Intro to 3D Graphics

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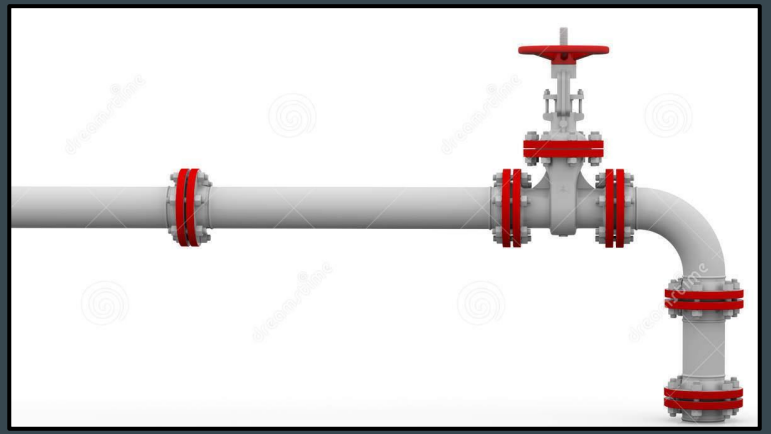
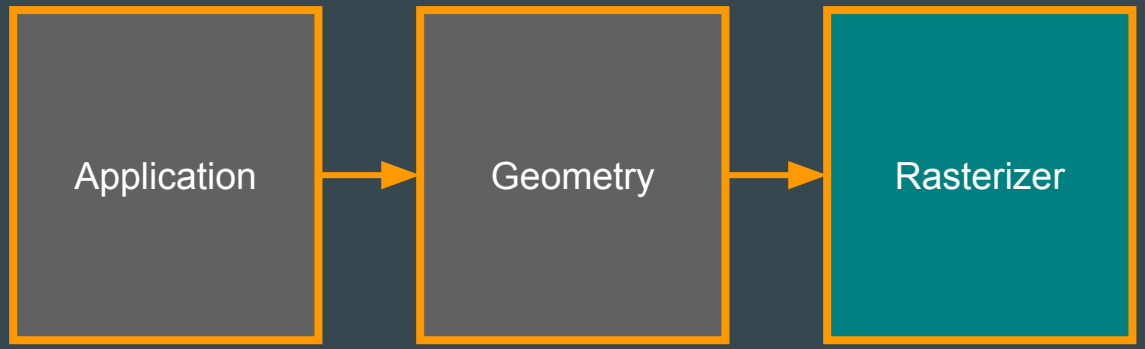
Pipeline

- The concept of a **pipeline** is widely used in video games
- Every process that follows stages that need to be completed is a pipeline
- The slowest step is called **bottleneck**
- Every step could contain a sub pipeline
- Some processes could be parallelized
- You have been using pipelines already



Real Time Rendering Pipeline

- Classical conceptual pipeline for a Graphics application was:



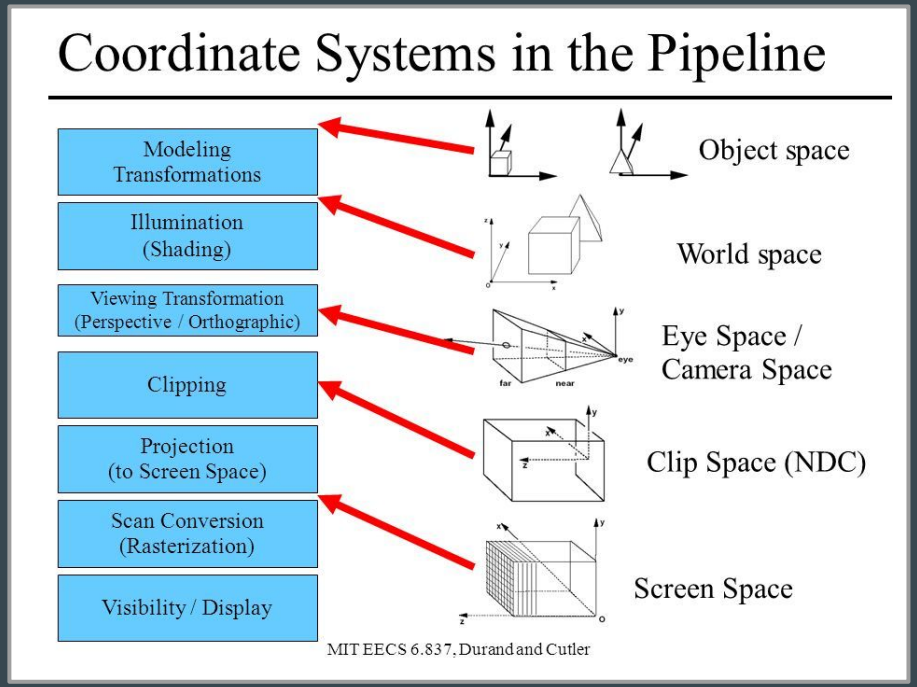
Real Time Rendering Pipeline

Application stage :

