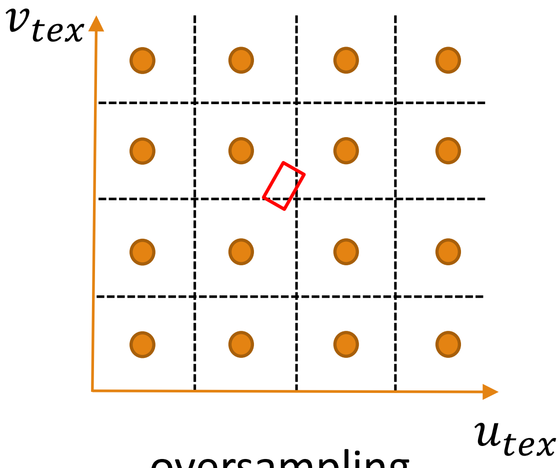
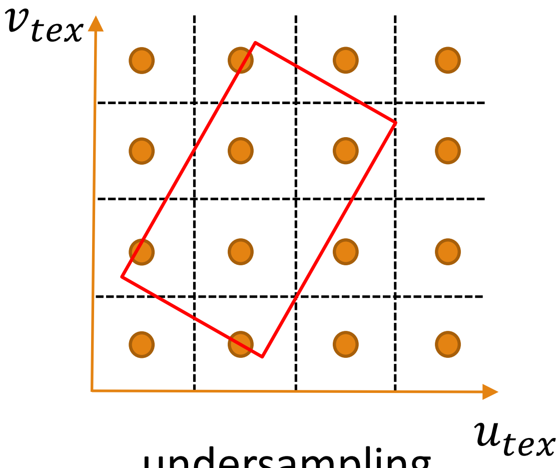


Issues of Texture Mapping

- Oversampling (magnification): one pixel is corresponding to less than a texel
- Undersampling (minification): one pixel is corresponding to more than a texel



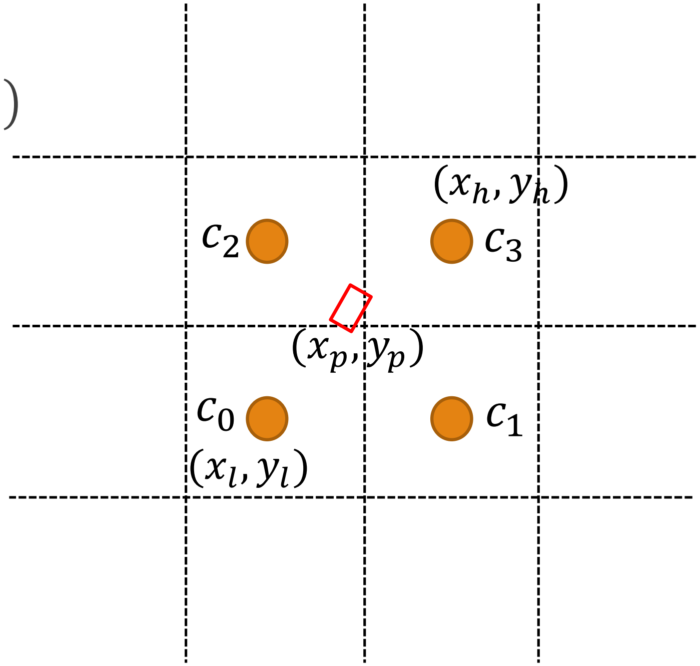
oversampling



undersampling

Texture Filtering for Oversampling

- Filtering methods
  - Nearest neighbor: take the color of the closest texel
  - Bilinear interpolation:
    - $\alpha = \frac{x_p - x_l}{x_h - x_l}$
    - $\beta = \frac{y_p - y_l}{y_h - y_l}$
    - $c_p = (1-\beta)\big((1-\alpha)c_0 + \alpha c_1\big) + \beta\big((1-\alpha)c_2 + \alpha c_3\big)$



