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Cube Maps

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OpenGL®

Overview

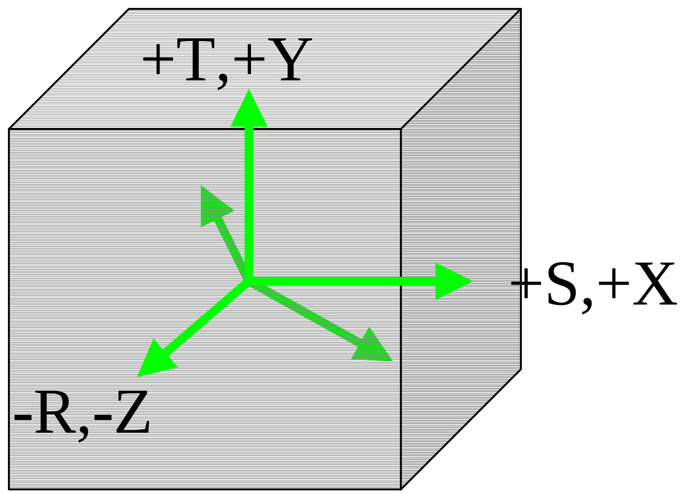
- What are Cube Maps?
- How to Create a Cube Map
- Using Cube Maps for Environment-Maps
- Pre-Calculated Specular & Diffuse Lighting

What Are Cube Environment Maps?

- **Cube Maps are made up of 6 square textures of the same size, representing a cube centered at the origin**
- **Each cube face represents a set of** directions **along each major axis**
- **+X, -X, +Y, -Y, +Z, -Z**
- **Think of a unit cube centered about the origin**
- **Each texel on the cube represents what can be 'seen' from the origin in that direction**

Visualizing the Cube Map

The Cube map is accessed via vectors expressed as 3D texture coordinates (S, T, R).



The greatest magnitude component, S, T or R, is used to select the cube face. The other 2 components are used to select a texel from that face.

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Cube Map Texture Coordinates

The calculation that is performed to generate the coordinates is simply a 3D $\rightarrow$ 2D projected texture.

1. **Select the highest magnitude component, let's say -T**
2. **Divide the other components by -T, giving**

$$S' = S / -T$$

$$R' = R / -T$$

Creating Cube Maps in OpenGL

- ARB_texture_cube_map & EXT_texture_cube_map
- Defines <cap> parameter
  GL_TEXTURE_CUBE_MAP_EXT
- Defines new texture <target> parameters for texture functions such as:
  glTexImage2D()
  glCopyTexImage2D()
  glCopySubTexImage2D()
  …

Creating Cube Maps in OpenGL

- ARB_texture_cube_map & EXT_texture_cube_map

- Defines new texture coordinate generation modes

  GL_REFLECTION_MAP_EXT

  GL_NORMAL_MAP_EXT

Creating Cube Maps in OpenGL

```
glTexImage2D( GL_TEXTURE_CUBE_MAP_POSITIVE_X_EXT, 0,
              GL_RGB8, w, h, 0, GL_RGB, GL_UNSIGNED_BYTE, face_px );
glTexImage2D( GL_TEXTURE_CUBE_MAP_NEGATIVE_X_EXT, 0,
              GL_RGB8, w, h, 0, GL_RGB, GL_UNSIGNED_BYTE, face_nx );
glTexImage2D( GL_TEXTURE_CUBE_MAP_POSITIVE_Y_EXT, 0,
              GL_RGB8, w, h, 0, GL_RGB, GL_UNSIGNED_BYTE, face_py );
glTexImage2D( GL_TEXTURE_CUBE_MAP_NEGATIVE_Y_EXT, 0,
              GL_RGB8, w, h, 0, GL_RGB, GL_UNSIGNED_BYTE, face_ny );
glTexImage2D( GL_TEXTURE_CUBE_MAP_POSITIVE_Z_EXT, 0,
              GL_RGB8, w, h, 0, GL_RGB, GL_UNSIGNED_BYTE, face_pz );
glTexImage2D( GL_TEXTURE_CUBE_MAP_NEGATIVE_Z_EXT, 0,
              GL_RGB8, w, h, 0, GL_RGB, GL_UNSIGNED_BYTE, face_nz );

glEnable( GL_TEXTURE_CUBE_MAP_EXT );
/* Render geometry. */

glDisable( GL_TEXTURE_CUBE_MAP_EXT );
```

