Rendering Photorealistic Mountain Terrain

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Agenda

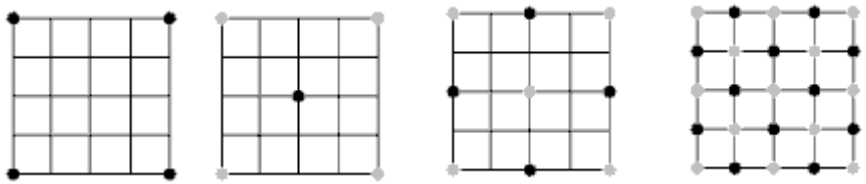
- Overview
- Background & Motivation
- Height-map Generation
- Rendering Techniques
- Technology
- Challenges
- Conclusion
- Future Work
- Demo
- Questions

Overview

- Height map generation
- Tessellation
- Lighting
- Texturing
- Skybox
- Camera Controls
- Performance Statistics

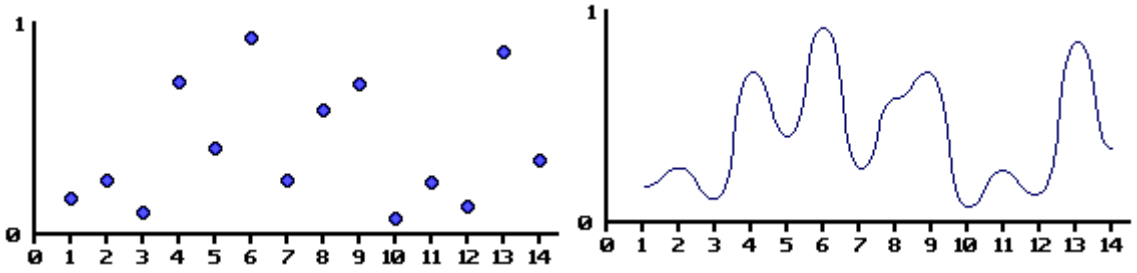
Height map generation

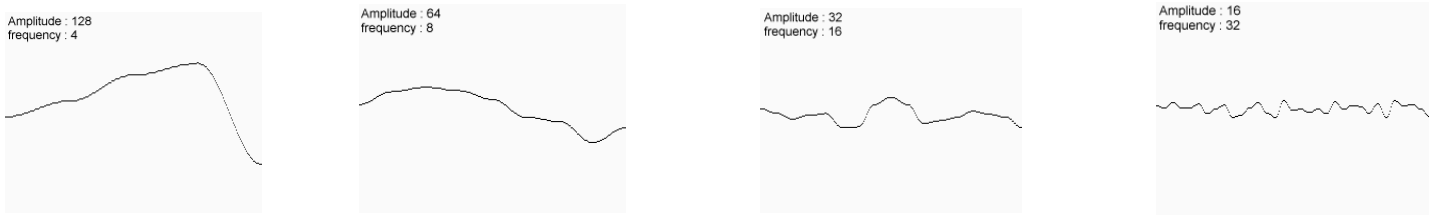
- John Carpenter – “Computer Rendering of Fractal Curves and Surfaces” 1979-80
- Diamond Square Recursive Subdivision