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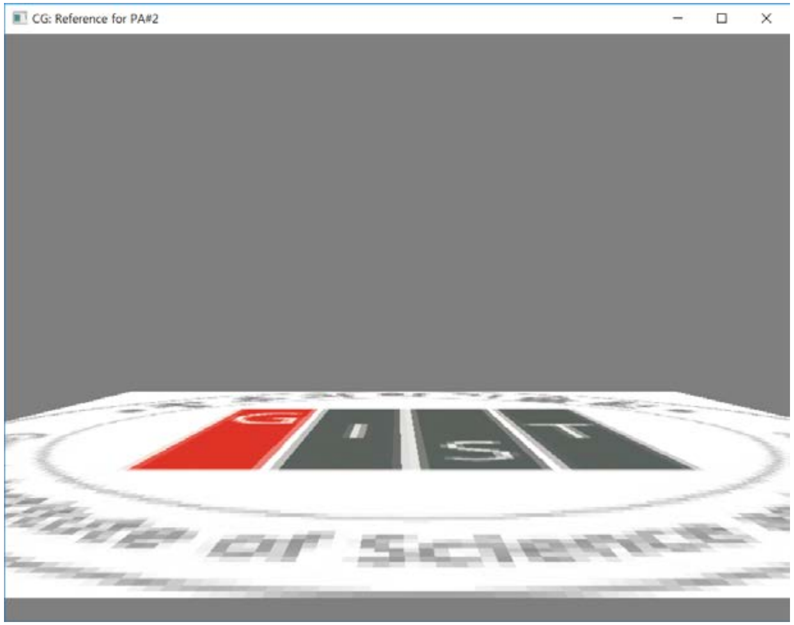
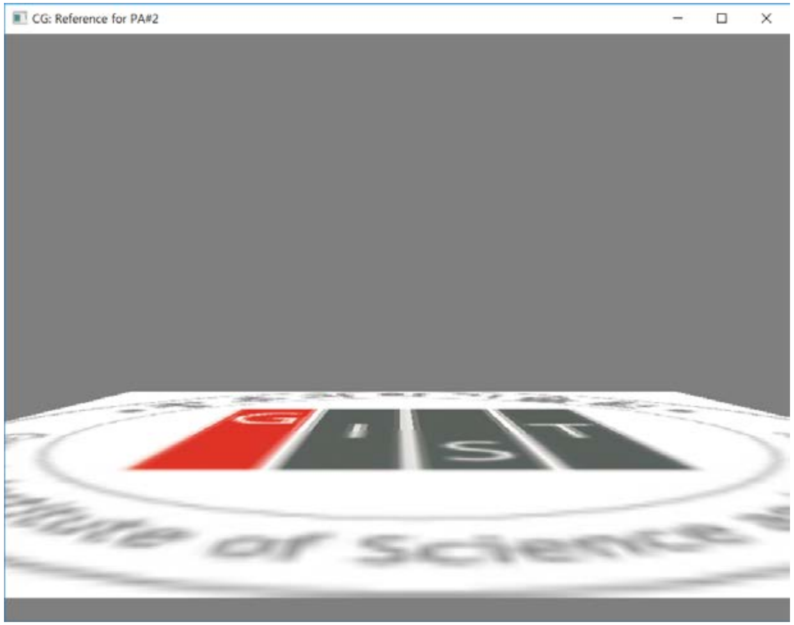
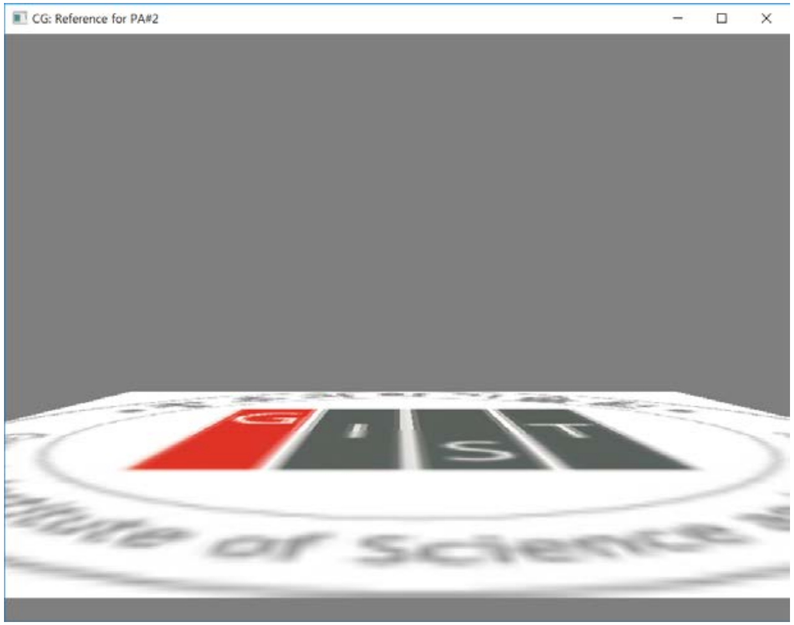
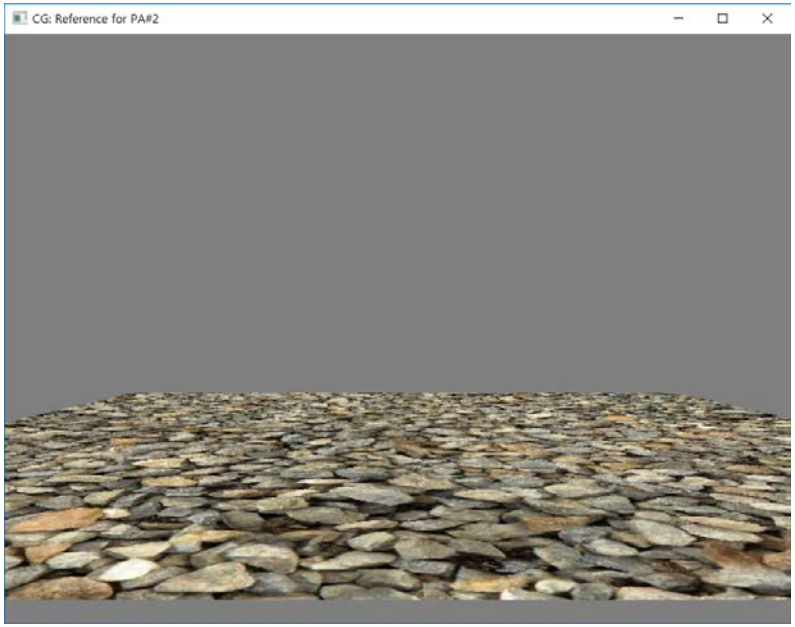




