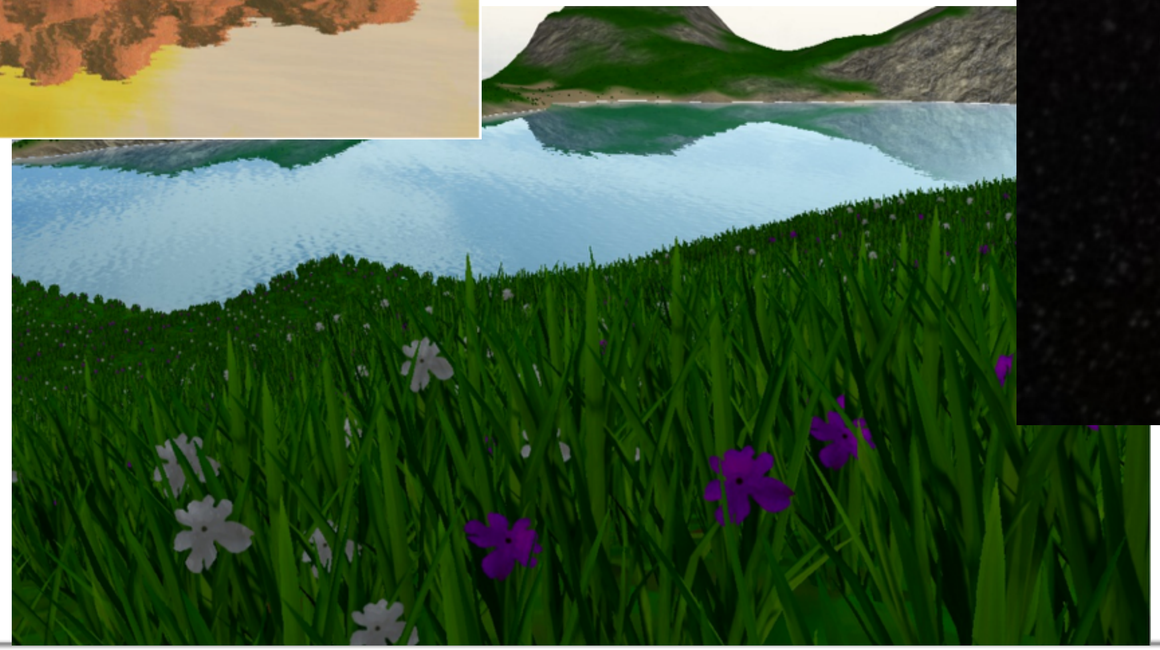
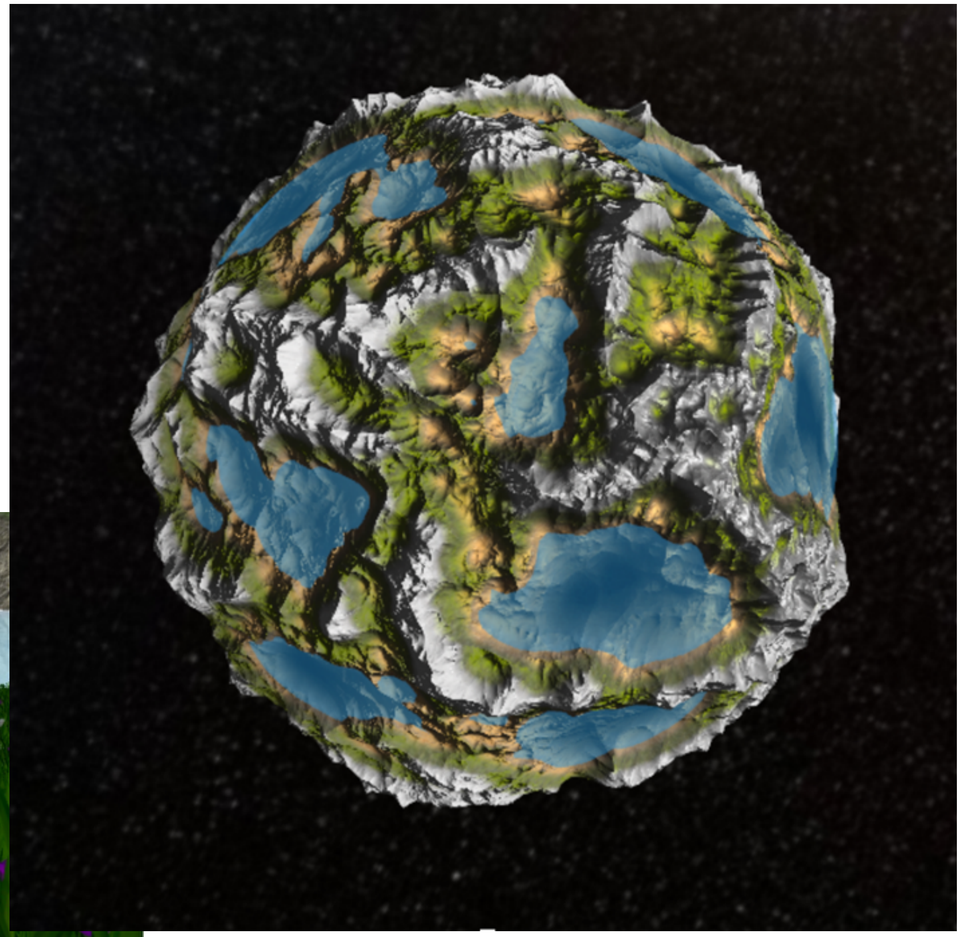
Intro to Computer Graphics