Height-map Generation

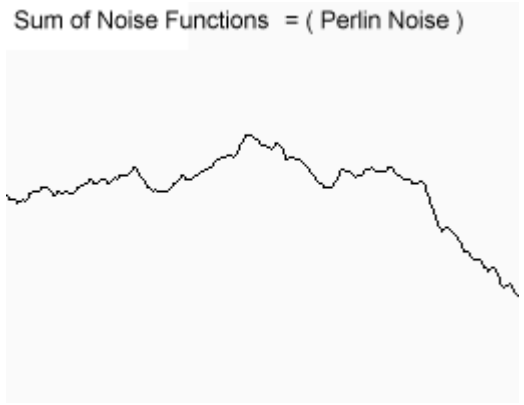
- Perlin Noise Generation





Height map generation

- Perlin Noise Generation

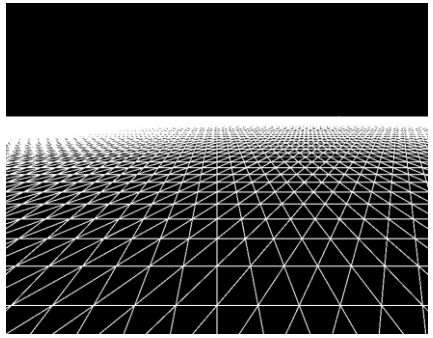


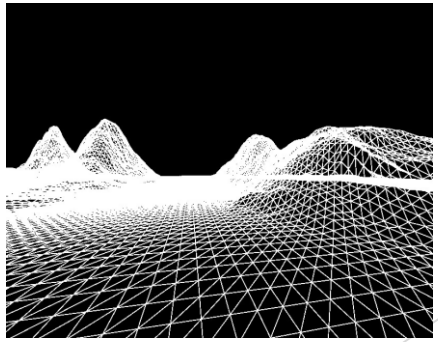
Learning here

- Perlin Noise generation – Good for parallel programming
- Save the generated height map
  - Avoid run time calculation
  - Can use bitmap compression techniques if needed
- Control of the roughness/smoothness of the height-map is desired

Tessellation

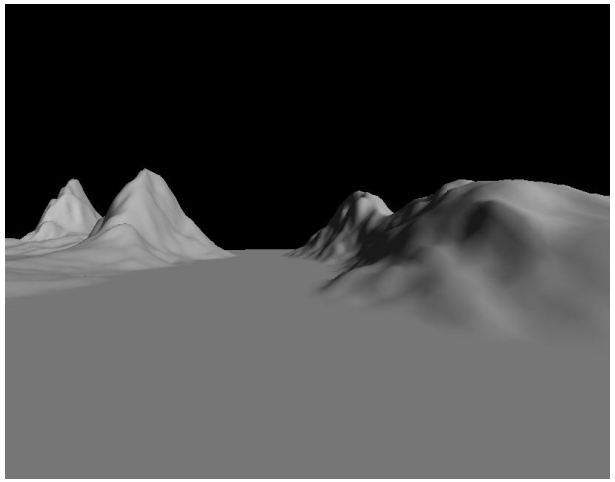
- Convert the height map into triangles
- Grid of M*N rectangles – divided into 2 triangles each
- Use of index buffer
- Render wire-mesh
- Calculating Normals
  - $n = (b - a)\ X\ (c - a)$
- Tessellation shader (future work)





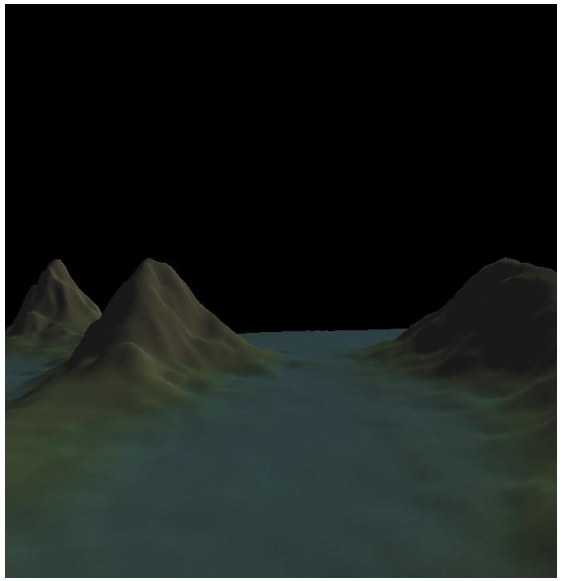
Lighting

- Fixed shader pipelines vs programmable shader pipeline
- Ambient Light
- Diffuse Light
- Single source – directional light
- Calculated at the pixel shader



Texturing

- Slope factor
- S = Up . N where,
  S - is the slope factor being calculated
  Up - is the Up vector (0,1,0)
  N – is the normal calculated for the vertex
- S is used to calculate percentage combination grass and rock texture
- Sea level
  - Transition from water to rock



Gains in this technique

- Uses the Normal and the up-vector
- Normal vector is needed for lighting calculation
- Up-vector is required for camera movement
- No additional resources such as UV maps are required
- Simple and intuitive
- Can easily be implemented at the pixel shader

Tri-planar mapping

- Image stretching
- Cannot calculate texture mapping in 2 dimensions
- Must take into account height
- 3 phases
  - XZ mapping
  - XY mapping
  - YZ mapping
- Slope determines the contribution of each phase (already calculated)

Gains in this technique

- Need to sample thrice – but is still fast
- Textures are already loaded into memory
- No additional resources/complex computations required
- Slope factor has already been calculated
- Works well even with extremely steep and extremely flat surfaces
- Simple and intuitive
- Easily implemented in the pixel shader

