EECS 487 PA3: Textures, Buffers, Shaders

This assignment is due on Wednesday Nov. 12, 2014 at 10:00 pm

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Overview

In this assignment you will create a scene consisting of multiple spheres and cubes, apply a different texture to each object, and give a bumpy-looking appearance to each surface using normal mapping. You will also get a chance to exercise your understanding of vertex-array object, the use of shader custom vertex attributes and texture samplers, and the use of multiple texture units.

Graded tasks summary (100 points)

1. Transfer your vertex-buffer object code from Lab 6 to the provided support code. (5 points)
2. Create and texture a cube: fill out `init_cube()` and `draw_cube()`, both in `objects.cpp`. (15 points)
3. Use vertex-array object to alternately display a sphere or a cube. (5 lines in `init_world()` and 2 lines in `draw_world()`, both in `objects.cpp`). (10 points)
4. Load multiple textures and texture the objects in task 2 using a different texture for each object. (3 lines in `scene.cpp:init_texture()` and 2 lines in `objects.cpp:draw_world()`). (10 points)
5. Replace client-side vertex attribute with shader attributes (`objects.cpp:init_{sphere,cube}(), nmap.vs`). (10 points)
6. Use shader texture samplers (2 lines in `scene.cpp:init_textures()`, 2 lines in `nmap.vs`, 3 lines in `nmap.fs`, and at least 4 lines in `objects.cpp:init_{sphere,cube}()`). (15 points)
7. Use multiple texture units and implement normal mapping. (25 points)
8. Make a scene that incoprates at least 3 objects consisting of normal-mapped sphere(s) and cube(s). Preferably the scene tells a story or expounds upon a concept. (10 points)

The tasks above build on each other, so you should finish debugging one task before moving on to the next task. You may not be able to return to work on the previous task once you have started on the next one.

Implementation details

TASK 1: Vertex-Buffer Object

This assignment builds upon Lab 6. As with PA1, your first task is to transfer your Lab 6 solution to the provided support code. You will be modifying files `scene.cpp` and `objects.cpp` for this task. Your solution to Lab6 is required to have used `GL_TRIANGLE_STRIP` instead of `GL_QUADS`. All vertex attributes (position, color, normal, tangent, texture coordinates) must use vertex-buffer object with

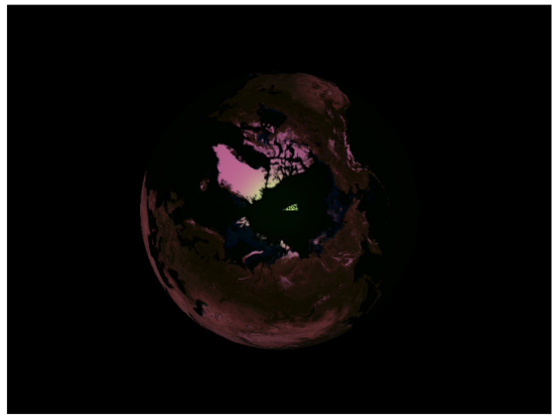
HW1

HW2

Don't see the menu?

mapped buffer instead of copying from client-side vertex arrays or using immediate mode. If you are not able to complete Lab 6, you may use our solution instead. However, we will not be making the solution available until after Lab 6 is due and you will be forfeiting the 5 points of this task.

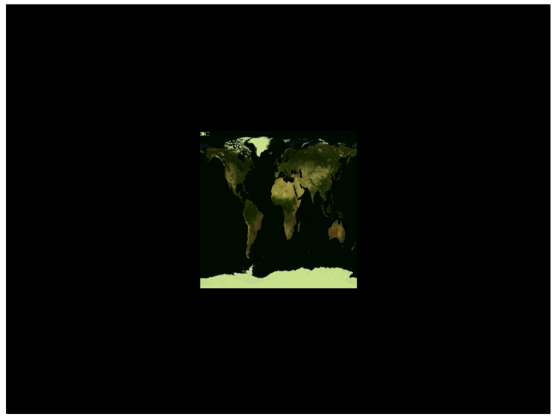
As usual, the provided code files are commented to mark the locations of each task. They also come with sometimes helpful remarks and hints. After you have completed Task 1, running the provided code using the command line: `scene -t images/BlueMarble2004-08.tga` renders one of the following images. The image is generated by modulating the texture with surface shading instead of just replacing it. All keyboard shortcuts controlling modeling transforms from Lab 6 apply.



Visual Studio: to process the commad line options, we use the `getopt()` API. If you're building on Windows with Visual Studio, you need to add `common/src/wingetopt.c` and `common/src/wingetopt.h` to your project. You may also need to tell Visual Studio the location of `wingetopt.h`. If you don't know how to do that, please consult the course note on the topic.