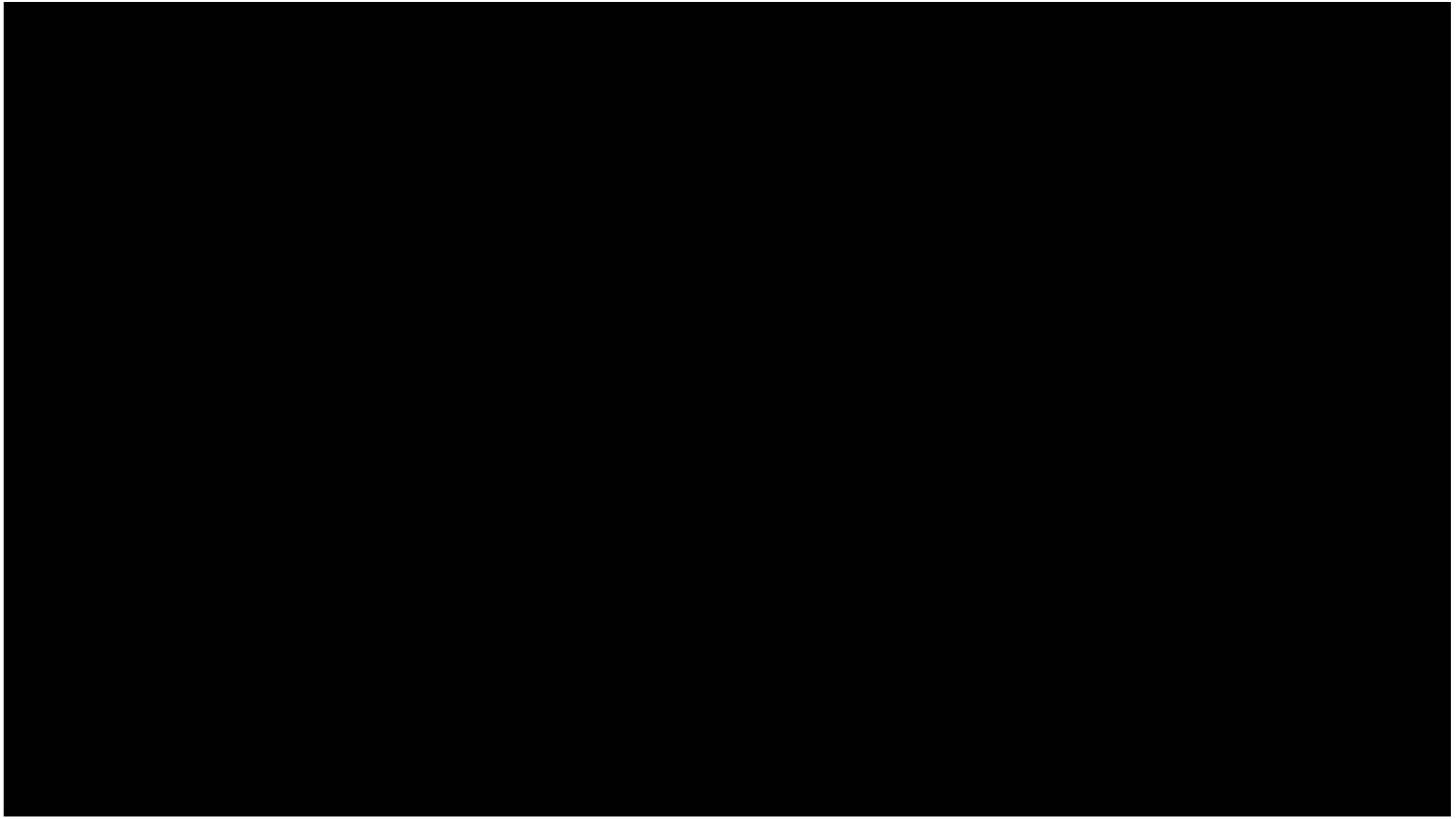
Project Part 1
Procedural Terrain

Demos from Last Year





Demos from Last Year



Demos from Last Year

Project Announcement

- 3 parts
  - Procedural modeling (2 weeks)
  - Rendering/texturing (3 weeks)
  - Animation/interaction/particle systems (2 weeks)
- No more solutions from now on
- TAs are around every Thursday afternoon for support
- Code base: take any of the HWs/practicals used so far
- Competition & presentation of best projects in week 14

Timeline

Week	What
6	Project Part 1 Start: Procedural Modeling
7	
8	Project Part 2 Start: Rendering / Texturing
9	Midterm Feedback Session
10	Holiday
11	Project Part 3 Start: Interaction / Animation / Particles
12	
13	Video Submissions for Competition
14	Project Grading Sessions / Code Submission / Presentations

Grading

- Grading done in the last week of the semester
  - Each group will have ~10min to demonstrate and explain to us (the TAs) what you did and answer our questions
  - Needs to run only on your laptop (no INF3 compatibility anymore)
  - You'll have to declare who in the team worked on what
- Midterm evaluation session in week 9
  - 5min per group
  - Mandatory, but doesn't count for final grade
  - You'll get feedback and know where you stand

Grading / Minimal Requirements

- The project is open ended
- We only explain the minimal requirements for 4.0
  - defined on slides 12 and 16 for Project Part 1
- To get a higher grade, extend the project with
  - your own ideas
  - online tutorials
  - some of our suggestions (slide 22)

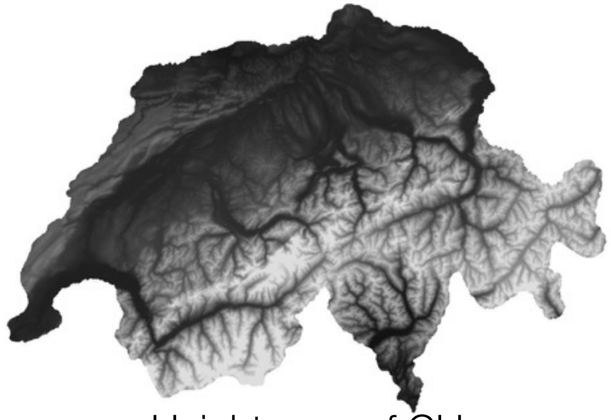
Project Part 1 - Terrain

- Procedural Terrain
  1. Generate a height map for a terrain on the GPU
  2. Render the terrain to the screen

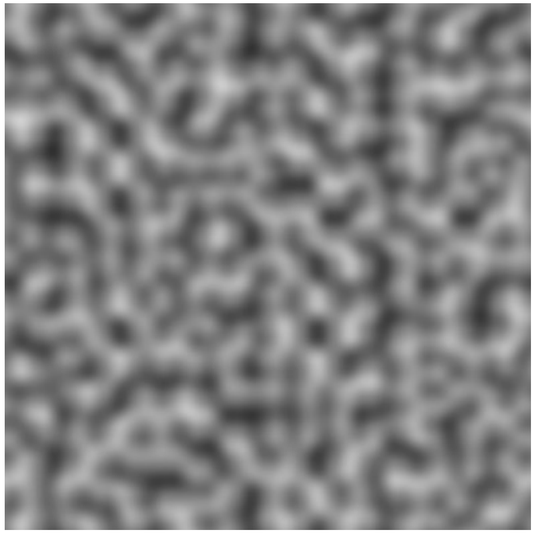
Procedural landscape by Iñigo Quilez

Part 1.1 Height Map Generation

- Height map
  - Image/texture with only one ‘color’ component
  - Like a topographical map: (u, v) = position, pixel value = elevation
- Use OpenGL shader to generate height map
  - Draw fullscreen quad to a framebuffer object
  - For every pixel, the fragment shader calculates a height value (using Perlin noise or combinations of it)
- Height map generation as preprocessing step
  - More performant than recalculating the height values in every render iteration
- Reuse and adapt code from HW5