Camera Controls

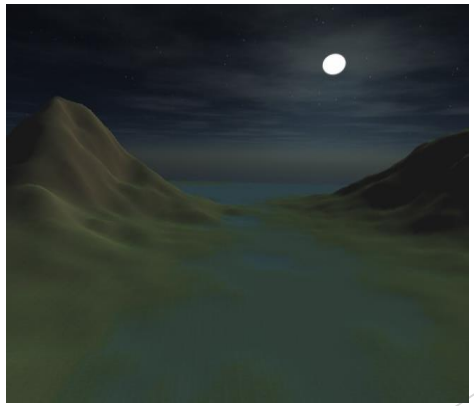
- Eye position (e) – position of the camera
- Look-at position (p) – the position in the 3d world that the camera is focused at
- Up vector (u) – the vector that is up relative to the view direction
- View direction (v) = (p-e)
- Right vector (r) = u X v

Camera controls

- Move forward/back
  - Move eye position and the look-at position along the view direction
  - Maintain distance between eye and look-at
- Yaw
  - Rotate look-at position around the axis defined by up-vector and the eye position
  - Maintain distance between eye and look-at
- Pitch
  - Rotate the look-at position around the axis defined by right-vector and the eye position
  - Maintain distance between eye and look-at

Skybox

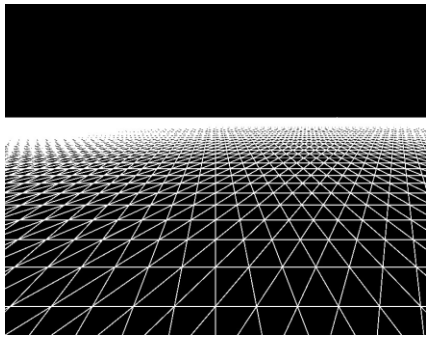
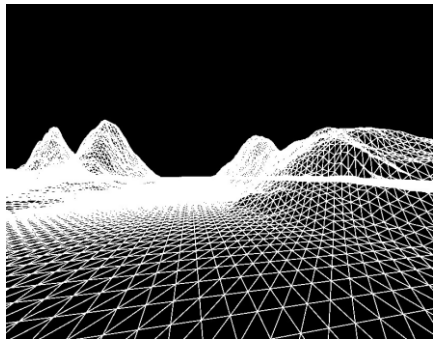
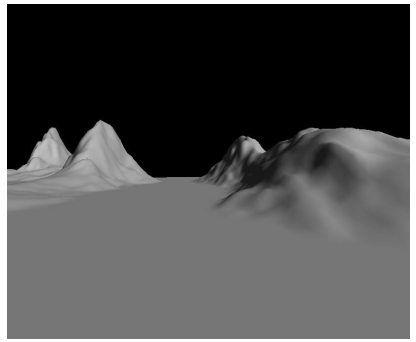
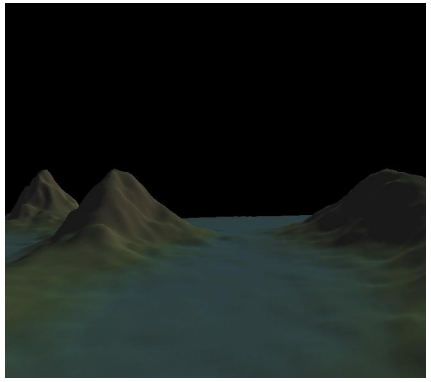
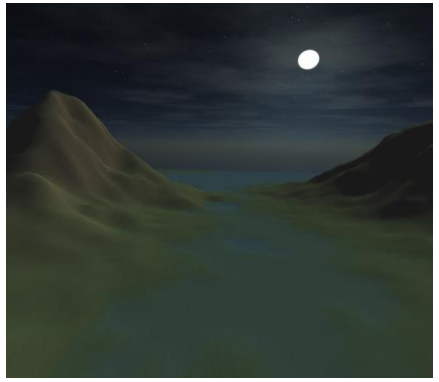
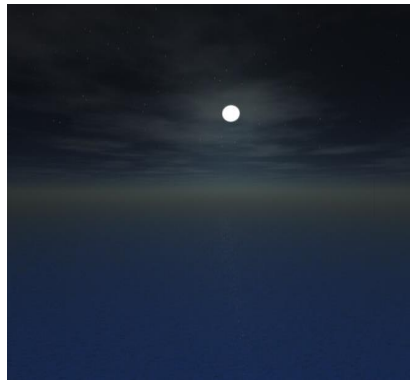
- Cube centered at the camera position
- Perception of infinite distance
- Must be closer than the far plane
- Try to line up direction of light with placement of sun/moon
  - Use a separate sprite for sun/moon (future work)