TASK 2: Cube rendering

Your second task is to render and texture a cube using client-side vertex attributes. Review the code in `init_sphere()` and `draw_sphere()` and adapt them to draw a cube. Modern OpenGL no longer supports `GL_QUADS`, thus you *must* use `GL_TRIANGLES` to model your cube. The important thing to remember here is that you want your cube to have sharp edges. Polygons sharing a cube edge all face different directions, so the normals of shared vertices should not be averaged. In modeling your cube, you *must* use vertex-buffer object with mapped buffer instead of copying from client-side vertex array or using immediate mode. After you've completed `init_cube()` and `draw_cube()` in `object.cpp`, set `drawobject=CUBE` in `scene.cpp:main()` before re-building the binary. Upon completion of this task, running the program with the "Blue Marble" texture should render this image (the orientation of the texture doesn't matter):



TASK 3: Vertex-array object

In this program we recognize only three shape alternatives: `SPHERE`, `CUBE`, and `NOBJS`, where `NOBJS` means both sphere and cube (see `objects.h`). Your third task is to encapsulate all the states for rendering each shape in a vertex-array object. This is accomplished in `objects.cpp:init_world()` by first generating `NOBJS` vertex-array objects, then binding to the vertex-array object for `SPHERE` before calling `init_sphere()`, and then binding to the vertex-array object for `CUBE` before calling `init_cube()`. To enable alternate rendering of the sphere and cube, in `objects.cpp:draw_world()`, bind to the corresponding vertex-array object before calling `draw_sphere()` or `draw_cube()`. You may use a global array to hold the vertex-array object handles so that they are accessible in both `init_world()` and `draw_world()` functions. Set `drawobject=NOBJS` in `scene.cpp:main()` before re-building the binary. When you run the updated program, you'll see a blank, black screen. Pressing the '`b`' or '`c`' key renders a sphere or a cube as shown above respectively.

TASK 4: Multiple texture objects

As is, `scene.cpp:init_textures()` creates `ntexs` number of texture objects, but the code from Lab 6 loads only a single texture. Modify the function such that it loads `ntexs` number of textures into as many texture objects. Then in `objects.cpp:draw_world()` bind with the corresponding texture before calling `draw_sphere()` and `draw_cube()`. Run the updated program with two different textures, e.g., `scene -t images/BlueMarble2004-08.tga -t images/borg_Celtic_Entropy.tga`. You'll see a blank, black screen; pressing the '`b`' or '`c`' key renders a sphere or a cube as before, but each textured differently.

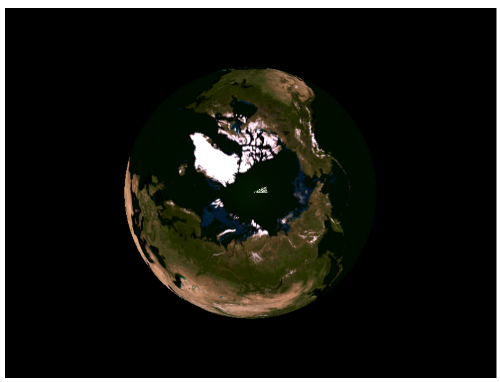
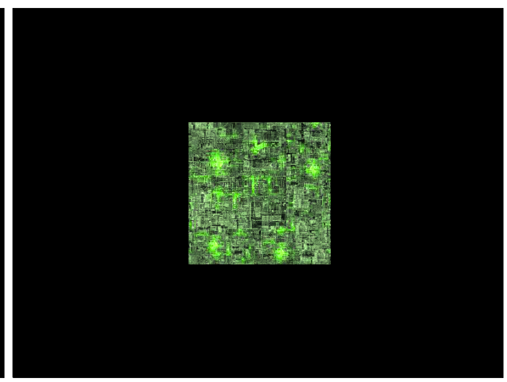
TASK 5: Shader custom vertex attributes

The provided, skeletal vertex shader `nmap.vs` uses client-side vertex attributes such as `gl_Vertex` and `gl_Normal` to perform its computations. Modify `nmap.vs` to use custom vertex attribute variables for vertex position and vertex normal. In `objects.cpp:init_sphere()`, first get the location of the custom vertex attributes using `glGetAttribLocation()`, then enable the vertex attributes and pass the corresponding attribute arrays to the shader using `glEnableVertexAttribArray()` and `glVertexAttribPointer()`. The shader program handler that you need to set the custom vertex attributes is declared as a global variable (`spd`) in `scene.cpp`. Near the top of `scene.cpp` replace the default `shader_mode` from `NONE` to `NMAP` to have the program load your shaders instead of using the fixed-function pipeline. You should be able to build an updated program that renders an untextured sphere when '`b`' is pressed. Similarly enable vertex position and normal attributes in `init_cube()` to render an untextured cube when pressing 'c'.