- Everything that happens before drawing
- Collision detection, input management, audio, animation, etc.
- All those process output geometry to be rendered later
- All this stage is done in the **CPU**

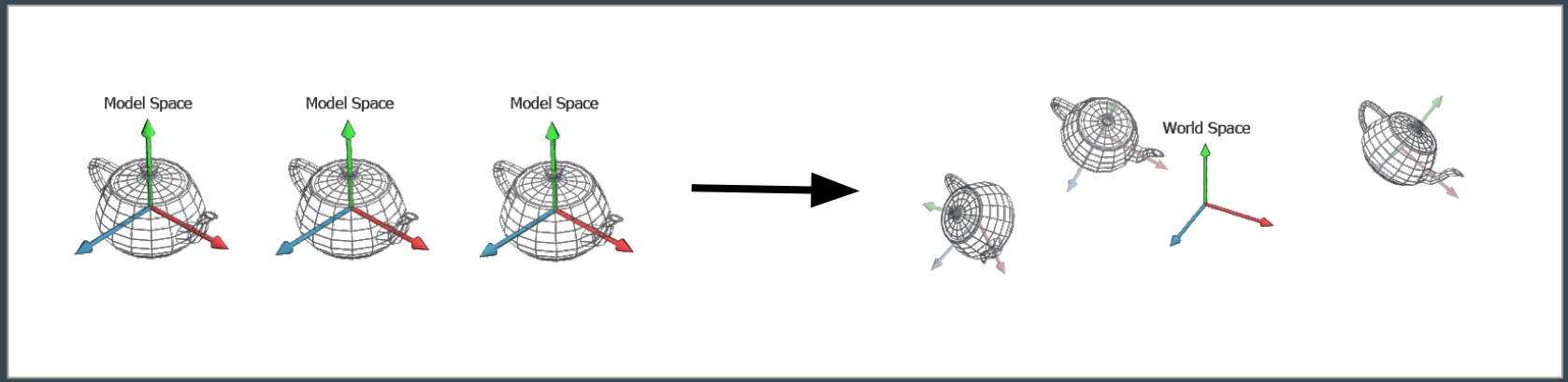
Real Time Rendering Pipeline

1. Geometry stage:
    - Model & View Transform
    - Lighting/Shading
    - View/Projection
    - Clipping
    - Screen Mapping
2. Rasterization Stage
    - Rasterization
    - Display



Real Time Rendering Pipeline

Model Transform:



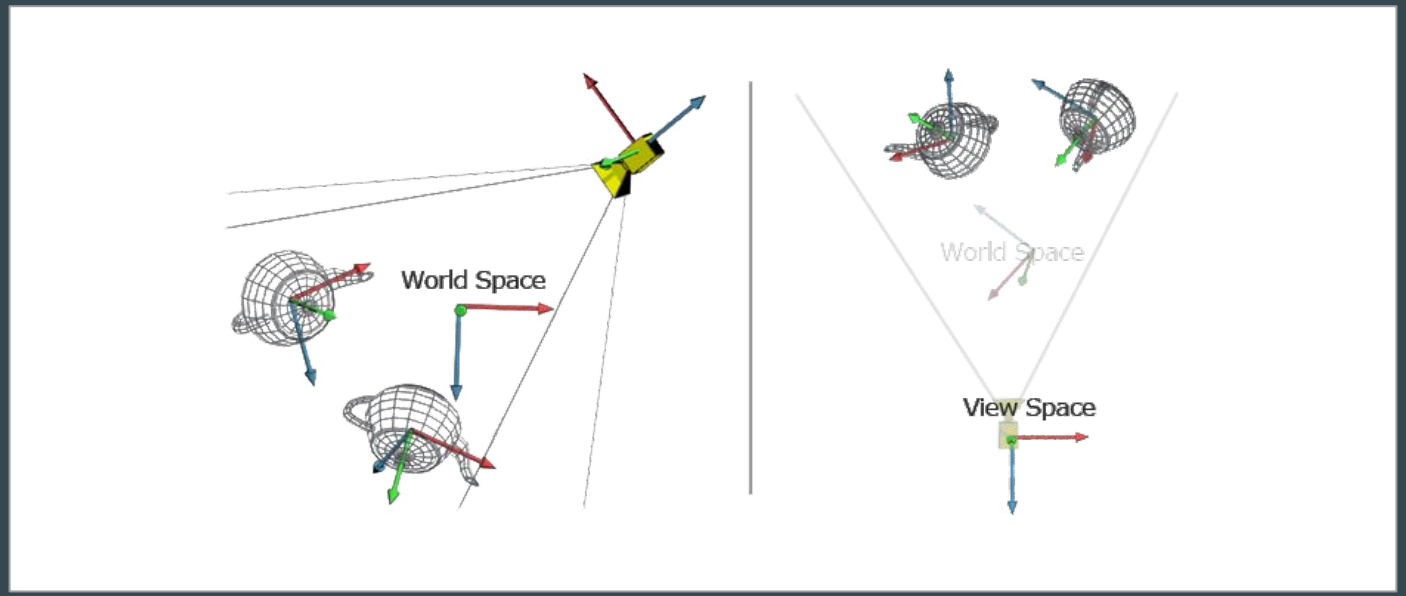
Real Time Rendering Pipeline

Lighting and Shading:

ambient + diffuse + specular = final result

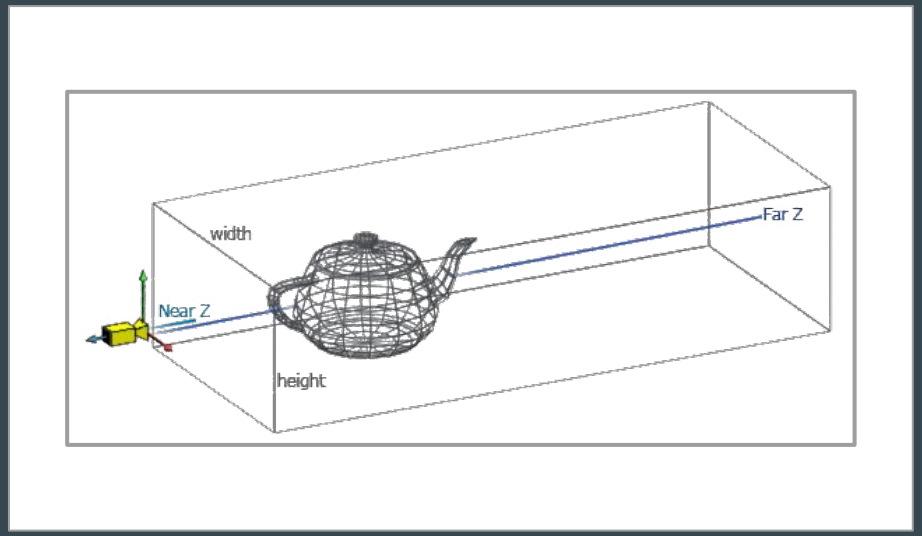
Real Time Rendering Pipeline

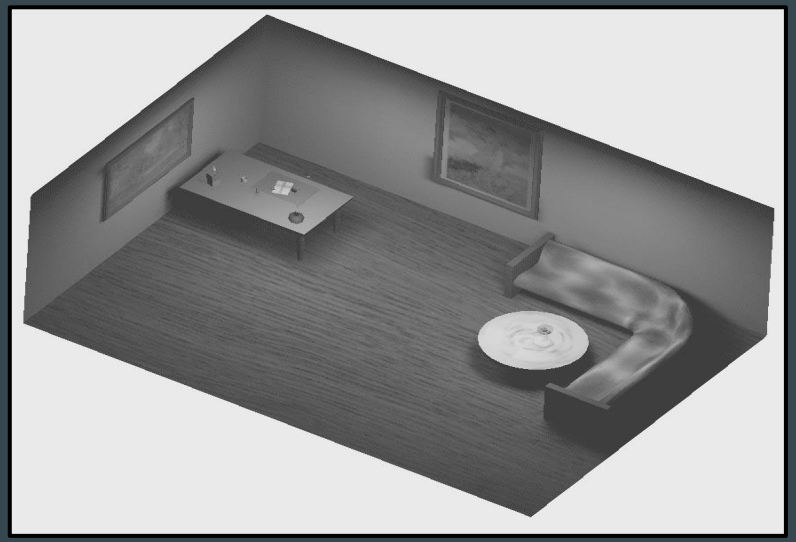
View Transform:



Real Time Rendering Pipeline

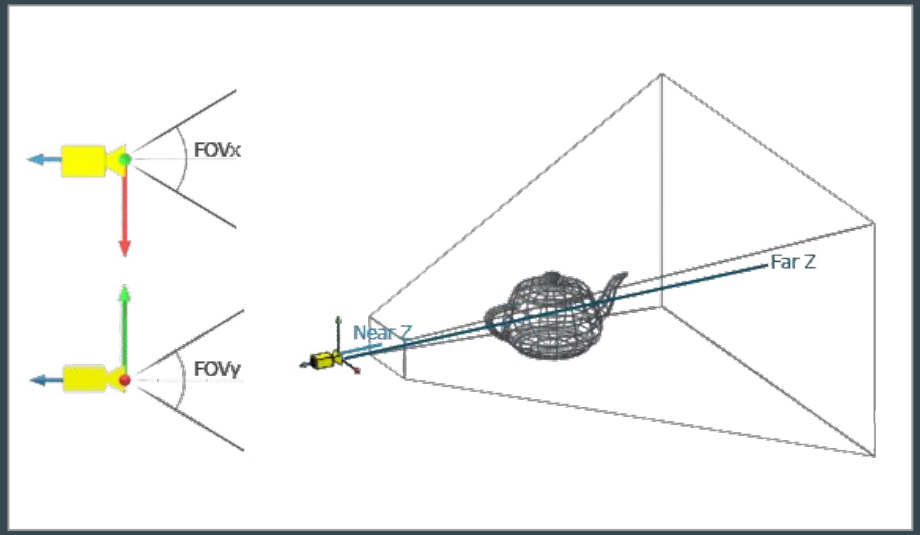
Orthographic Projection

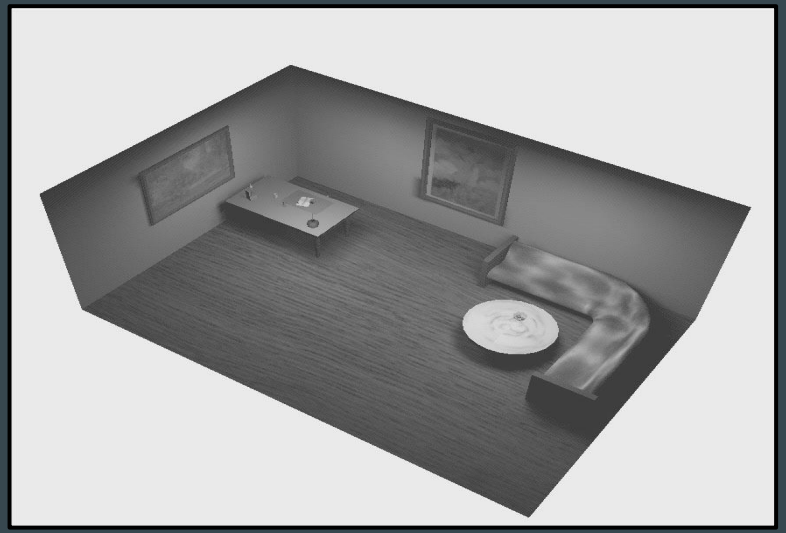




Real Time Rendering Pipeline

Perspective Projection

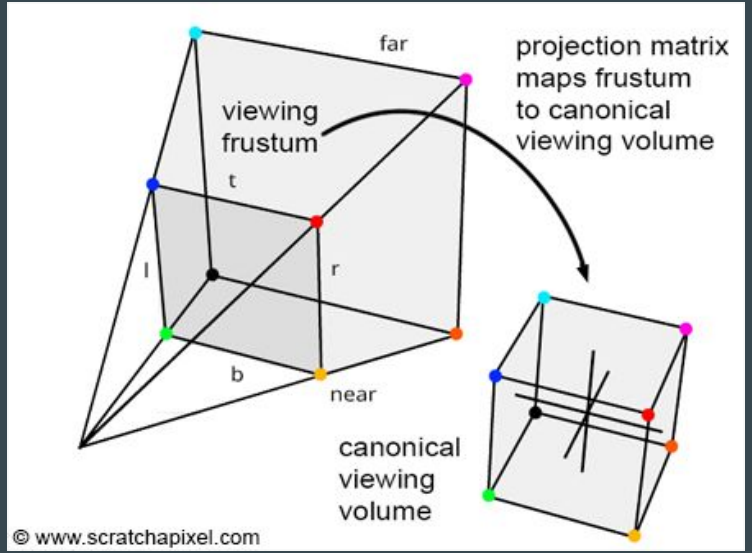




Real Time Rendering Pipeline

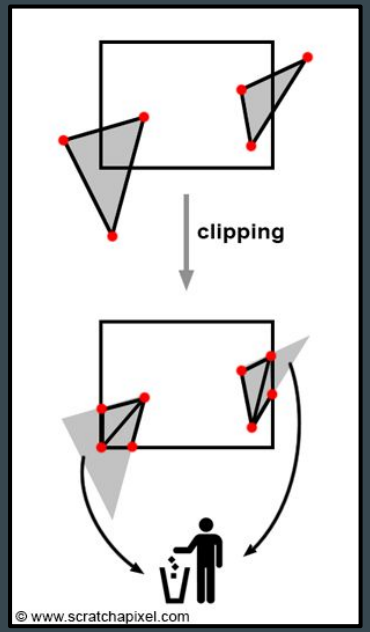
Clipping Space:

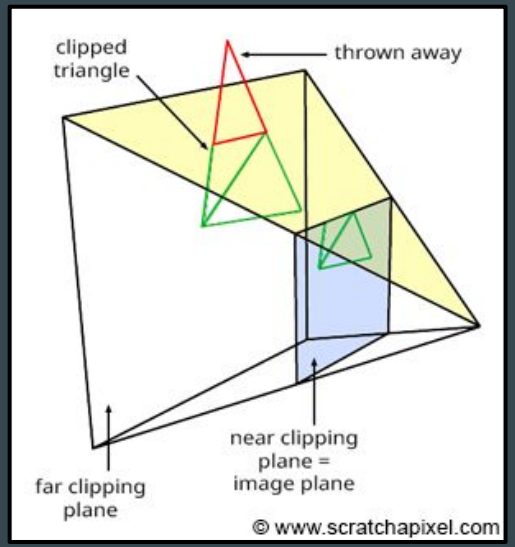
- Projection converts geometry to **Clipping Space**
- If we apply projection to camera frustum it´s converted to a canonical view volume



Real Time Rendering Pipeline

- During clipping:
  - Primitives *totally* **inside** pass to next stage
  - Primitives *totally* **outside** are discarded
  - Primitives intersecting the cube are **clipped** (new vertices are created)

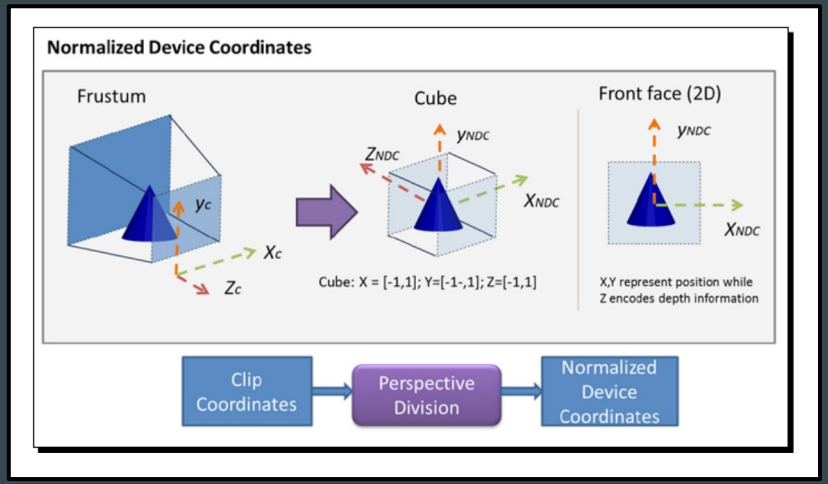




Real Time Rendering Pipeline

Normalized device coordinates:

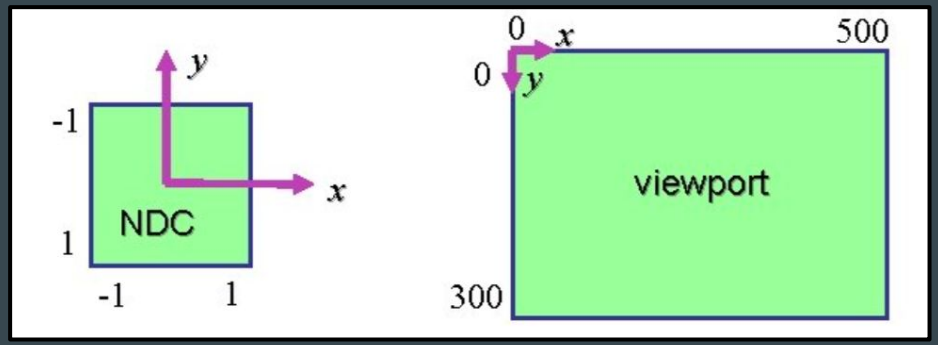
- Dividing clipping space (positions results of projection) by w, converts them into Normalized Device ⇒ Remaps canonical view volume to [-1, -1, -1] → [1, 1, 1]
- These are the coordinates sent to next stage