Feature Toggling

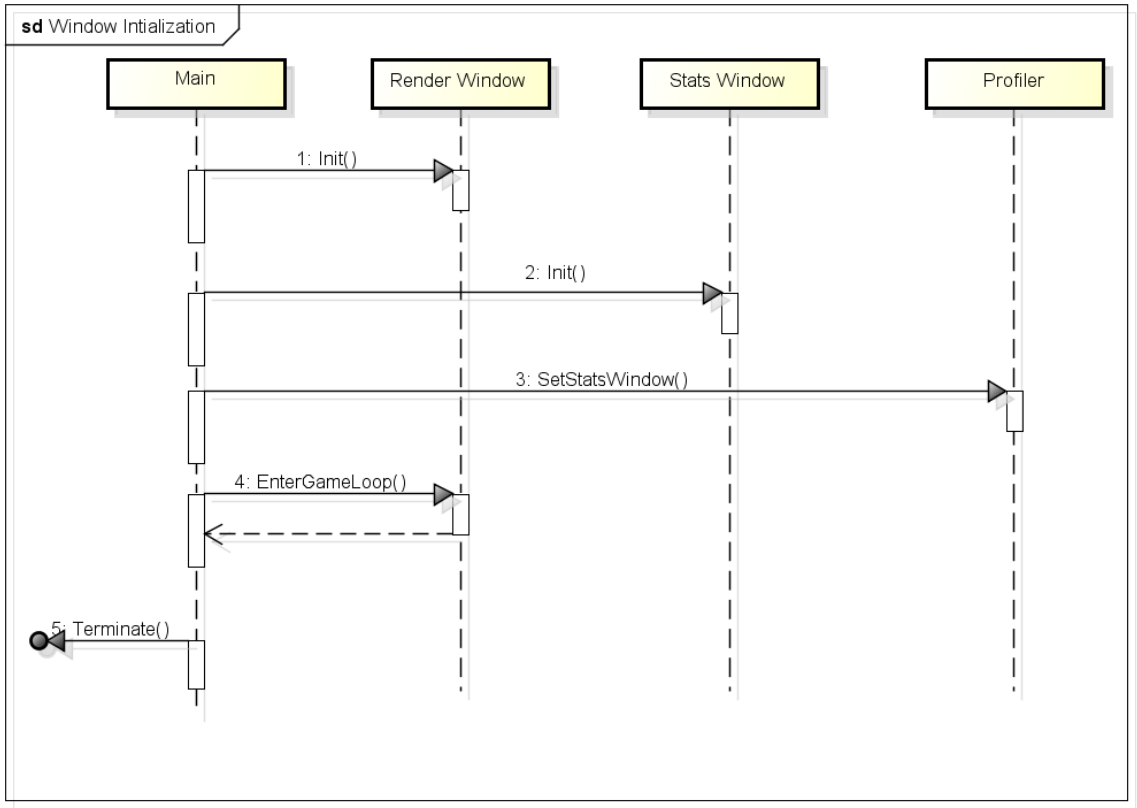
- Importance learnt from previous project
- Valuable while developing features in isolation and combination
- Extremely valuable while debugging
- Great to explain the techniques to a graphics enthusiast