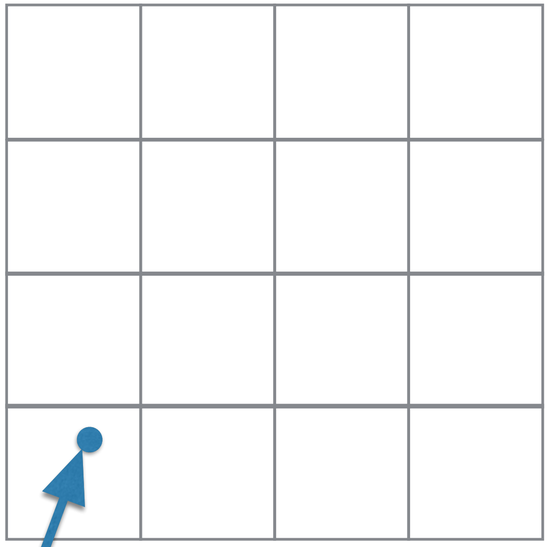
Height map of CH



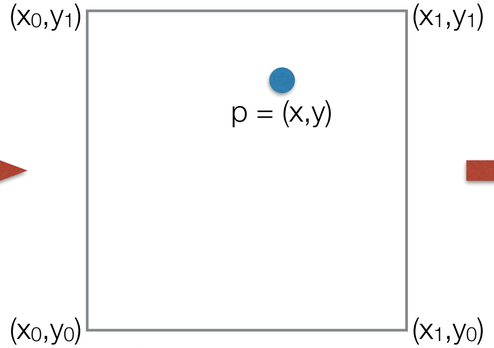
Perlin noise height map

Perlin Noise in 2D

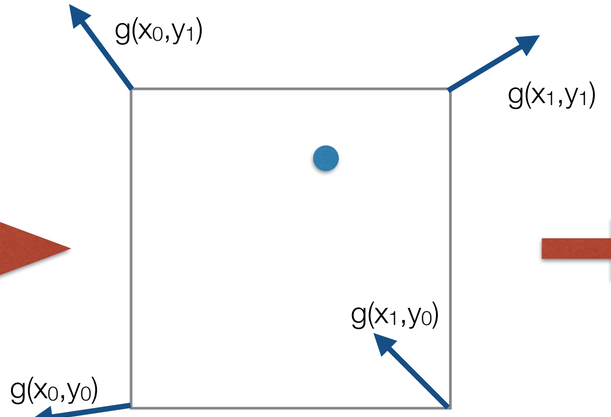
Subdivide domain into grid with unit cells



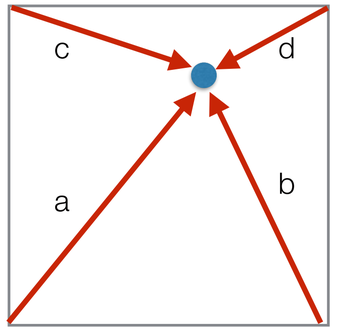
Find cell that your point is in



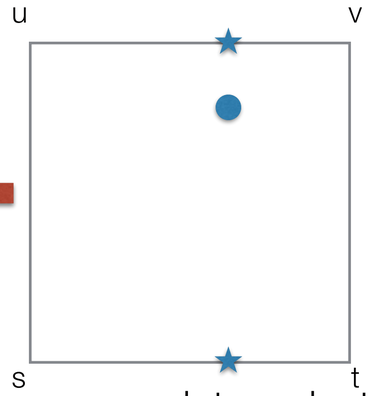
Cell with point



Calculate random gradients **g** at cell corners

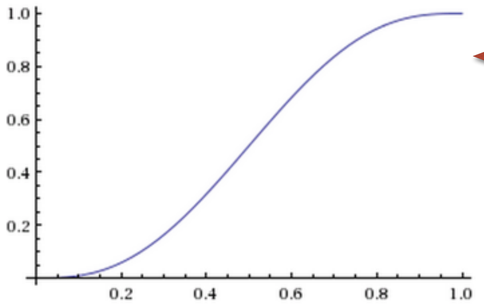


Calculate difference vectors from cell corners to **p**



$$s = g(x_0, y_0) \cdot a$$
$$t = g(x_1, y_0) \cdot b$$
$$u = g(x_0, y_1) \cdot c$$
$$v = g(x_1, y_1) \cdot d$$

dot products to get scalar values for the corners



Smooth interpolation function
C^2 continuity at the boundaries

$$f(t) = 6t^5 - 15t^4 + 10t^3$$

$$mix(x, y, \alpha) = (1 - \alpha) \cdot x + \alpha \cdot y$$

$$\begin{aligned} st &= mix(s, t, f(x)) \\ uv &= mix(u, v, f(x)) \\ noise &= mix(st, uv, f(y)) \end{aligned}$$