Texture Filtering for Undersampling

- High-frequency details in a small region introduce an image artifact (e.g., aliasing)
  - Should integrate multiple texels on the fly
    - Requires multiple read operations (expensive)





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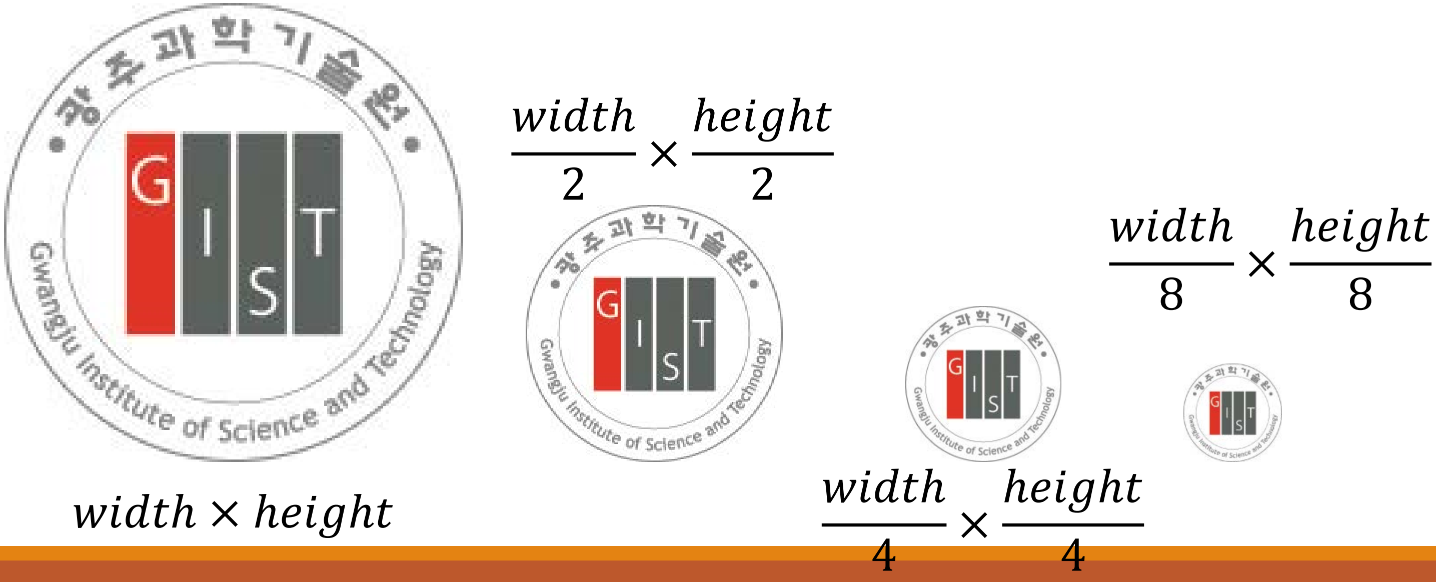
  - MIP Mapping: Prepare multiple-resolution (pre-filtered) images in preprocessing and select a texel from a MIP level