Real Time Rendering Pipeline

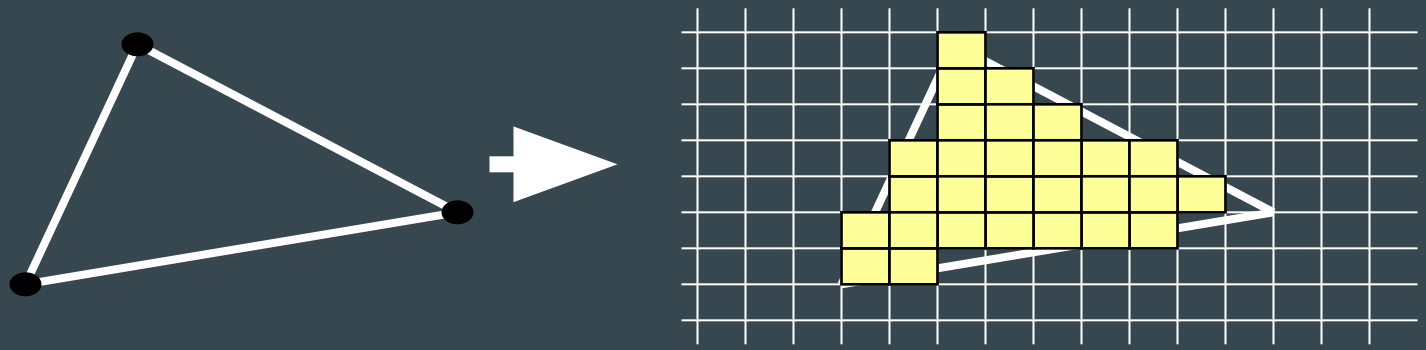
Screen Mapping:

- **Normalized Device Coordinates** x,y are mapped to screen/viewport.
- Z coordinate (depth value) remains the same.
- Screen space coordinates are sent to the rasterizer stage



Real Time Rendering Pipeline

- Turns geometry into pixels (discretization) to send to the screen
- Adds texturing and other pixel / fragment operations
- Uses z (depth) on each pixel to calculate visibility based on distance to camera



Main Graphics APIs

- **OpenGL**: generic and multiplatform (our choice)
- DirectX for Microsoft Platforms: proprietary
- Most games that execute on Microsoft platforms use DirectX
- Still, the differences are considered minor
- Now Vulkan vs DirectX 12 are becoming new standards
- Other APIs: WebGL, OpenGL ES, Metal

OpenGL Graphics

- OpenGL 1.0 (1992) direct mode was the main tool for drawing
- OpenGL 1.5 (2003) introduces *Vertex Buffer Objects*
- OpenGL 3.3 (2010) deprecated direct mode and forces *programmable shader pipeline* (tip: Shaders will be a personal feature)
- Latest is OpenGL 4.6 (2017) with all features supported also in DirectX 12
- Vulkan (2015) low overhead API to take over OpenGL

Documentation

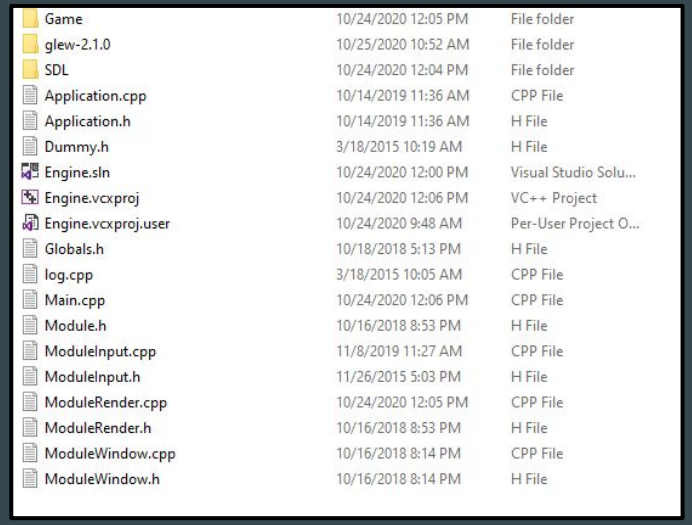
- Real-Time Rendering is the core book in the field
- DirectX site at Microsoft has several resources
- OpenGL site has articles and documentation to get you started
- Well explained pipeline for OpenGL transformations
- Nice collection of code about graphics
- OpenGL tutorials: here, here and here
- But much more! Google is your fiend :)

OpenGL Initialization

- OpenGL is big, with many versions and deprecated functionality
- Using OpenGL extensions (functions) is a disaster: It requires querying each function pointer before using it.
- We will use glew lib that helps to wrap each new OpenGL extension at application initialization.