Part 1.1 TODO

1. Create an FBO with a texture attached to it with 1 component
   The attached texture stores the height map

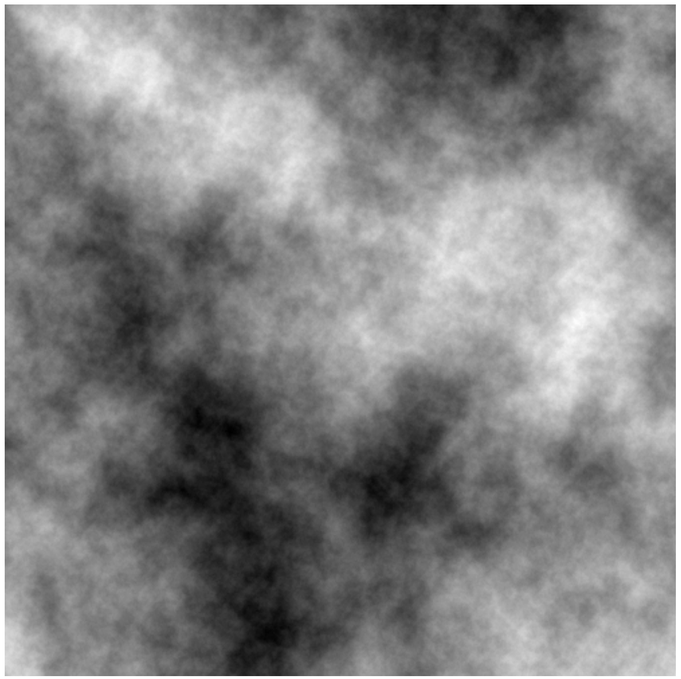
2. Create and bind a shader program for rendering to that FBO

3. Create a Perlin noise function in the fragment shader
   The fragment shader writes the height values into the texture

4. Render a full screen quad
   The quad reaches from [-1, -1, 0] to [1, 1, 0]. Don't forget to resize the viewport to the texture size for this to work correctly (and to reset it after height map generation.

5. Render height map before the main render loop
   Unbind the FBO after terrain generation, otherwise you keep rendering to it instead of the screen

6. Implement *fractal Brownian motion* (fBm)



fBm height map

Perlin Noise Resources

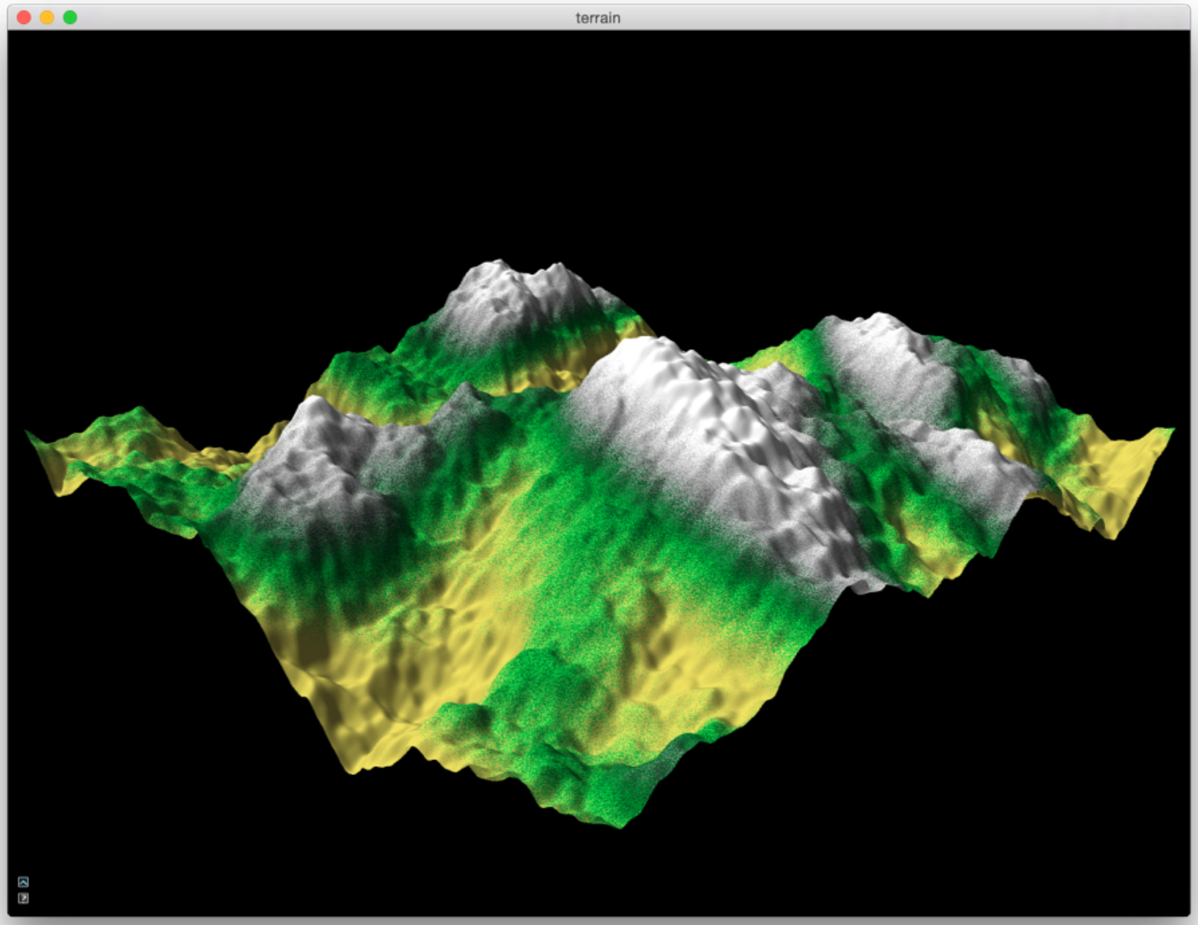
- Ken Perlin: **Improved Noise**, *SIGGRAPH 2002*
  - http://mrl.nyu.edu/~perlin/noise/
  - source code available
- Simon Green, **Implementing Improved Perlin Noise**, *GPU Gems 2*
  - http://http.developer.nvidia.com/GPUGems2/gpugems2_chapter26.html
  - source code available, needs to be ported from HLSL to GLSL
- Matt Zucker, **The Perlin noise math FAQ**
  - http://webstaff.itn.liu.se/~stegu/TNM022-2005/perlinnoiselinks/perlin-noise-math-faq.html
  - explains maths behind Perlin Noise

Part 1.1 Pitfalls

- Pay attention to texture formats
  - Default OpenGL textures are clamped to [0, 1].
  - We recommend to use unbounded floating point textures for the height map, e.g., **GL_R32F**
  - https://www.opengl.org/wiki/Image_Format
    https://www.opengl.org/wiki/GLAPI/glTexImage2D
- If using the GPU Gems 2 tutorial (previous slide)
  - You will use multi-texturing to store gradient and permutation tables
  - Tutorial on texture units and multi-texturing: https://open.gl/textures
  - Alternatively store gradients & permutations in global array in fragment shader

