CS300: Assignment 1
Where do I Start?

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First Steps

- Download the framework off of Distance
- This presentation is included with it
- Even if you are writing your own framework, it is a great reference to getting started.
- It also has a sample executable on (roughly) how your assignment 1 should behave.

People Willing to Help

- Professor Karnick
  - On all topics regarding CS300
  - Email: pushpak.karnick@digipen.edu
- TA Ben Henning
  - Wrote most of the assignment 1 framework
  - Created this presentation
  - Email: b.henning@digipen.edu
- TA Tyler Pugmire
  - Help with framework 1 and an excellent resource for help with OpenGL 3.
  - Email: tyler.p@digipen.edu

Brief Introduction to Assignment 1

- Create an application that supports OpenGL 3
- Use VBOs and IBOs for rendering meshes
- Can load and render Wavefront OBJ files
- Can render debug normals for vertices and faces
- Compute vertex and face normals for meshes
- Have basic vertex-based directional lighting
- Have support for 2 lights
- Lighting model supports ambient and diffuse
- Support translation and rotation of the model
- Some sort of GUI support to control these features
- Anything else missing will be covered on the rubric
- Perspective projection matrix correctly implemented

Getting Started with the Framework

Getting Started with the Framework

- Reminder: you can write your own
  - Rest of the presentation covers the framework
  - Also covers some necessary OpenGL 3 concepts
- Begin with extracting the framework, going into premake folder, and running build.bat.
- Creates the Visual Studio 2013 solution
- No support for earlier versions due to C++11
- **If you need support for 2012 or earlier, please email one of us.**

Getting Started with the Framework

- Open up the solution and start in Main.cpp
  - Entry point to the application
  - Primary place where you will be doing work
- Throughout source code there are lines starting with: *// TODO(student):* and *// TODO:*
  - *// TODO(student)* refers to code you must implement in order to meet the requirements.
  - *// TODO* refers to code you may implement, but do not necessarily need to.

Getting Started with the Framework

- Check out these files (the number in parentheses refers to the number of TODO(student) lines in that file):
  - src/math/Matrix.cpp (2)
  - src/graphics/MathFunctions.cpp (2)
  - src/graphics/MeshLoader.cpp (1)
  - src/graphics/TriangleMesh.cpp (1)
  - src/Main.cpp (20)
- Nearly the entire framework is documented and commented
- The math library is from Zero engine
  - Not documented in the same format
  - If you need help with it, please email one of us

Getting Started: C++11 Primer

Getting Started: C++11 Primer

- C++11 is used throughout the framework, but nothing very complicated
- You may encounter the following features:
  - `std::shared_ptr` and `std::unique_ptr`
  - Initializer lists
  - Enum classes (`enum class`)
  - Unordered containers
  - Deleting methods
  - `override`
  - `auto`

Getting Started: C++11 Primer

- `std::shared_ptr` and `std::unique_ptr`
  - Shared and unique pointers are smart pointers
  - They essentially wrap around pointers and reference count them
  - When the reference count is up, they are deleted
- Initializer lists
  - Allow easy creation of STL containers, e.g.:
  - `std::vector<int> v = { 1, 2, 3, 4 };`

Getting Started: C++11 Primer

- Enum classes are very similar to regular enums, just with a few extra restrictions (see resources for more)
- Unordered containers (such as `std::unordered_map`)
  - Hashed data structures
  - Interface extremely similar to counterparts, e.g. `std::map` for the one above

Getting Started: C++11 Primer

- Deleting methods
  - `MyClass(MyClass const &) = delete;`
  - Disallows the method from being implemented
  - Framework uses to disallow copying an object
- `override`
  - Specifies a virtual method in a base class is overriding one of the same name from the parent.
  - Does extra checking to verify that it worked
- `auto:` Make the compiler automatically infer the type of a variable.

Getting Started: C++11 Primer

- References:
- http://cplusplus.com
- http://www.codeproject.com/Articles/570638/Ten-Cplusplus-Features-Every-Cplusplus-Developer (covers some of these)
- http://en.wikipedia.org/wiki/Unordered_associative_containers_%28C%2B%2B%29

OpenGL For Assignment 1

OpenGL For Assignment 1

- OpenGL features used within the framework:
  - Enabling/disabling GL states
  - Clearing buffers on the screen framebuffer
  - Changing the buffer clear color
  - Managing Vertex Buffer Objects
  - Managing Index Buffer Objects
  - Managing Vertex Array Objects
  - Managing GLSL shader programs
  - Setting up vertex input layouts for the shaders
  - Assigning values to shader uniform constants
  - Rendering meshes in indexed drawing mode
- Most of these features will be covered shortly