$width \times height$

$\frac{width}{2} \times \frac{height}{2}$

$\frac{width}{4} \times \frac{height}{4}$

$\frac{width}{8} \times \frac{height}{8}$

Texture Filtering for Undersampling

- High-frequency details in a small region introduce an image artifact (e.g., aliasing)
  - Should integrate multiple texels on the fly
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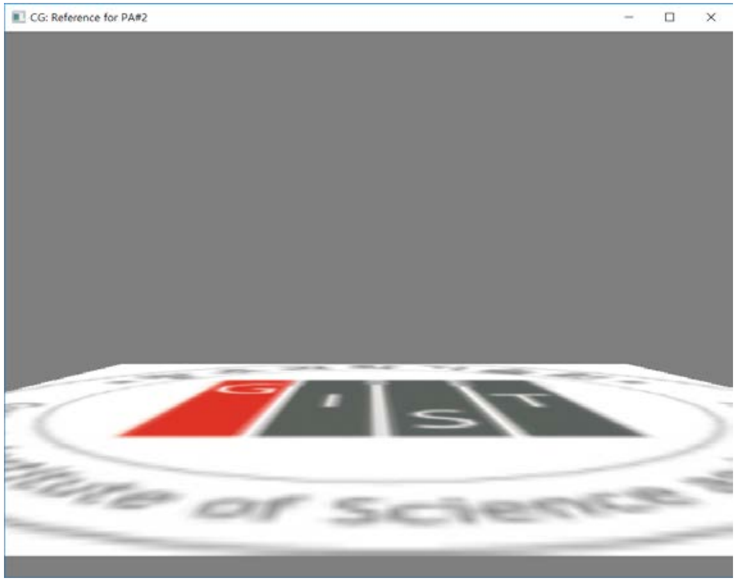
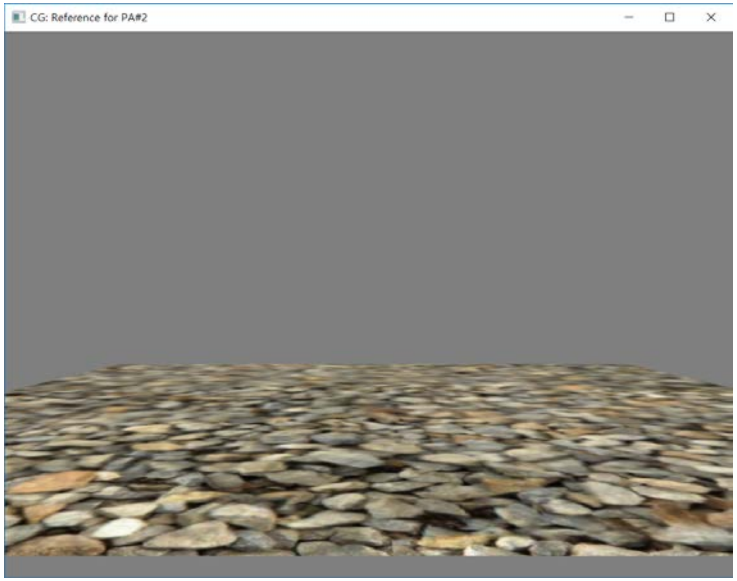
  - MIP Mapping: Prepare multiple-resolution (pre-filtered) images in preprocessing and select a texel from a MIP level
    - Two adjacent MIP levels can be interpolated





Texture Filtering in OpenGL

- MIP map generation
  - gluBuild2DMipmaps(GL_TEXTURE_2D, 3, width, height, GL_RGB, GL_UNSIGNED_BYTE, image data);
- Filtering methods
  - glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, filter);
  - glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, filter);
- Filters for magnification
  - GL_NEAREST, GL_LINEAR
- Filters for minification
  - GL_NEAREST, GL_LINEAR, GL_NEAREST_MIPMAP_NEAREST, GL_LINEAR_MIPMAP_NEAREST, GL_NEAREST_MIPMAP_LINEAR, GL_LINEAR_MIPMAP_LINEAR
  - Note: GL_XX_MIPMAP_LINEAR // choose the two MIP maps that closely match the size of pixels for an interpolation
  - Note: GL_LINEAR_MIPMAP_NEAREST // use the GL_LINEAR interpolation within a MIP level

