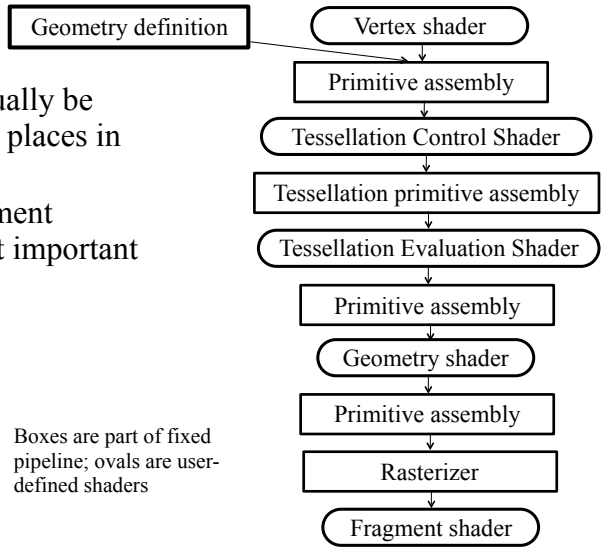
CS770/870 Fall 2015 Advanced GLSL

Based on material from
Bailey notes from Oregon State and
web sources cited in slides and others to be documented later.

Expanded Graphics Pipeline

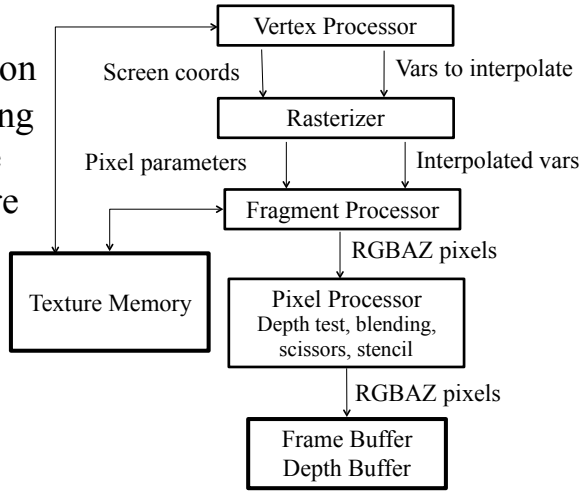
- Shaders can actually be inserted in more places in pipeline
- Vertex and fragment shaders are most important



Boxes are part of fixed pipeline; ovals are user-defined shaders

Fragment Processing Pipeline

- *pixel*: rgbaz for a frame buffer location
- *fragment*: everything needed to compute pixel: rgbaz, texture coords, and more

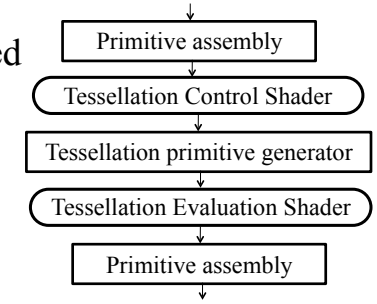


Topics of Interest

- **Tessellation**
  - tessellation control shader
  - tessellation evaluation shader
- **Geometry** shader
- Textures v. **samplers**
- Framebuffer objects
- **WorkGroups**
- Advanced vertex shader functionality
  - drawArraysInstanced, drawArraysBaseInstanced, multiDrawArrays, drawArraysIndirect

Tessellation

- Optional **Vertex Processing**
  - vertex patch data is subdivided
  - generates new vertices
  - need to specify new vertex attributes: position, color, normal, texture coords, etc.



