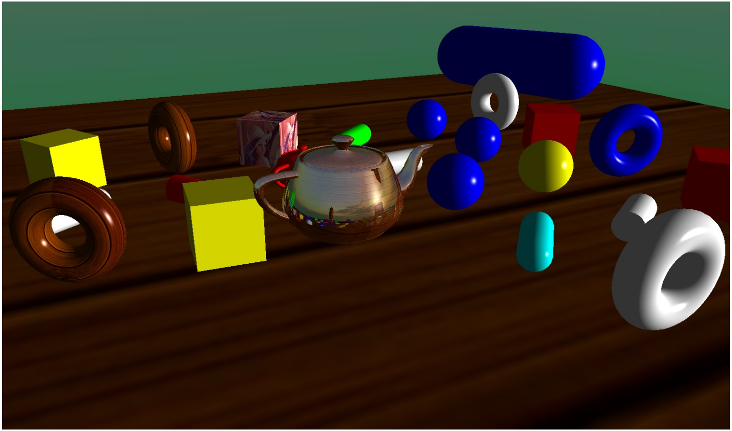
Lesson 8 – Geometry shaders
Environment mapping

PV227 – GPU Rendering

Jiří Chmelík, Jan Čejka
Fakulta informatiky Masarykovy univerzity

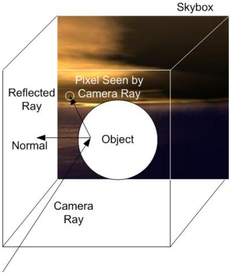
6. 11. 2017

Intermezzo – Environment mapping



Reflections: Environment mapping

Environment mapping



Source: Wikipedia

- $\overrightarrow{ReflectedRay} = \overrightarrow{CameraRay} - 2 \cdot \overrightarrow{N} \cdot dot(\overrightarrow{N}, \overrightarrow{CameraRay})$
- In GLSL: $ReflectedRay = reflect(CameraRay, N)$
- Assumes N is normalized

Task: Implement environment mapping

- **Task 1:** Implement environment mapping in *reflection_fragment.glsl*
  - Mix the environment reflection with the color of the object

Updating the cube map

- When the surrounding changes, the cube map with the environment should be updated.
- Six faces of the cube map means:
  - six cameras,
  - six framebuffer objects
  - six times traversing the scene
- Already implemented in the code.

Layered rendering

- Renders into multiple textures at the same time
  - Good for cube maps, stereo rendering etc.
- Different from attachments of FBOs
  - Attachments: Primitives are rasterized at the same places
  - Layers: Each layer has different primitives
- Renders triangles into layered textures:
  - cube maps (6 layers)
  - 2D texture arrays
  - 3D textures, 1D texture arrays, cube map arrays
- Use *glFramebufferTexture* to attach a layered texture into a framebuffer
  - All textures at all attachments must be layered
- Another usage of geometry shaders
- New output variable in geometry shaders: *gl_Layer*
  - Specifies the index of the layer into which the primitive is sent

Updating the cube map – layered rendering

- Updating all faces simultaneously means:
  - six cameras available at the same time
  - one framebuffer object with all faces
  - traversing the scene once
  - special vertex and geometry shaders

Task: Implement layered rendering

- **Task 2:** Implement layered rendering in *texture_to_cube_geometry.glsl* and compare the rendering speed
  - Generate 6 triangles (18 vertices), one for each face
  - Some vertex data do not change, the are computed in VS
    - ⋆ Pass them through geometry shader without change
  - Some vertex data (*gl_Position* and *gl_Layer*) are different for each face.
    - ⋆ Compute their values in geometry shader
- **Optional task:** Implement the same for the skybox in *skybox_to_cube_geometry.glsl*
- Test on the central object, use cube or sphere without reflections

Instanced geometry shader

- Problem: the geometry shader processes 18 vertices sequentially, not in parallel
- Possible solution: Instanced geometry shaders
  - Similar to instancing
  - Geometry shader is run multiple times per each input primitive
  - In GS: Instances = Incovations
  - Defined in geometry shader:

    layout (triangles, invocations = 6) in;
    layout (triangle_strip, max_vertices = 3) out;
  - Special variable *gl_InvocationID*:
    - Only in geometry shader
    - Similar to *gl_InstanceID*

Task: Implement instanced geometry shaders

- **Task 3:** Implement instanced geometry shaders in *texture_to_cube_invocations_geometry.glsl* and compare the rendering speed
  - Generate 1 triangle (3 vertices), 6 incovations, one invocation for each face
- **Optional task:** Implement the same for the skybox in *skybox_to_cube_invocations_geometry.glsl*

Parallelize even more

- Use instancning, i.e. render each object six times.
- Everything is computed in vertex shader, all vertices in parallel
- Geometry shader only copies the data of each vertex and sets *gl_Layer*
- **Task 4:** Implement this in *texture_to_cube_instancing_vertex.glsl* and *texture_to_cube_instancing_geometry.glsl* and compare the rendering speed
  - **Option:** Implement the same for the skybox in *skybox_to_cube_instancing_vertex.glsl* and *skybox_to_cube_instancing_geometry.glsl*

Parallelize even more, skip geometry shaders

- Modern graphics card may set *gl_Layer* also in vertex shaders, thus skipping the geometry shader completely
  - We need OpenGL extension *GL_ARB_shader_viewport_layer_array*, unfortunately, it is not available on computers in B311
- **Optional task 5:** Implement this in *texture_to_cube_instancing_no_gs_vertex.glsl* and in *skybox_to_cube_instancing_no_gs_vertex.glsl* and compare the rendering speed

Geometry Shaders Today

- not for tessellation, surpassed by tessellation shaders
- probably not for culling (not necessary)
- expanding a point to a quad (particle systems), compete with instancing
- expanding a line to a quad (grass, hair), in combination with tessellation shaders
- transform feedback (outputs vertices back into VBOs)
- layered rendering, instanced geometry shaders
    - not enough parallel, compete with instancing, not necessary when *gl_Layer* is set in vertex shaders