Part 1.2 Terrain Rendering

- Create a terrain from the pre-calculated height map



colored fBm terrain

Part 1.2 TODO

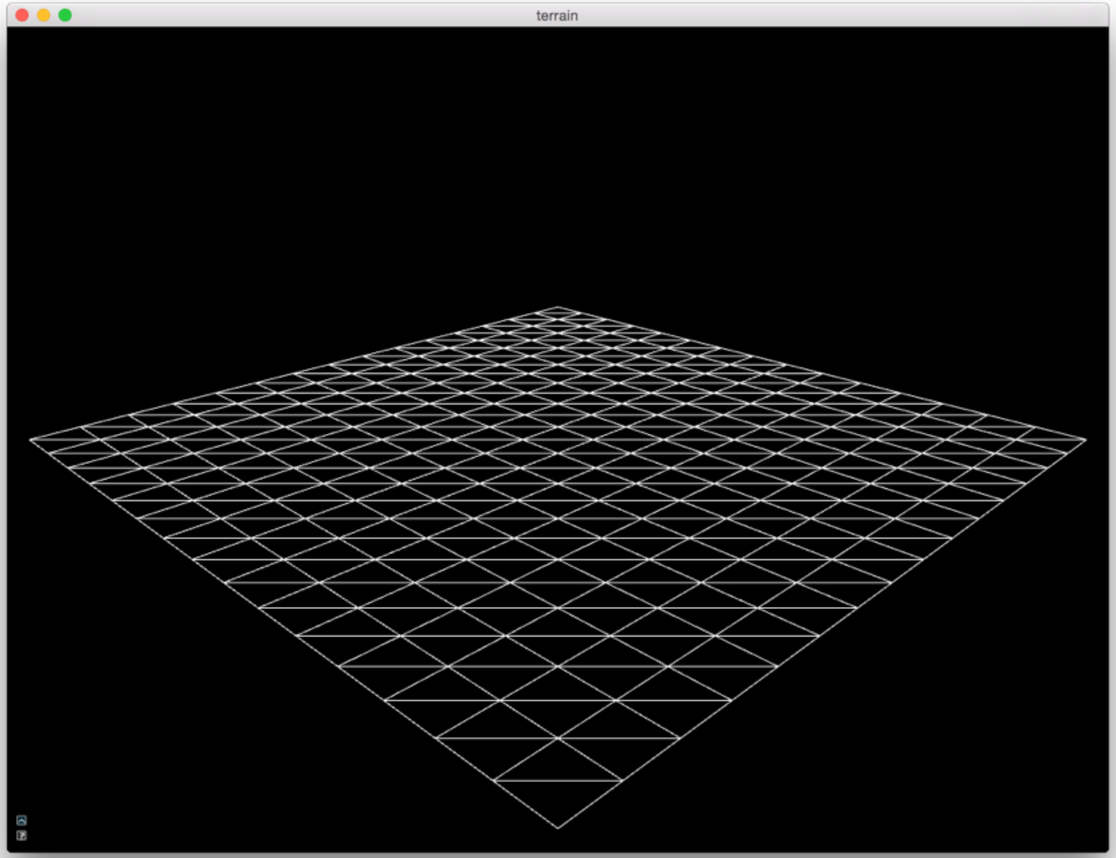
1. Create triangle grid to represent the terrain (at least 512x512).
   (reuse from HW3)

2. Create a shader program for terrain rendering.
   The vertex shader samples the height map texture an displaces the vertices according to the height. (reuse/adapt from HW3)

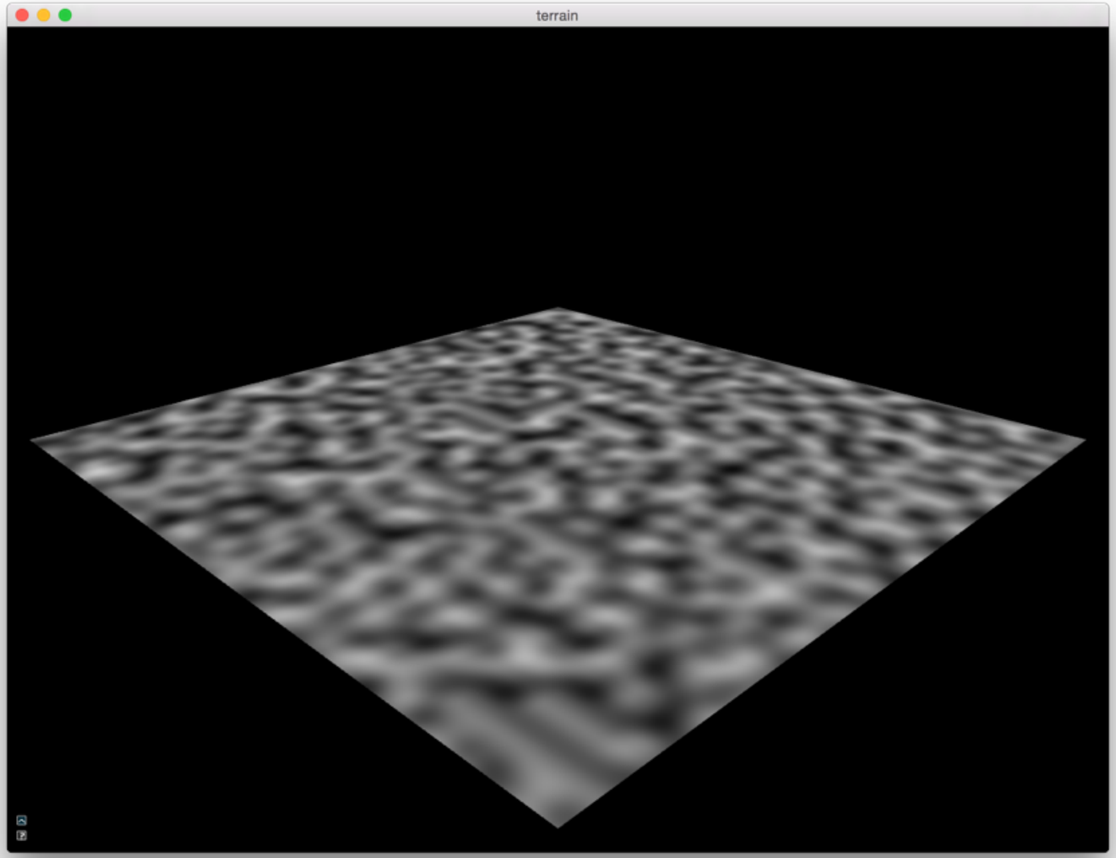
3. Diffuse shading of the terrain in the fragment shader.
   You have calculate the normal at every position in the fragment shader.
   One way to do this is by using finite differences: you can find the gradient at the current pixel position by comparing the elevation with the elevation of the neighboring pixels in the height map.