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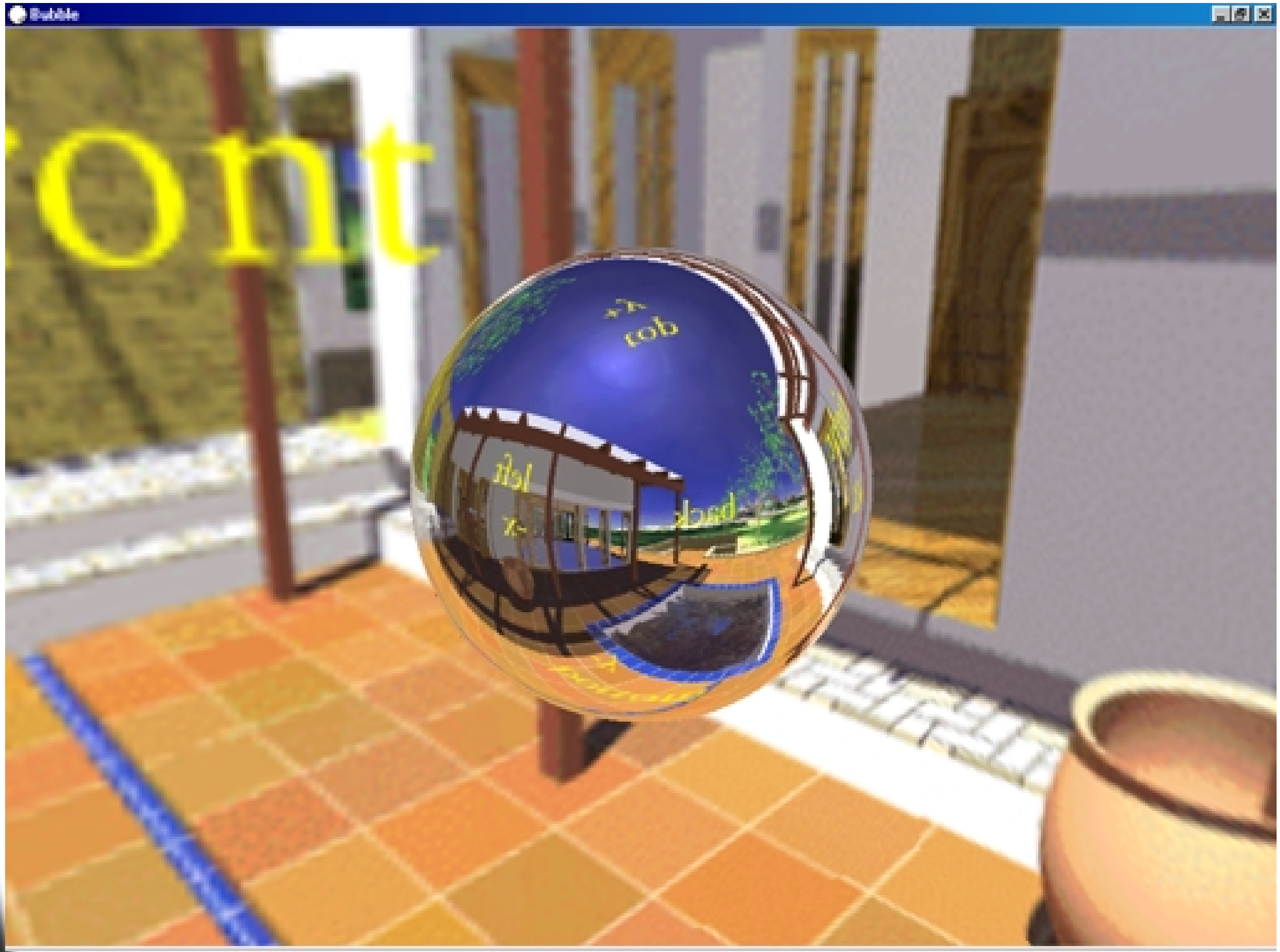
Environment Mapping with Cube Maps

- Reflections of environment on shiny objects
- Other techniques
  - Exhibit interpolation artifacts
  - More difficult to generate for dynamic scenes
- Cube Environment maps
  - Easy to generate on the fly
  - S,T,R can be automatically calculated in HW
  - Improved interpolation

Generating an Environment Map

- Set up a 90° FOV camera at the object's location
- Point the camera along +X, and render the (approximate) scene around your object into the first face of the cube map
- Repeat the process, facing -X, ± Y and ± Z into each face of the cube map
- You now have a dynamically generated environment map!