Applications: Material Parameters

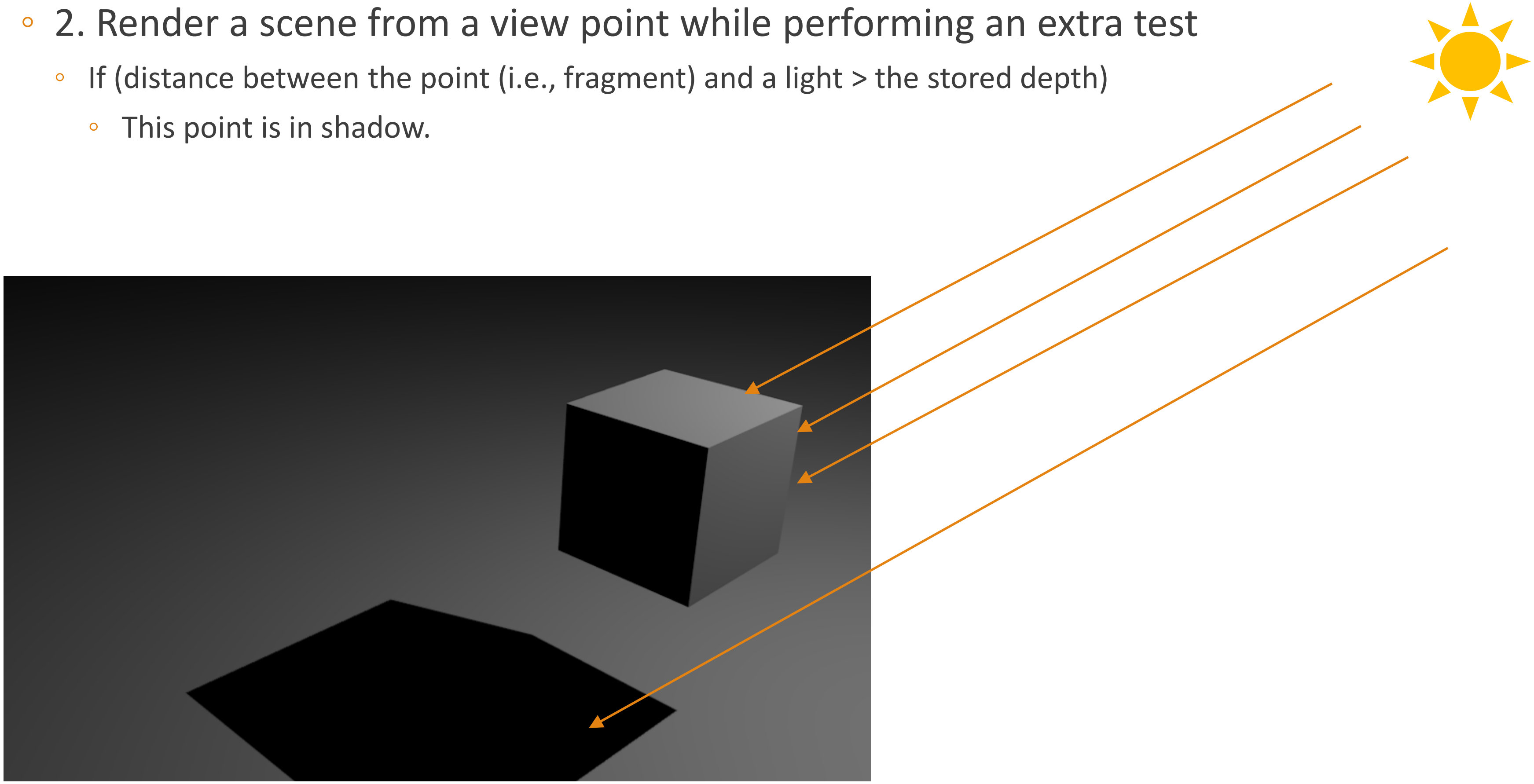
- Phong illuming model
  - $I = \sum_{i=1}^{\# \, of \, lights} L_a^i k_a + L_d^i k_d \max(0, \boldsymbol{n} \cdot \boldsymbol{l^i}) + L_s^i k_s \max(0, \boldsymbol{r^i} \cdot \boldsymbol{v})^s$

- Q. Which parameters can be changed from the texture mapping?
  - k_a, k_d, k_s

- Lights can be textured as well
  - e.g., TV screen or your monitor (area lights)