As of OpenGL 3.1, using vertex-array objects, vertex-buffer objects, and custom vertex attribute locations is considered the ``correct'' way of passing vertex attributes from the application to the shader. With OpenGL ES (WebGL), this is the *only* way. The way we passed vertex attributes in lab5 and lab6 and prior to this task are considered "deprecated."

TASK 6: Shader texture sampler

Modify `objects.cpp:init_sphere()` to pass texture coordinates to the shader as a vertex attribute. Similarly, modify `object.cpp:init_cube()`. In `nmap.vs`, pass the texture coordinates attribute as a varying variable to the fragment shader. In `scene.cpp:init_textures()` use `glGetUniformLocation()` and `glUniform1i()` to get the texture sampler location and specify texture unit 0 as the texture sampler. In `nmap.fs` declare the texture sampler as a uniform variable to be set by the application and the texture coordinates as a varying variable to be passed in by the vertex shader. Then sample the texture at the texel specified by the texture coordinates and compute lighting at the fragment using the texel. Running the updated program with `scene -t images/BlueMarble2004-08.tga -t images/borg_Celtic_Entropy.tga` and pressing "b' and 'c' should render the following images respectively.

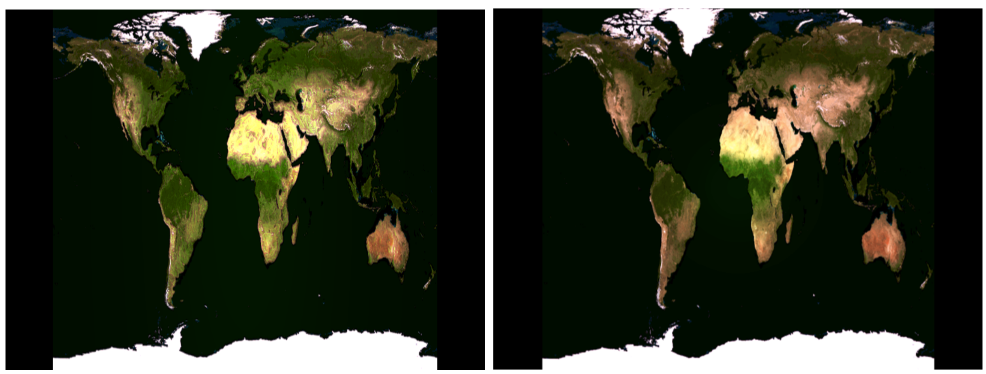



TASK 7: Multitexturing and Normal Mapping

Normal maps can be specified on the command line using the `-n` option, e.g., `scene -t images/BlueMarble2004-08.tga -n images/BlueMarble2--4=08-Normal.tga`. If multiple texture and normal maps are specified, the program pairs them up in order. In `scene.cpp:init_nmaps()` load the normal maps into texture unit 1. This function pretty much duplicates `scene.cpp:init_textures()` except you need to call `glActiveTexture()` before creating the texture objects and loading the texture files. It is made a separate function from `init_textures()` simply for ease of separating the tasks in this assignment. In `objects.cpp:draw_world()`, for each texture unit, bind the appropriate texture object you have intended for each shape before calling its draw function.

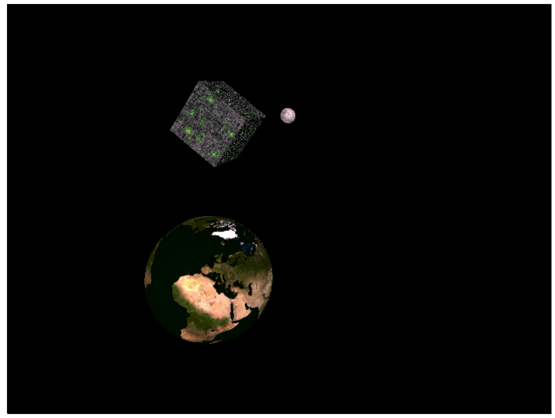
You may want to review the lecture notes on normal mapping. As explained in the lecture notes, the next step is to compute a tangent per vertex. If a vertex is shared by multiple polygons forming a curved surface, you most likely want to compute an average tangent for the vertex, including at the seam where the texture wraps around and meets itself. Modify your code in `objects.cpp:init_sphere()` and `objects.cpp:init_cube()` to compute and pass along per vertex tangent to the vertex shader. You would need to add the tangent attribute to the `sphere_vertex_t` structure (and the corresponding structure for your cube). Figuring out how to compute average tangent per vertex could be rather time consuming (though it's more straightforward for cube than for sphere). For that reason, you may want to complete the earlier tasks as soon as they have been covered in lecture and not wait for the last week before the due date to start this assignment.