Adding glew library

- Download binaries from http://glew.sourceforge.net/ and add to your project directory
- Add glew to your projects directory
- Copy glew32.dll to your Game directory (will be your starting working directory)



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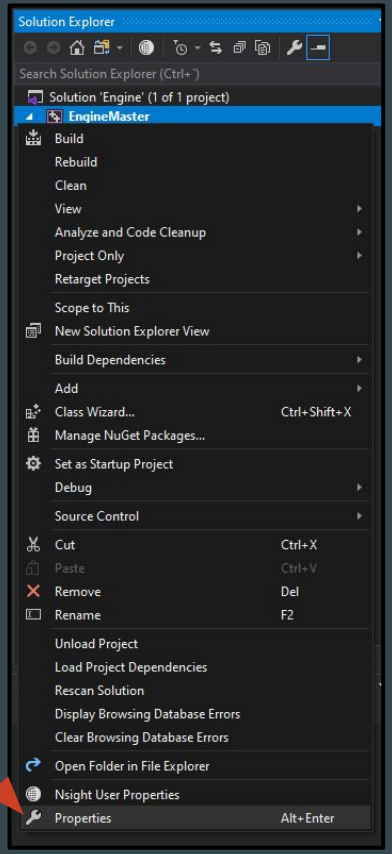
glew-2.1.0	10/25/2020 10:52 AM	File folder
SDL	10/24/2020 12:04 PM	File folder
Application.cpp	10/14/2019 11:36 AM	CPP File
Application.h	10/14/2019 11:36 AM	H File
Dummy.h	3/18/2015 10:19 AM	H File
Engine.sln	10/24/2020 12:00 PM	Visual Studio Solu...
Engine.vcxproj	10/24/2020 12:06 PM	VC++ Project
Engine.vcxproj.user	10/24/2020 9:48 AM	Per-User Project O...
Globals.h	10/18/2018 5:13 PM	H File
log.cpp	3/18/2015 10:05 AM	CPP File
Main.cpp	10/24/2020 12:06 PM	CPP File
Module.h	10/16/2018 8:53 PM	H File
ModuleInput.cpp	11/8/2019 11:27 AM	CPP File
ModuleInput.h	11/26/2015 5:03 PM	H File
ModuleRender.cpp	10/24/2020 12:05 PM	CPP File
ModuleRender.h	10/16/2018 8:53 PM	H File
ModuleWindow.cpp	10/16/2018 8:14 PM	CPP File
ModuleWindow.h	10/16/2018 8:14 PM	H File