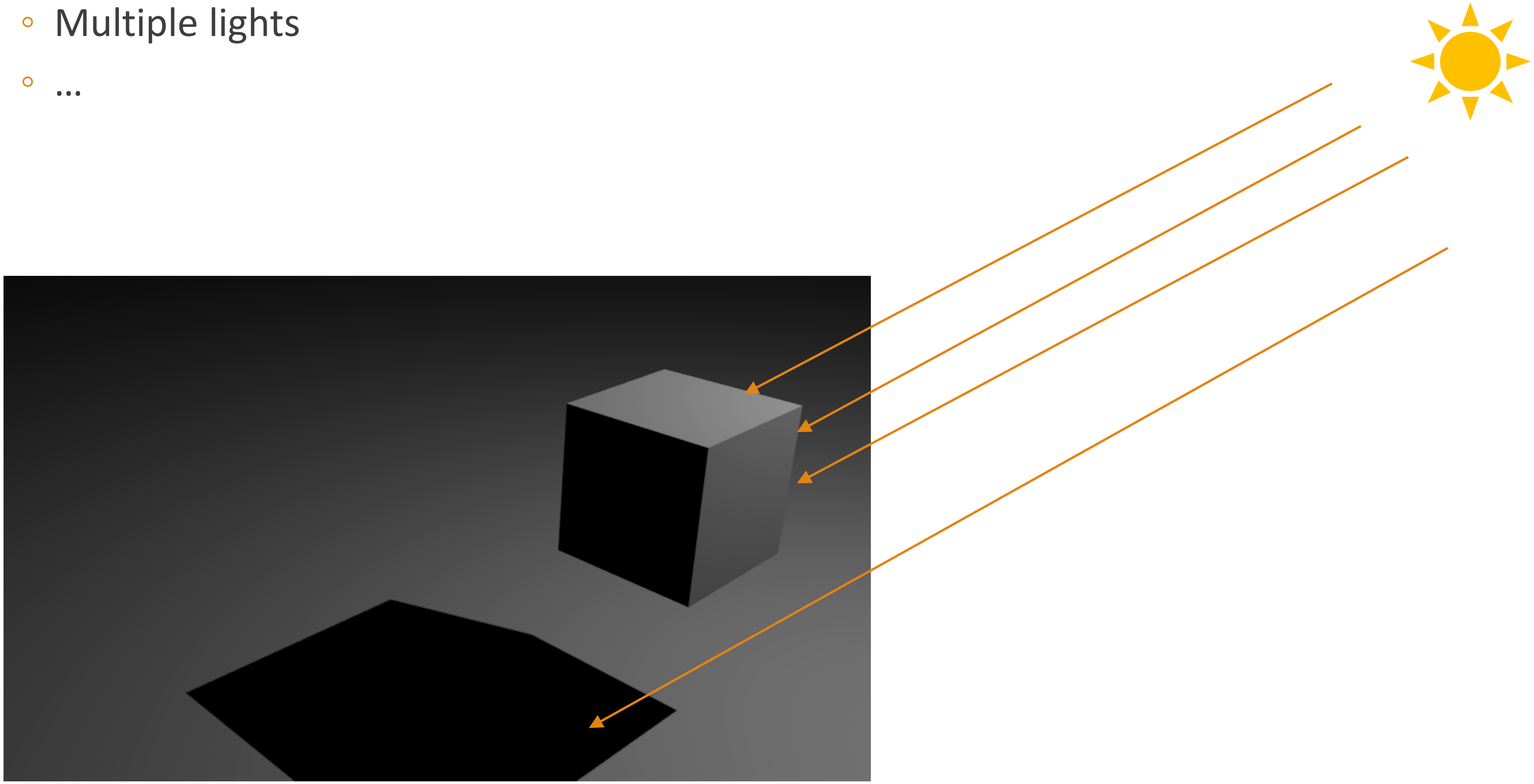
Applications: Shadow Maps

- Shadow mapping
  - 1. Pre-render a scene from a light source and store depths in a shadow map
  - 2. Render a scene from a view point while performing an extra test
    - If (distance between the point (i.e., fragment) and a light > the stored depth)
      - This point is in shadow.