Example of Cube Environment Mapping



Optimizations

- Dynamic Cube Maps don’t have to be full resolution
- They also don’t need updating every frame
- Allowing updates to lag behind a frame prevents stalling in some cases

Cube Map for Pre-Computed Specular lighting (Illumination map)

- Use a cube map as a specular lighting solution for reflective objects :
  - The cubemap can be thought of as a function of a vector that returns a RGBA value.
  - Therefore, any lighting that relies on only a vector and constant values can be precalculated and stored in the cube map
  - Render only your specular lighting into your cube map (only valid for the current view vector)
  - Use camera space reflection texture coordinate generation
  - Use blurred or low resolution cube map for rough surfaces

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Cube Map for Diffuse Lighting

- To use the environment map as a diffuse lighting solution for diffuse objects :
  - Render only diffuse lighting into cubemap
  - Use GL_TEXTURE_GEN_MODE
    GL_NORMAL_MAP_EXT
  - Works well for directional (and distant) lights
  - Does not work well when light is very close to surface.

Dynamic Cube Maps

- **Cube map only needs to be updated when surrounding lights change**
  - **Can use the cube map to store pre-calculated lighting (i.e. lightmaps), and add in other lights on top**
- **Don’t typically have to update the cube map every frame**
  - **roughly represent the environment, it will look good**

Cube Maps as Vector Lookups

- **Think of a cube map as a way to store/lookup a function with a vector**
  - **The function can store a color or a vector**
  - **Can also store an alpha**

- **For example, a cube map can store color which represents a normalized a vector**
  - **Allows vector interpolation with normalization**
  - **V' = Normalize(V) on a per-pixel basis**
  - **Useful for bump mapping and per-pixel lighting**
  - **Called a *Normalization Cube Map***

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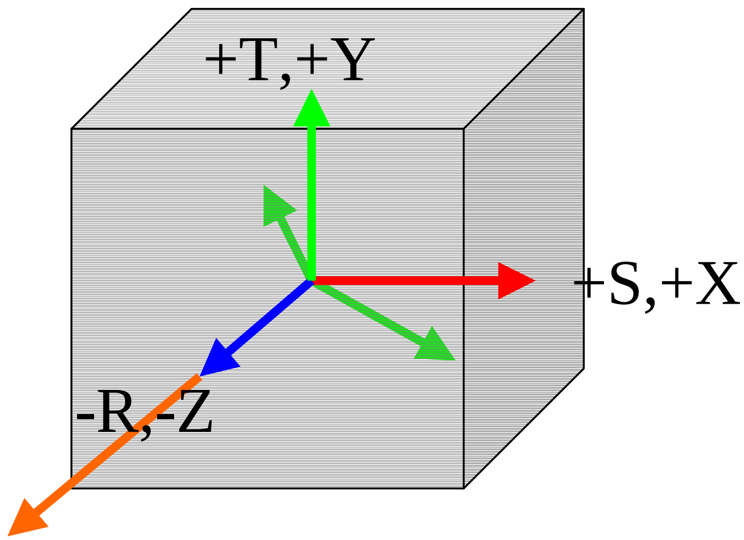
The Normalization Cube Map

The Cube map is accessed via vectors expressed as 3D texture coordinates (S, T, R).



The Orange Vector < 0, 0, -8 > is passed in.
The Blue Vector < 0, 0, -1 > is returned in RGB form as < 0x80, 0x80, 0x00 >.

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Cube Maps as Vector Lookups

- **Other useful functions**
  - **V' = -**V
  - **Color = (** L • N **)**
  - **Color = (** R • V **)^{n}**

Questions, comments, feedback

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