4. Use simple schema to color the terrain according to height.

Part 1.2 Terrain Rendering

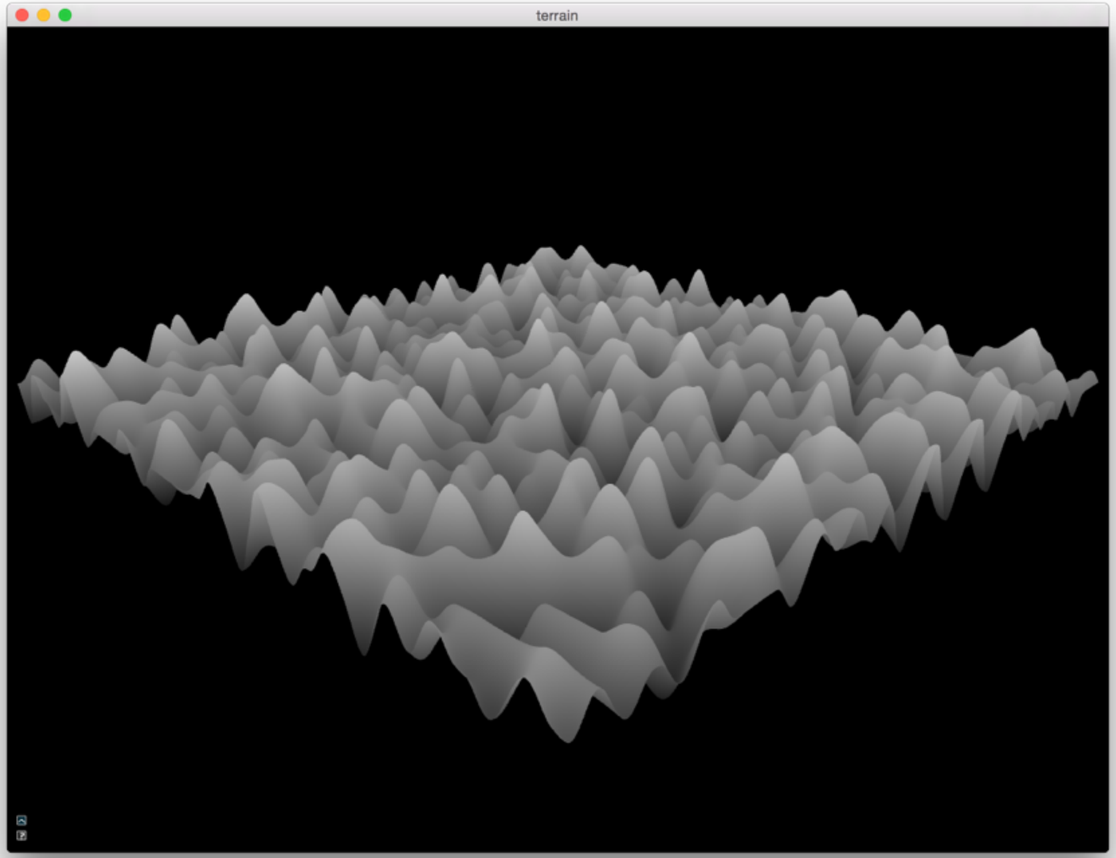


Step 1: triangle grid
(only 16x16 for visualisation)