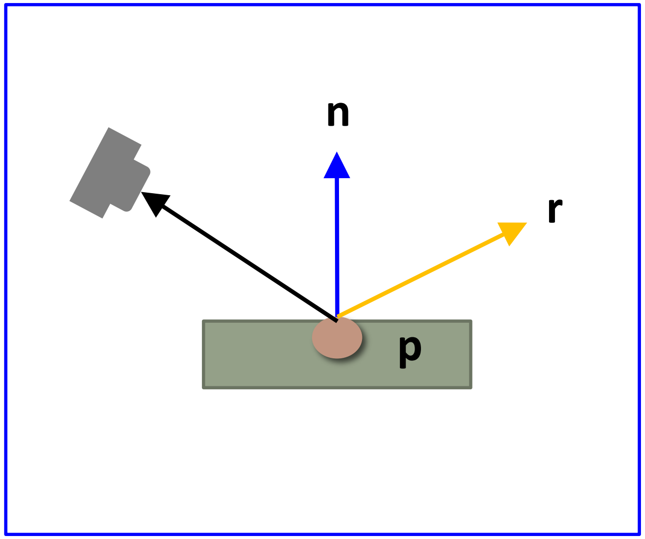
Applications: Shadow Maps

- Issues with shadow mapping
  - Area lights
  - Multiple lights
  - …



Applications: Environment Maps

- Environment mapping (reflection mapping) is an image-based lighting that approximates reflections (e.g., indirect illumination) on surfaces, by using pre-computed textures
  - Simple geometries (e.g., sphere, cube) are usually used to approximate the environment
    - The geometries are intermediate objects for texture mapping