OpenGL For Assignment 1

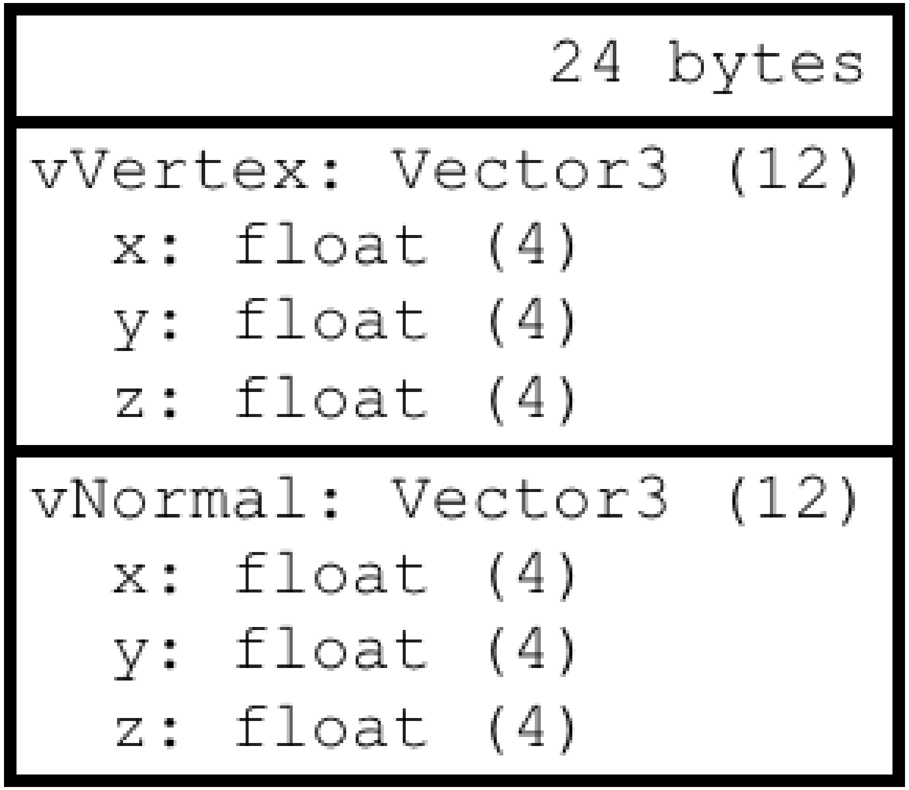
- You have already covered OpenGL basics in an earlier lecture.
- We will be covering Vertex Array Objects, buffer objects and types, vertex input layouts, and interacting with shader programs.
- All of this functionality is implemented and thoroughly commented in the framework.

Vertex Buffer Objects (VBOs)

- Recall how OpenGL buffers work from your last lecture.
- VBOs are a special type of buffer designed to store vertex information and attributes.
- Each vertex stored in the buffer is stored subsequently in a contiguous fashion.
- The next slide shows a sample vertex structure and, roughly, what the memory may look like for the VBO containing those vertices.
- Refer to **VertexBufferObject.h/.cpp** for more information and the syntax of needed OpenGL calls.

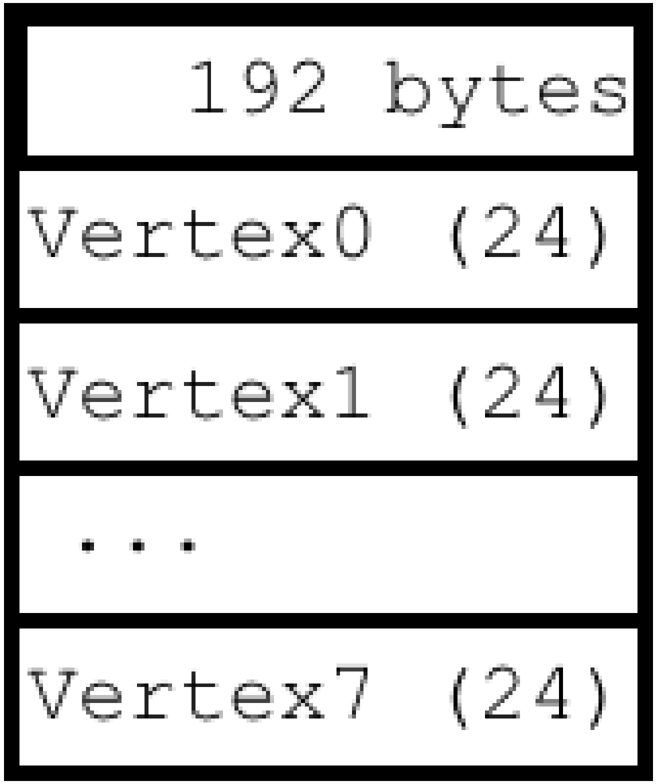
Vertex Buffer Objects (VBOs)