Feature Toggling

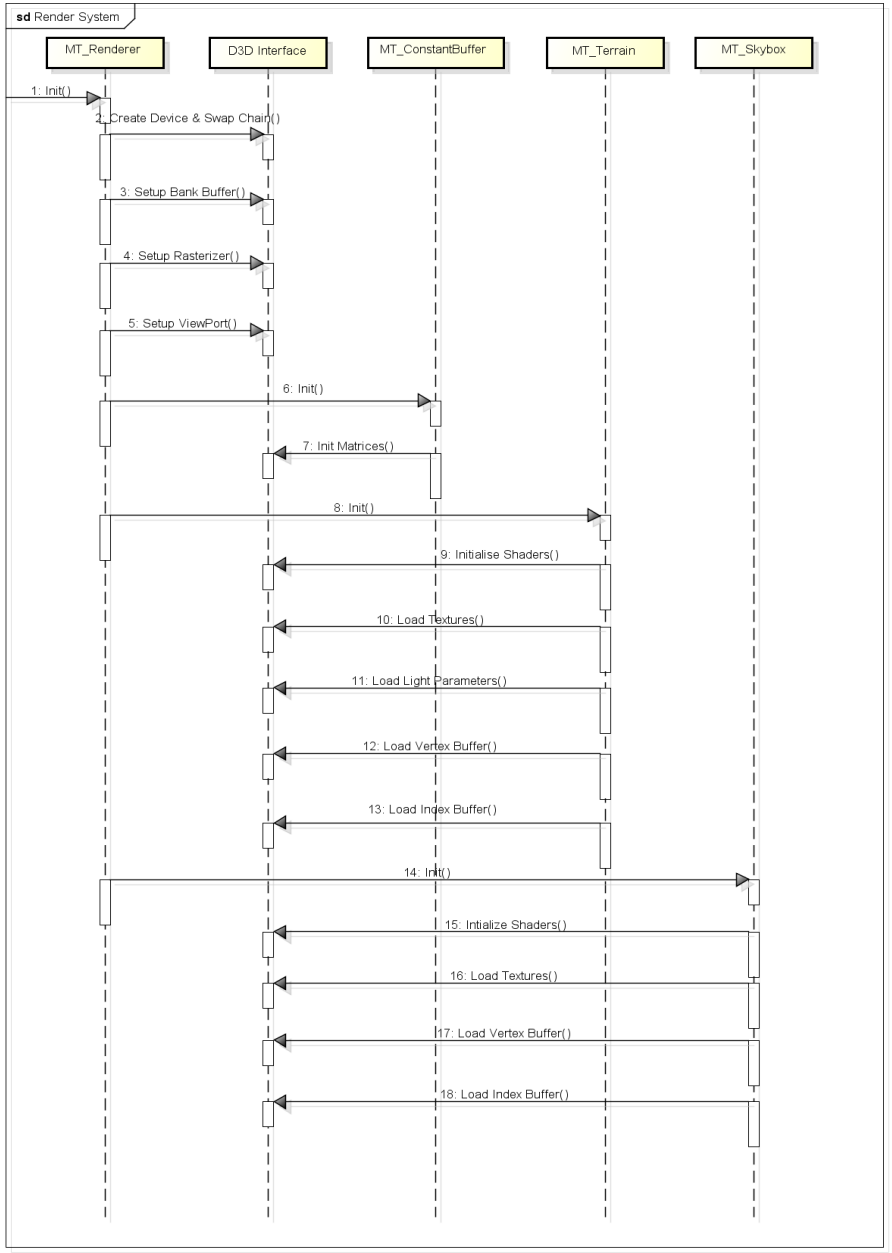
Implementation

- Window Initialization



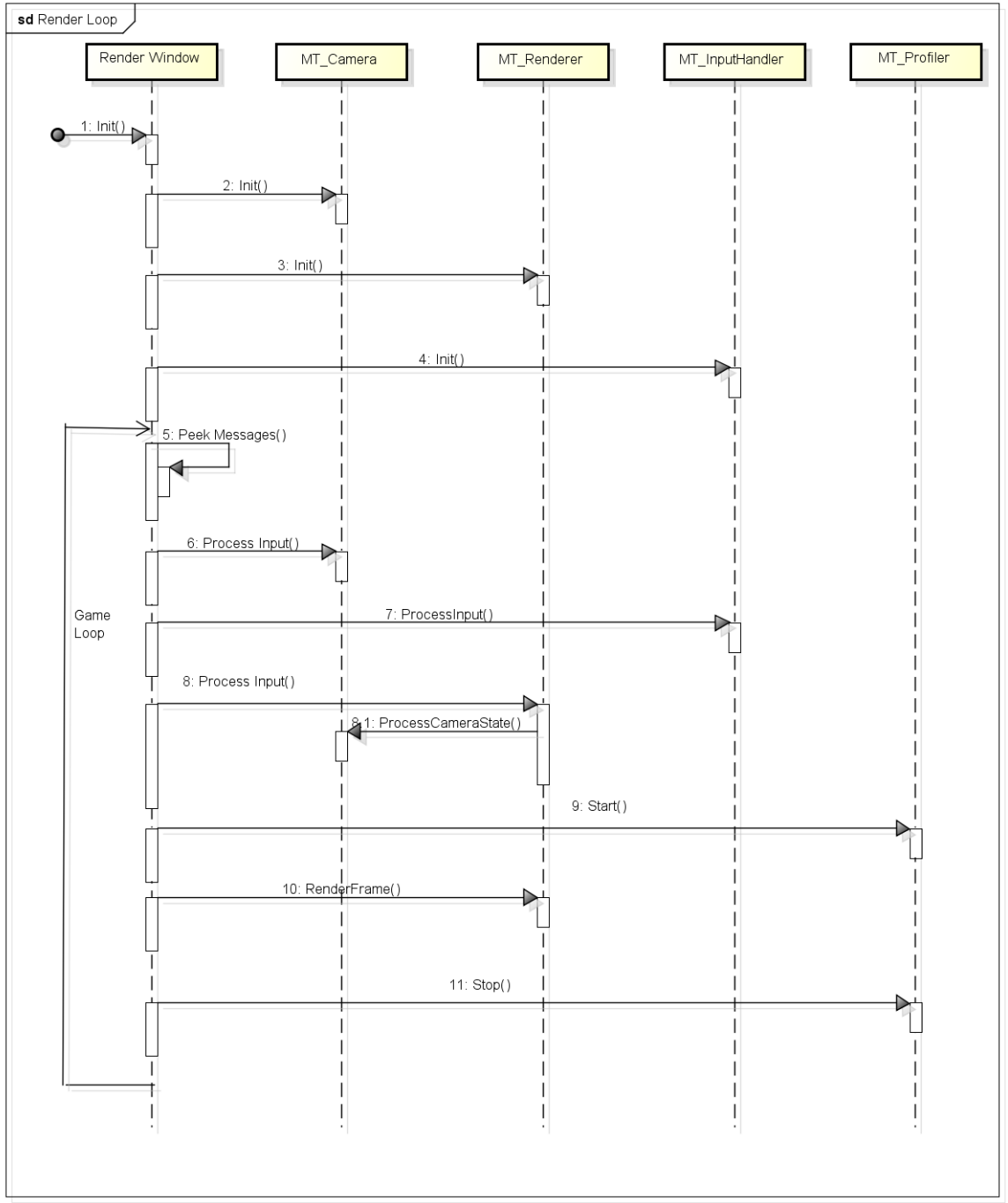
Implementation

- DirectX interface setup
  - Create device and swap chain
  - Setup Back buffer
  - Setup Rasterizer
  - Setup Viewport
- Preparing for the render loop
  - Initialize Shaders
  - Load Textures
  - Initialize Lighting parameters
  - Load Vertex buffer
  - Load Index buffer