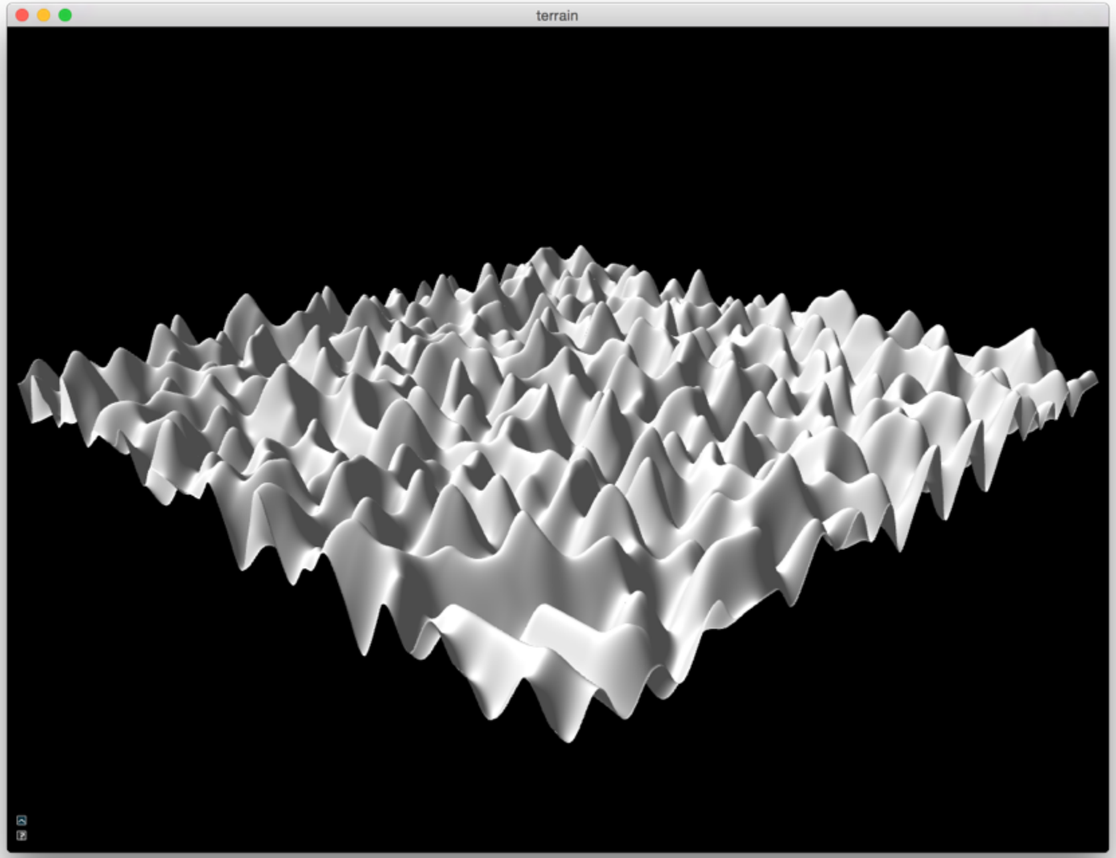


Grid textured with Perlin noise height map

Part 1.2 Terrain Rendering

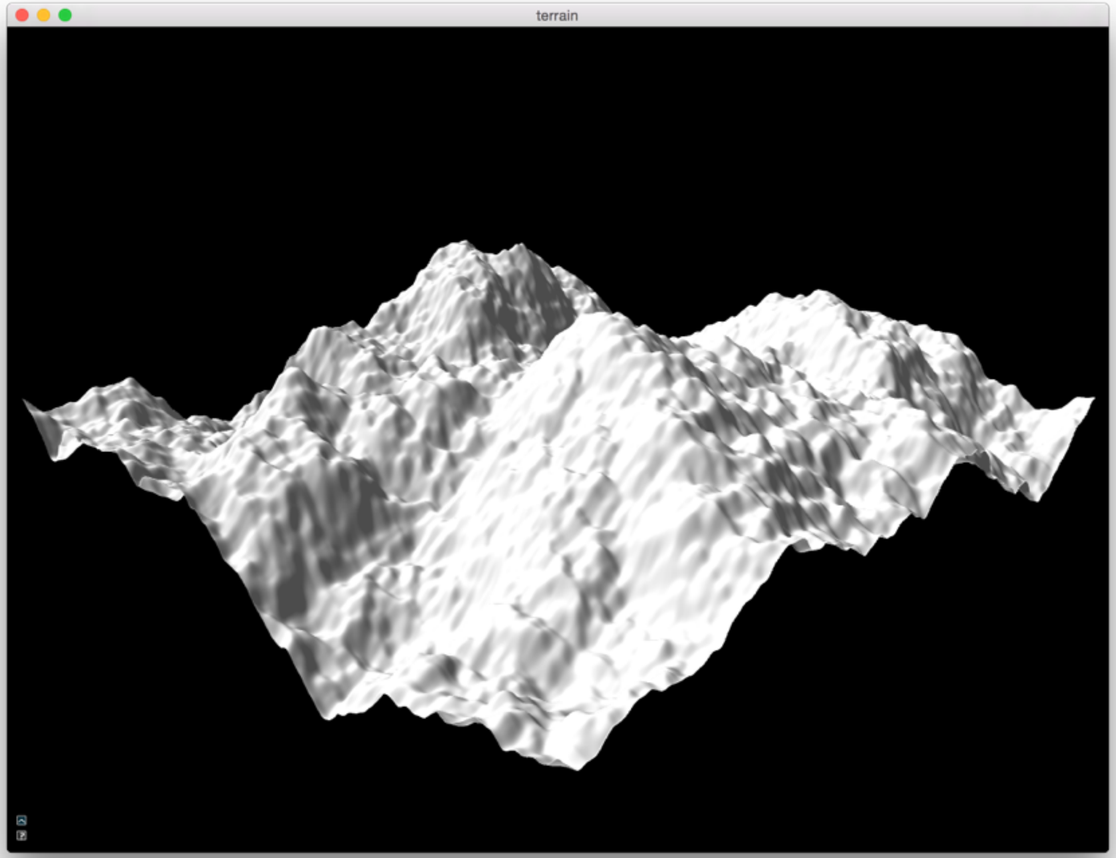


Step 2: Displacing vertices
(on 512x512 grid)