Example vertex



```
                    24 bytes
vVertex: Vector3 (12)
  x: float (4)
  y: float (4)
  z: float (4)
vNormal: Vector3 (12)
  x: float (4)
  y: float (4)
  z: float (4)
```

VBO memory layout



```
   192 bytes
Vertex0 (24)
Vertex1 (24)
 ...
Vertex7 (24)
```

Index Buffer Objects (IBOs)

- Very similar to VBOs, except they store indices that are used to lookup vertices inside the VBO.
- This is referred to as *indexed drawing* or *element drawing*.
- We end up saving a lot of memory by having a separate buffer which represents the shape by simply storing indexes to the vertex, rather than the whole vertex itself.
- IBOs can store meshes of all sorts of primitives (triangles, lines, points, etc.)
- Refer to **IndexBufferObject.h/.cpp** for more information and syntax of the needed OpenGL calls.

VBOs and IBOs: Rendering

- Once you have a VBO and IBO for a mesh created, you can render it.
- We will be assuming triangles are stored in the IBO (so 3 indices per face) and using the same vertex structure shown before.
- The following slide contains the code needed to render with those objects (it is stripped of GL conventions to keep it shorter).

VBOs and IBOs: Rendering

```
BindBuffer(ARRAY_BUFFER, vboHandle);
BindBuffer(ELEMENT_ARRAY_BUFFER, iboHandle);
// vertex layout: covered in greater detail later
EnableVertexAttribArray(0);
EnableVertexAttribArray(1);
// enable vVertex attribute (0)
VertexAttribPointer(0, 3, FLOAT, FALSE,
  sizeof(Vertex), 0);
// enable vNormal attrib. (1), offset after vVertex
VertexAttribPointer(0, 3, FLOAT, FALSE,
  sizeof(Vertex), (void *)sizeof(Vector3));
// draw 12 triangles
DrawElements(TRIANGLES, 12, UNSIGNED_INT, 0);
// disable vertex attribs
// unbind buffers
```

Shaders

- We will not go over implementing shaders from scratch, but we will discuss important concepts.
- Shaders are programs that assist in the transformation and rasterization pipelines on the GPU.
- In fact, almost the entire transformation pipeline in OpenGL 3 is handled manually in a vertex shader.

Shaders

- Shader programs consist of one vertex shader and one fragment shader.
- The vertex shader takes in vertex attributes based on the vertex input layout (see VBO/IBO rendering code for more), transforms it to NDC space, and sends it to the fragment shader.
- The fragment shader is responsible for outputting a color value for that particular fragment/pixel.

Shaders

- This entire process is very similar to code written in CS200 and CS250, except it's in GLSL (similar to C).
- Shaders also have **uniform constants**
  - Variables that do not change throughout the runtime of a shader
  - Values are controlled via `glUniform` calls
  - See ShaderProgram::SetUniform() for more information
- Overall, data passed to a shader must come from vertices or from uniforms
- Refer to **ShaderProgram.h/.cpp** for much more detail on how to create these OpenGL objects.

Shaders and VBOs

- IBOs do not matter with shaders; the process of looking up vertices using indexes from an IBO is all handled internally.
- We must bind the shader before we can render VBOs.
- Recall earlier that we had to manually enable portions of the vertex buffer in order to draw (vertex input layout).
- This was based on the vertex structure example from earlier.
- The following GLSL code inside a vertex shader corresponds to the `EnableVertexAttribArray` calls from earlier:

Shaders and VBOs

```
layout(location = 0) in vec3 vVertex;
layout(location = 1) in vec3 vNormal;

// See assets/shaders/shader.vert for
// more information on how these are used
// and what they exactly mean.
```

Vertex Array Objects (VAOs)

- VAOs are not necessary to complete assignment 1, but the framework uses them.
- OpenGL 3 construct that allows n VBOs, up to 1 IBO, and the vertex input layout to all be stored within one data structure.
- For information on what OpenGL code is needed to create a VAO, see **VertexArrayObject.h/.cpp**.
- Rendering VAOs is trivial compared to before:

Rendering VAOs

```
// shader program should already be bound
BindVertexArray(vaoHandle);
// draw 12 triangles using the IBO and VBO
// of this VAO (and vertex input layout)
DrawElements(TRIANGLES, 12,
  UNSIGNED_INT, 0);
BindVertexArray(0);
```

Algorithms and More for Assignment 1

Computing Face Normals

- Iterate through all triangles in the mesh
- Take two adjacent edge vectors that are starting from the same vertex and cross them.
- The cross product, normalized, represents the face normal.