In `nmap.vs` use the tangent and normal vertex attributes to compute the bitangent at the vertex and compute an orthonormal TBN matrix. Use the inverse of the TBN matrix to transform the light and view vectors to tangent space and pass them to the fragment shader. In `nmap.fs`, sample the normal map passed in by the application at the texture coordinates passed in by the vertex shader (the same ones used to sample the texture map) and use the sample from the normal map as the per-fragment normal. Using the view and light vectors in tangent space passed in by the vertex shader, along with the sampled normal, compute the per-fragment lighting. Modulate the computed light with the texel sampled from the texture map to shade each fragment. The following images show the "BlueMarble" texture mapped onto a cube face with and without normal mapping respectively. Note the extra details in north Africa, for example, in the image rendered with normal mapping.



TASK 8: Make a scene!

Let your creativity loose and create a scene involving at least 3 objects incorporating both spheres and cubes. Remember that you can shear the shapes and apply other transforms to them. You also don't have to limit yourself to the provided texture and normal files (if I forgot to talk about how to create normal maps using `gimp`, please ask me). Don't skip this step. Even if you have completed only the first three tasks, if your scene is compelling enough, you will get partial credit for it. Here's an obvious scene (you have to come up with something better!). Running your program should now show your scene. To help debug each individual shape, you can switch to showing only the first sphere or the first cube by pressing '`b`' or '`c`' respectively. Pressing '`a`' returns you to full scene rendering.



Submission Guidelines

As with PA1, to incorporate publicly available code in your solution is considered cheating in this course. To pass off the implementation of an algorithm as that of another is also considered cheating. For example, if the assignment asks you to implement sort using heap sort and you turn in a working program that uses insertion sort in place of the heap sort, it will be considered cheating. If you can not implement a required algorithm, you *must* inform the teaching staff when turning in your assignment, e.g., by documenting it in your writeup.

The creative portion of this project, Task 8, will take a long time if you are interested in getting a good grade. This involves a lot of trial and error. You **must** post the image(s) from your Task 8 to the course's [Image Gallery](#) by logging in to a CAEN/ITD linux machine and running the following:

```
% cd <to where your image.png file is located>
% /afs/umich.edu/class/eecs487/scripts/postimg <image.png>
[<image2.png ...>]
```

Test the compilation! Your submission must compile without **errors** and **warnings**. Code that does not compile will be heavily penalized.

Create a writeup in **text format** that discusses:

1. Your platform: Linux, Mac OS X, Windows, or any other.
2. Anything noteworthy about your implementation, e.g., if you implemented cube mapping.
3. URL of any web site you cited, either for texture file or cube modeling.
4. Feedback on the assignment.
5. Name the file writeup-*uniqname*.txt.
   For example, the person with uniqname *tarukmakto* would create *writeup-tarukmakto.txt*.

Your "*PA3 files*" then consists of your `writeup-uniqname.txt`, `scene.cpp`, `objects.cpp`, `nmap.vs`, `nmap.fs`, and any texture and normal map files you created or used for Task 8.

To turn in your PA3:

1. Email the GSI the SHA1's of your *PA3 files*. Use "EECS487: PA3 Submission" as your email's "Subject:" line. Once you've sent in your SHA1's, don't make any more changes to the files, or your SHA1's will become invalid.
2. Upload your *PA3 files* to your `pa3` folder on MFiles:
   `https://mfile.umich.edu/?path=/afs/umich.edu/class/eecs487/f14/FOLDERS/<uniqname>/pa3/`.

Replace "<uniqname>" with your uniqname. Please report any problems to ITCS.

3. Keep your own backup copy! Don't make any more changes to the files once you've submitted your final SHA1's.

The timestamp on your SHA1 email will be your time of submission. If this is past the deadline, your submission will be considered late. You are allowed multiple "submissions" without late-policy implications as long as you respect the deadline. Try not to email your SHA1 to the GSI until you've finalized your code. You don't want to annoy him.

Turn in ONLY the files you have modified. Do not turn in support code we provided that you haven't modified. Do not turn in any binary files (object, executable, dll, or library files) with your assignment.

Do remove all `printf()`'s or `cout`'s and `cerr`'s you've added for debugging purposes.

General Information

The General Information section from PA1 applies. Please review it if you haven't read it or would like to refresh your memory.