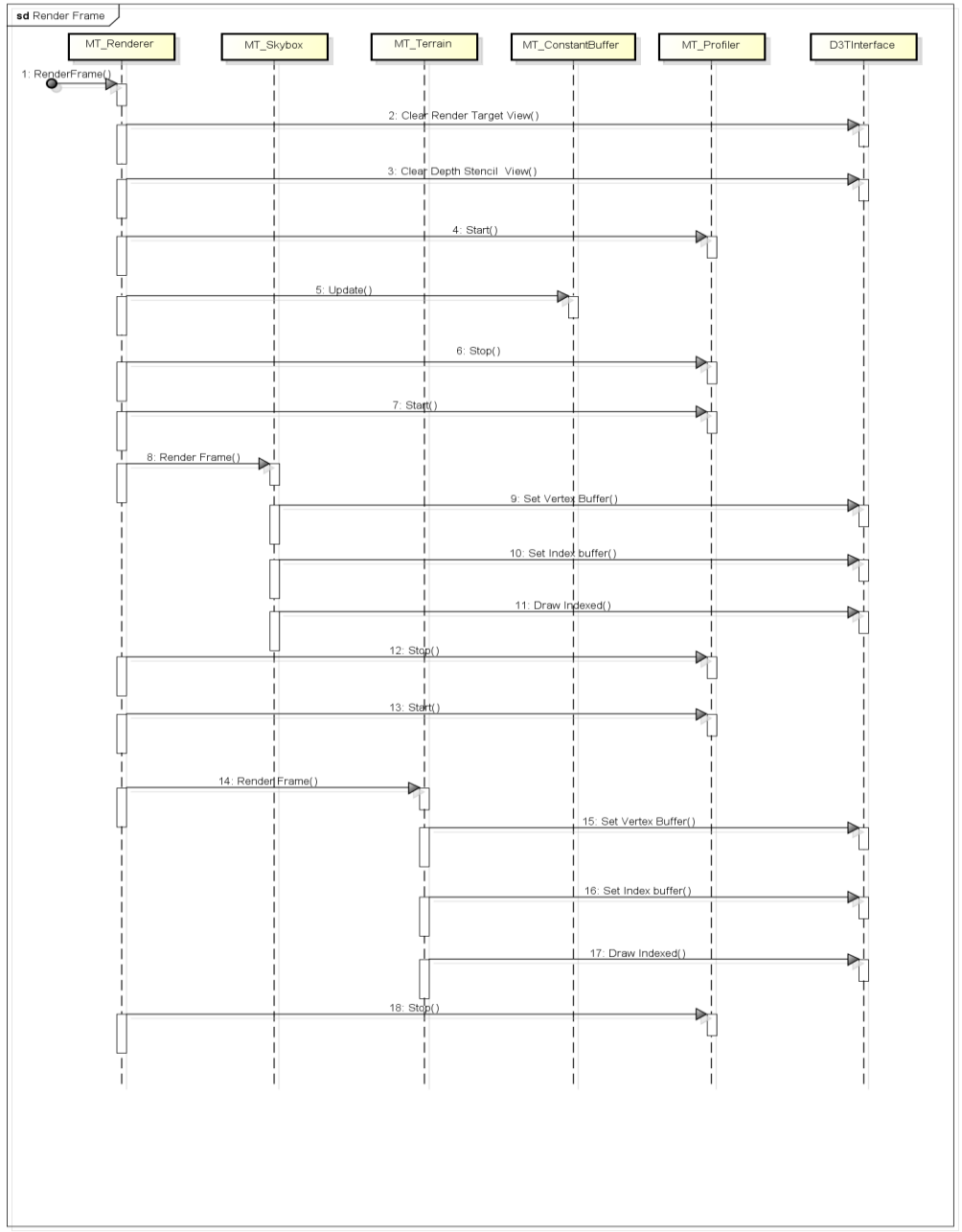
Implementation

- Render Loop
  - Message queue
  - Input Processing
  - Render frame
  - Profiling



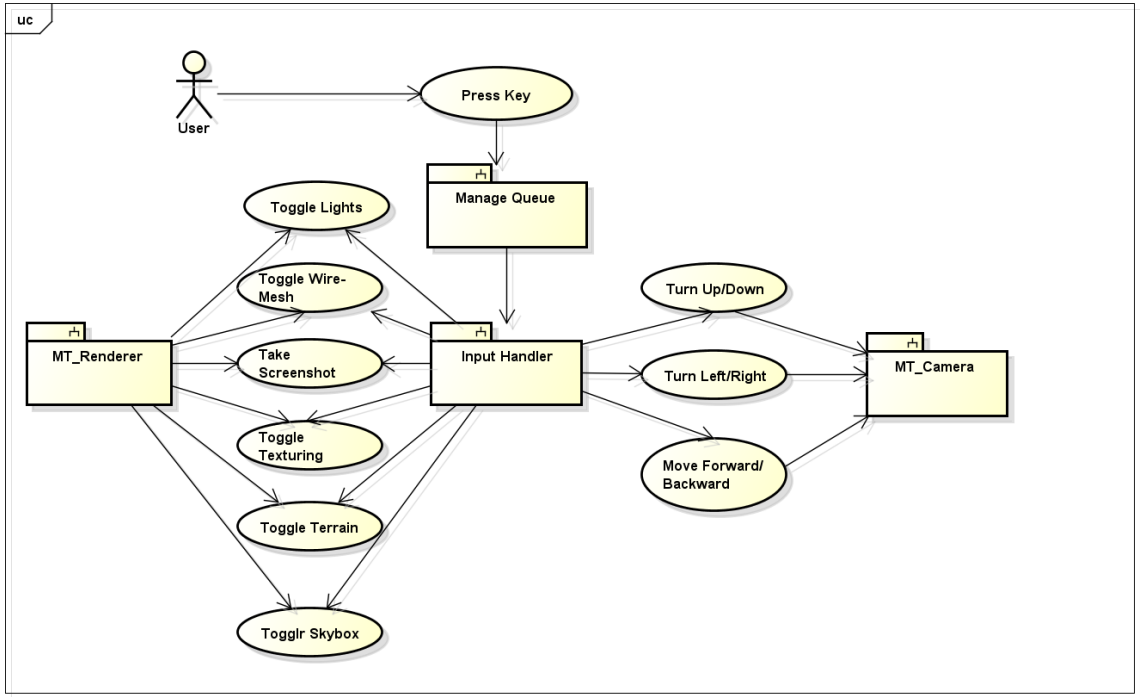
Implementation

- Render Frame
  - Update scene
  - Clear Render Target
  - Set active shaders
  - Set active vertex buffer
  - Set active index buffer
  - Draw calls
  - Profiling