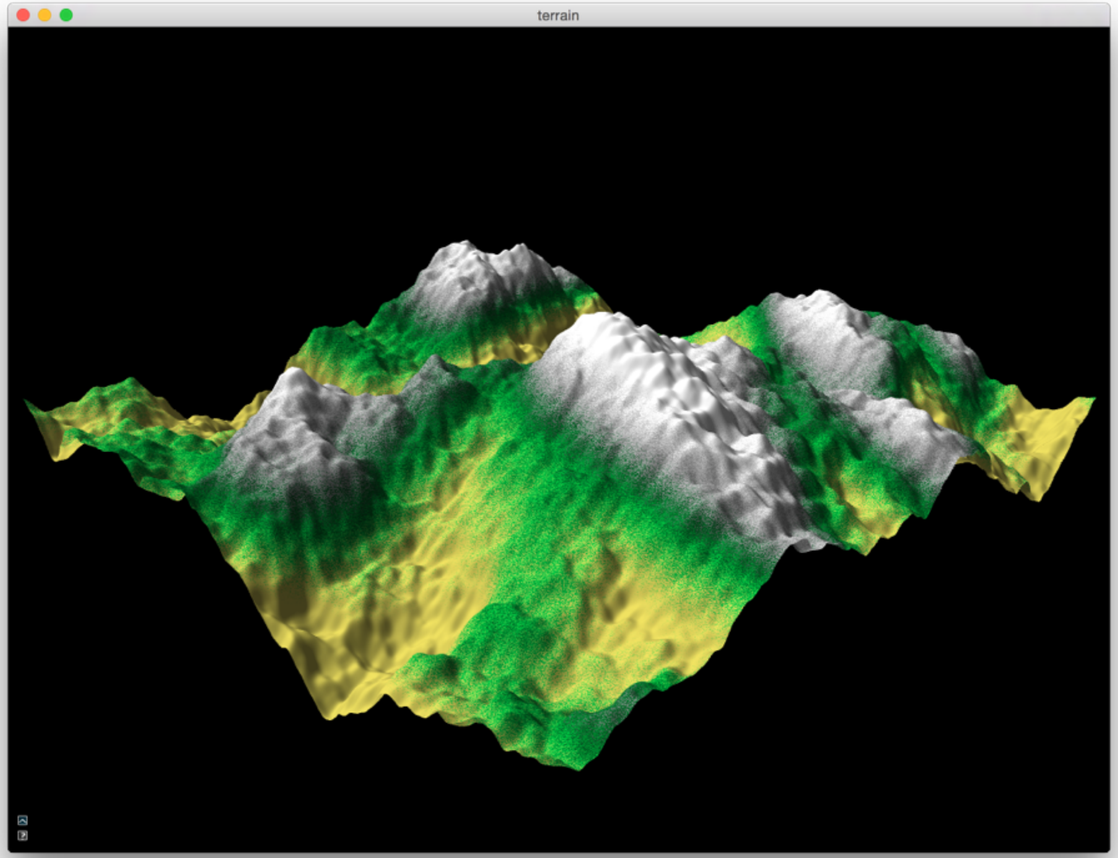


Step 3: Diffuse Shading

Part 1.2 Terrain Rendering



Fractal Brownian Motion (fBM) Terrain with diffuse shading

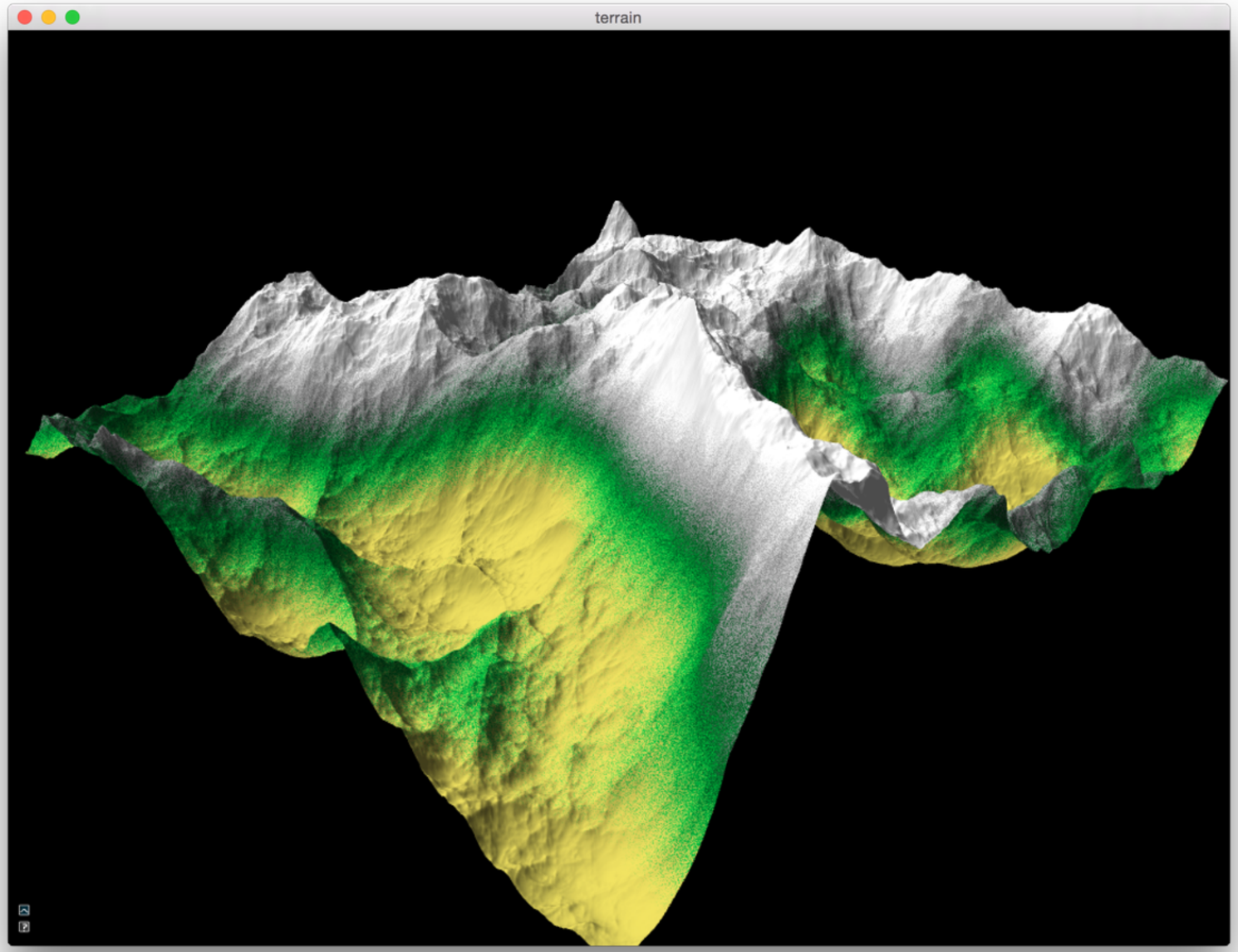


Step 4: Coloring schema depending on height

Project Part 1 Hints

- Impossible to visualize height map (Part 1.1) without being able to display it (Part 1.2)
  - In practice, it might make more sense to start with the Part 1.2
  - Figures on slides 17-19 show a possible implementation order
- Fractal terrains are extremely parameter sensitive
  - Correct implementation with bad parameters can look wrong
  - Map parameters to keys to interactively change them

Ridged Multifractal / Demo



Terrain Ressources

- Ken Musgrave, **Procedural Fractal Terrains**
  - http://www.cs.rit.edu/~jmg/courses/cgII/20033/slides/2-1-ProceduralModels.pdf
  - Good explanation of types of fractal terrains and their parameters
- Textbook: **Texturing & Modeling: A Procedural Approach**
  - more details than Ken's paper, but very chaotic
  - available online at http://library.epfl.ch

Extensions

- Some ideas to improve the project (and your grade)
  - **easy** – other combinations of noise functions for more interesting terrains, e.g., hybrid or ridged multifractals
  - **easy** – use 3D noise to create materials for meshes, e.g., wood or marble
  - **medium** – tessellation shaders for level of detail (LOD) terrain rendering
    Dynamically refine/coarsen the grid depending on the camera position
    This needs a GPU that supports OpenGL 4
  - **medium** – instead of using a flat triangle grid, use 3D noise and map it to a sphere in order to render a procedural planet
  - **hard** – make an infinite terrain that you can navigate through.
  - **very hard** – populate the terrain with procedural trees
  - Your own idea.

OpenGL Debugging

- Debugging OpenGL code can be painful. Start early!
- Helpful tools
  - gDEBugger (Win and Linux) http://www.gremedy.com/ (a bit outdated)
  - OpenGL Profiler (OSX, included in Xcode)
  - http://apitrace.github.io/
  - `check_error_gl()` in our framework