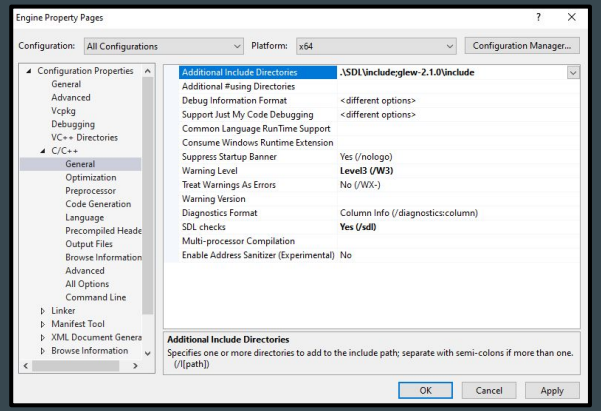
Adding glew library

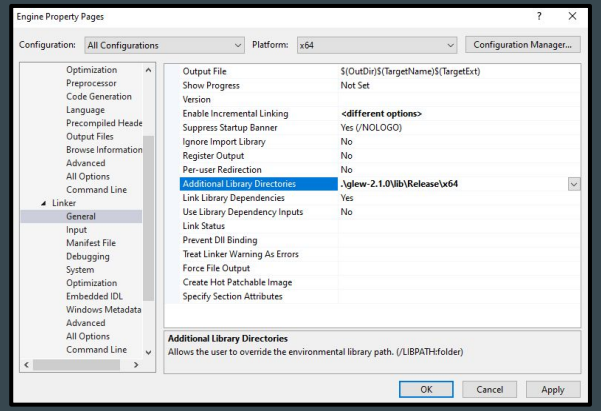
Configure your Visual Studio project



Adding glew library

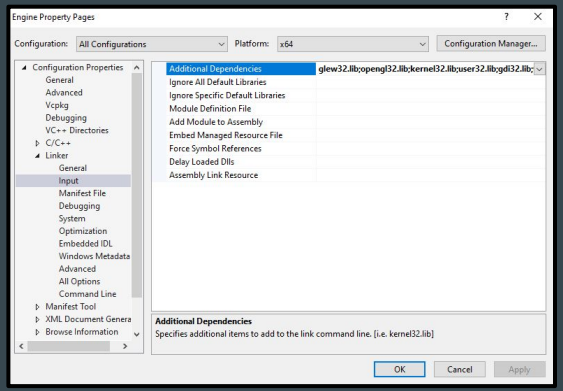
- Add glew/include to your project additional include directories
- Add glew/lib/Release/x64 to your project additional library directories

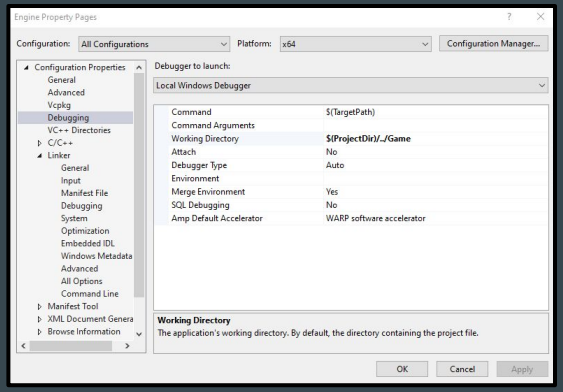




Adding glew library

- Add glew32.lib and opengl32.lib to additional dependencies
- Set Game as your starting working directory





OpenGL Initialization

- For initializing OpenGL we must create a **Context**
- You must think a context as an object that holds all OpenGL.
- A Context contains all **states** associated with OpenGL: active framebuffer, active texture, active vertex buffer, etc.
- There are two types of context : **core** and **compatibility**. First removes deprecated functionality, second keeps it.

OpenGL Initialization

We will initialize OpenGL via SDL. Use *ModuleRender*

- Setup attributes with SDL_GL_SetAttribute()

```
SDL_GL_SetAttribute(SDL_GL_CONTEXT_MAJOR_VERSION, 4);  // desired version
SDL_GL_SetAttribute(SDL_GL_CONTEXT_MINOR_VERSION, 6);
SDL_GL_SetAttribute(SDL_GL_CONTEXT_PROFILE_MASK, SDL_GL_CONTEXT_PROFILE_COMPATIBILITY);

SDL_GL_SetAttribute(SDL_GL_DOUBLEBUFFER, 1);    // we want a double buffer
SDL_GL_SetAttribute(SDL_GL_DEPTH_SIZE, 24);     // we want to have a depth buffer with 24 bits
SDL_GL_SetAttribute(SDL_GL_STENCIL_SIZE, 8);    // we want to have a stencil buffer with 8 bits
```

- Init once with: SDL_GL_CreateContext()

OpenGL Initialization

- Remember to create the SDL window with special flag:

  SDL_WINDOW_OPENGL (*ModuleWindow*) 

- After context creation, init the GLEW library (*ModuleRender*):

```
GLenum err = glewInit();
// … check for errors
LOG("Using Glew %s", glewGetString(GLEW_VERSION));
// Should be 2.0
```

OpenGL Initialization

- To detect our current hardware and driver capabilities we use glGetString()

```
LOG("Vendor: %s", glGetString(GL_VENDOR));
LOG("Renderer: %s", glGetString(GL_RENDERER));
LOG("OpenGL version supported %s", glGetString(GL_VERSION));
LOG("GLSL: %s\n", glGetString (GL_SHADING_LANGUAGE_VERSION));
```

- Initialize some OpenGL global states (check documentation)

```
glEnable(GL_DEPTH_TEST);    // Enable depth test
glEnable(GL_CULL_FACE);     // Enable cull backward faces
glFrontFace(GL_CCW);        // Front faces will be counter clockwise
```

OpenGL Frame Init

1. For clearing the screen, on ModuleRender PreUpdate function:
    a. Setup glViewport to 0, 0, window_width, window_height if window is resized:
        i. Use SDL_GetWindowSize
    b. glClearColor(0.1f, 0.1f, 0.1f, 1.0f);
    c. glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);
2. Swap frame buffer on ModuleRender PostUpdate function:
    a. Use SDL_GL_SwapWindow
3. Remove context at CleanUp function using SDL_GL_DeleteContext()

OpenGL Destruction