Implementation

- User Interaction



Technology

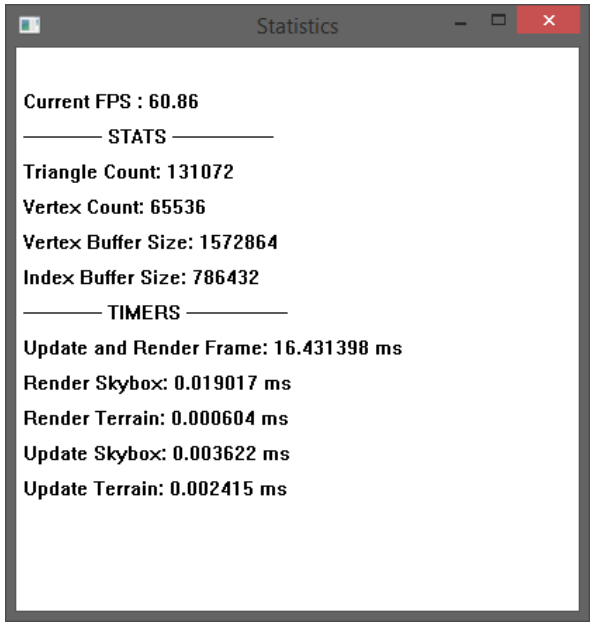
- C++
- Windows 8.1 SDK
- DirectX 11 SDK
- DirectXTK
- Visual Studio 2013
- Github / GitExtentions

Gains from using modern Graphics API

- Fixed shader pipeline vs DirectX 11 shader pipeline
- Vertex buffers and Index Buffers
- CPU vs GPU computation power
- Performance Gains
  - Unable to achieve 60fps in original implementation
  - Enough spare time to incorporate into much larger projects with this implementation
- No more keeping track of current “state” and matrix operations
- Development Tools
  - Visual Studio Editor and Debugger
  - Visual Studio Graphics Debugger

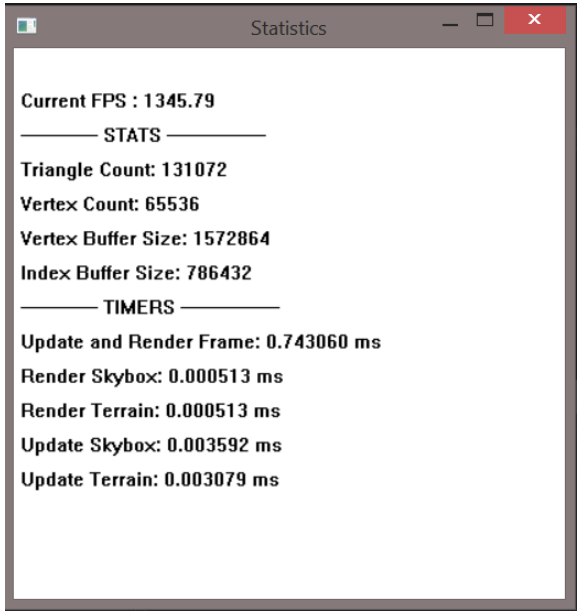
Performance Statistics

- With sync enabled



Performance Statistics

- With sync disabled



Performance Statistics

- Observations
  - Small frame time
    - Update + Render of Skybox and terrain together takes < 0.008ms
    - Majority of the frame time can be utilized to implement complex and/or interactive scenes
  - Small memory footprint
    - Buffers together are in the range < 2MB
    - No additional resources used for texturing

Challenges

- Sharp Transitions
  - Had to play with height generation parameters and smoothing
- Texture Stretching
  - Tri-planar texture mapping
- Sea Level Transition
  - Interpolating texture mapping between water and land
- Clipping
  - Skybox vs Far-plane
  - Collision detection (future work)
- Skybox Edges
  - Matching choice of skybox and water texture
  - Bounds to the scene

Conclusion

- Simple and intuitive techniques that can be examined in isolation
- Recap of texturing techniques gains
- Advantages of height map generation
- Gains observed in performance statistics
  - Frame time
  - Buffer sizes
- Candidate for integration into larger projects
- Importance of feature toggling
- Understanding contribution of each stage
- Benefits of DirectX 11
- Great for explaining techniques to a graphics enthusiast

Future Enhancements

- Shadow Mapping
- Tessellation Shader
- Terrain Editor
- Ocean Shader
- User Interface
- Collision detection
- Segue to Game Engine

Demo

- ‘w’ – Move camera forward
- ‘s’ – Move camera back
- ‘a’ – Yaw camera left
- ‘d’ – Yaw camera right
- ‘e’ – Pitch camera up
- ‘c’ – Pitch camera down
- ‘k’ –Screen shot
- ‘l’ – Toggle Lighting
- ‘m’ – Toggle wire-mesh
- ‘t’ – Toggle texturing
- ‘1’ – Toggle terrain
- ‘2’ – Toggle skybox

Questions ?

THANK YOU !

Karteek Mekala