Computing Vertex Normals

- More complicated process
- A vertex normal is the *average* all the face normals for each face that contains that vertex.
- There is an issue with this process: two polygons that exist on the same plane and share a vertex will end up double-affecting that vertex, which is incorrect.
- Imagine a triangulated cube; each face will have a situation where 2 triangles touch the same vertex and will produce this situation.
- This problem is solvable by keeping track of all face normals for each vertex and ensuring the same direction is not added to the vertex twice.

Wavefront OBJ File Format

- Rather than documenting the format within this presentation, the Wikipedia link on the format is extremely thorough and helpful:
- http://en.wikipedia.org/wiki/Wavefront_.obj_file
- Some implementation details:
  - You **should** parse vertex normals and vertex textures, but you do not need to do anything with the data (basically skip the lines if nothing else).
  - You do **not** need to support any of the versions of the face line with slashes in it; the standard ‘f v1 v2 v3’ style format is fine.
  - You do **not** need to support parsing non-triangle faces
  - You do **not** need to support parsing materials
  - You **should** support parsing and skipping comments

Premake, ImGui, Glew, and FreeGLUT

Premake

- Premake is a meta-build system used to data-drive actual project files.
- It greatly simplifies dealing with projects, since we no longer need to deal with merging Visual Studio solutions, project files, etc.
- The script files are defined in Lua
- Used in this framework to keep everything normalized and minimalized.
- Similar to CMake, but more cross-platform and portable.
- See https://bitbucket.org/premake/premake-dev/wiki/Home for more.

ImGui (Immediate Mode GUI)

- https://github.com/ocornut/imgui
- ImGui is a relatively new GUI library which is designed around the concept of immediate rendering.
- This means that if you suddenly desire adding some sort of GUI tweaking support anywhere in your code, you can do it right in that location.
- The GUI is recreated every frame and little to no state is stored within the GUI framework.
- This significantly shortens GUI code and, as a result, speeds up the process of building GUIs.

ImGui

- You are not required to use ImGui and are free to use any other GUI software you choose.
- From the TAs' experiences, though, ImGui is **much** faster to work with than AntTweakBar or WxWidgets.
- For excellent examples on using ImGui, see: https://github.com/ocornut/imgui/blob/master/imgui.cpp#L6962 (ShowTestWindow())

GLEW

- GLEW stands for: GL Extension Wrangler
- http://glew.sourceforge.net/
- OpenGL is made up of iterations of changes, called extensions.
- Major versions, if supported, guarantee certain extensions are functional (e.g. OpenGL 3.3 has guaranteed functionality if fully supported).
- GLEW has the terrible responsibility of dynamically loading all of the OpenGL functions from the driver's OpenGL DLL and verifying which extensions are supported.
- It can determine if a complete GL version is supported.

GLEW

- Due to how OpenGL is supported on Windows (only OpenGL 1.1 is built into Windows), GLEW is basically necessary.
- Dealing with OpenGL extensions without a library like GLEW can be very painful.
- It's easy to setup and compatible with most libraries that can create a GL context for you (GLUT, FreeGLUT, SDL, SFML, GLFW, etc.)

FreeGLUT

- A newer implementation of the original GLUT library.
- GLUT: GL Utility Toolkit
- http://freeglut.sourceforge.net/
- Contains a bunch of legacy GLU code, including generating interesting meshes during runtime.
- Also, contains windowing support, creating an OpenGL context, and attaching this context to a window; all functionality is cross-platform.

FreeGLUT

- Also, supports various messaging functions via callback mechanisms, just like original GLUT.
- It has some nice changes and functionality that were missing in GLUT.
- Fully compatible with OpenGL 3 and newer and works correctly with GLEW.
- Alternatives to using FreeGLUT: SDL2, SFML, and GLFW (there are other options that are platform-specific, too).

Wrapping Up

Checklist

- Before turning in, make sure your application:
  1. Follows all of the points mentioned in slide 4 (introduction to Assignment 1)
  2. Make sure you have at least looked at and implemented the functionality for all TODO(student) in the framework
  3. Make sure your application supports all the features demonstrated in the sample (see the sample's README)
- Do not submit the premake or sample folders
- **Remember to run clean.bat before archiving; build artifacts deduct points**
- If you changed premake4.lua, please email one of us
- Be sure to read the framework's README and update it
- Submission name format:

  digipen.login_cs300_1.zip

Conclusion

- Remember, if you have any questions, do not hesitate to email any of us.
- The framework is brand new and is bound to have issues; if you are getting stuck debugging code you did not write, please email us immediately.
- You always have the option of writing your own framework, as well.
- Good luck!

Framework Walk-Through and Sample Demonstration