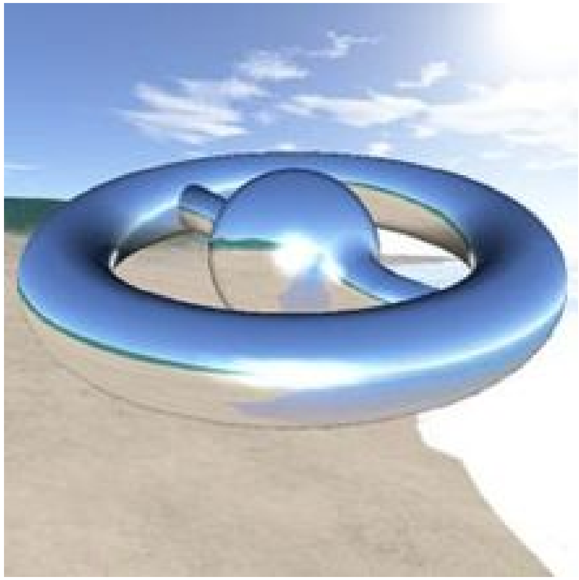


Image from en.wikipedia

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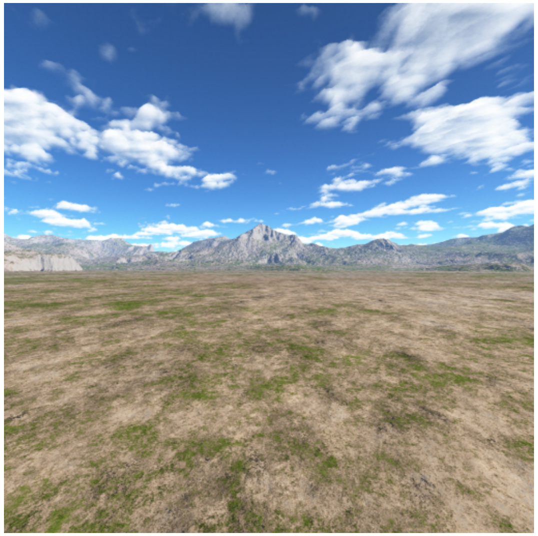
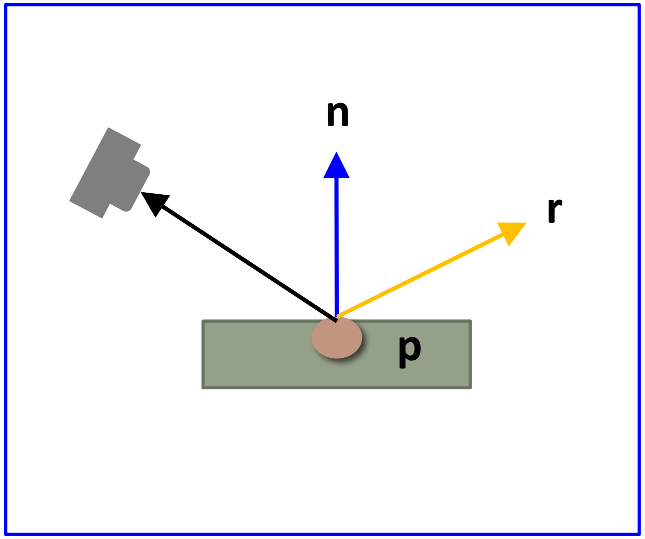
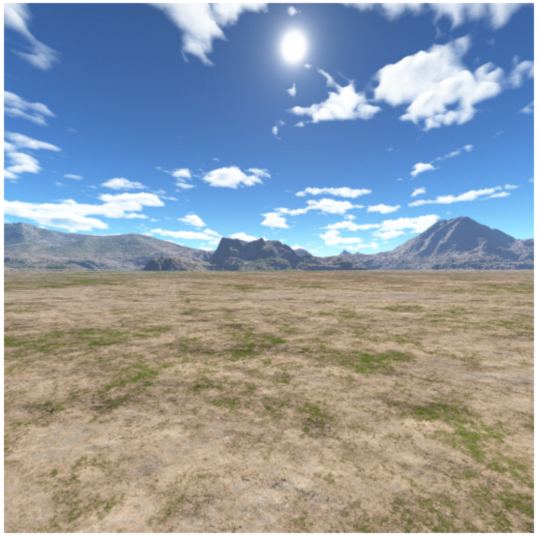
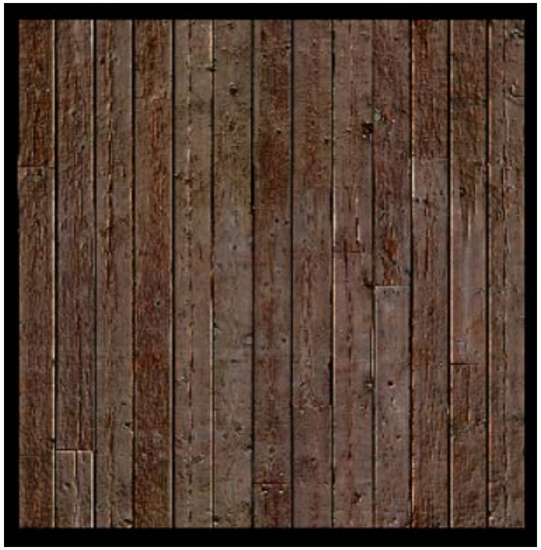






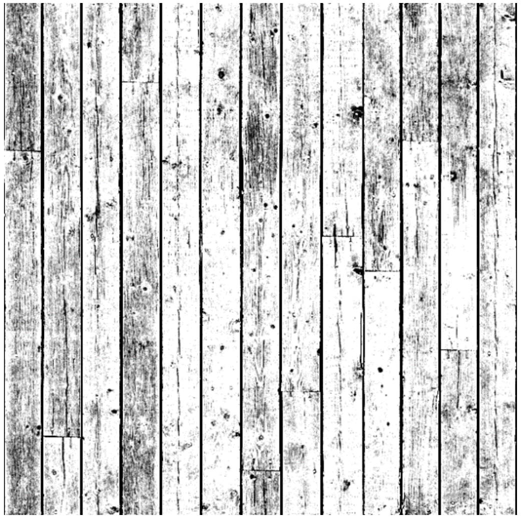
Applications: Bump Maps

- Approaches to model rough (bumpy) surfaces
  - Add complex geometries
  - Perturb surface normal based on a texture image



Rendering result

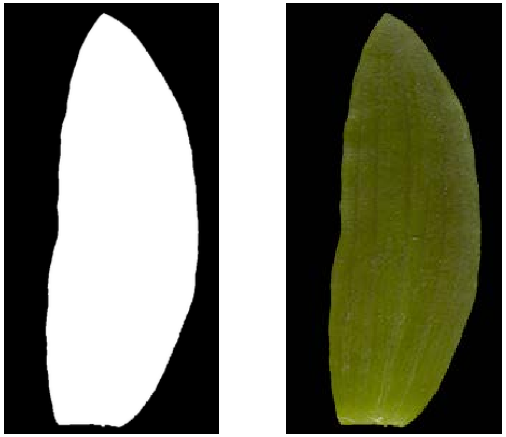
Diffuse texture map



Bump map

Applications: Other Maps

- Normal mapping
  - Replace the normal at a point with a pre-computed normal (r, g, b) at texel
- Opacity maps
  - Use black and white (or alpha channels) to make some areas of a surface transparent



Further Readings

- Chapter 11