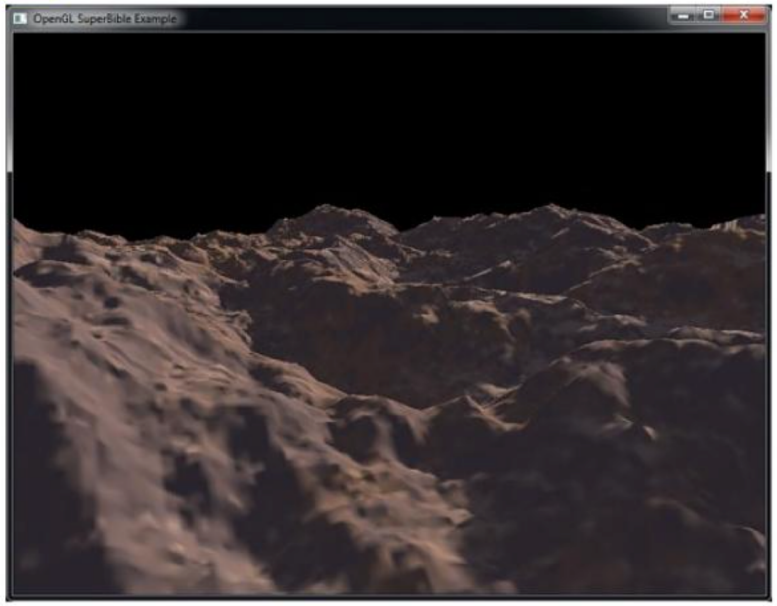


Figure 8.12: Terrain rendered using tessellation

From OpenGL SuperBible

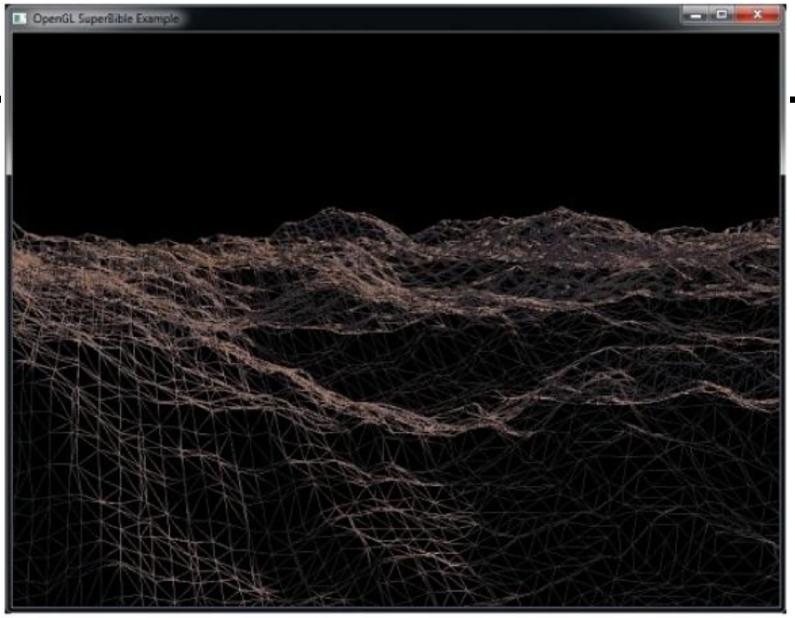


Figure 8.13: Tessellated terrain in wireframe

From OpenGL SuperBible

Patches

- OpenGL patch *primitive* is a block of vertices in which each successive *n* vertices constitutes 1 patch
  - *glPatchParameteri*(patchId, 6); // 6 verts per patch
  - vertices in patch often thought of as *control points*
  - max patch size is impl-dependent, but is >= 32
- No particular order is required in a patch; it depends on how the patch is used
- Can have all the attribute information associated with any vertex block: position, color, normals, texture coords, etc.

Tessellation Levels

- Patches have *inner* and *outer* ***edges***
- Tessellation level independently set for inner/outer edge types
- A level *n* means that the edge will be partitioned into *n* segments by the tessellation.
- *outer* edges usually have higher *n* than *inner* edges
  - Allows for better stitching between patches.

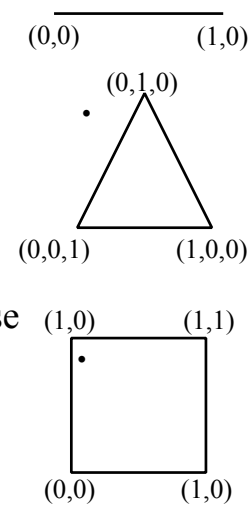
http://www.geeks3d.com/20100730/test-first-contact-with-opengl-4-0-gpu-tessellation/

Fractional Tessellation Levels

- Level specification is float
- 3 options for fractional component
  - *equal_spacing* : all segments same length
  - *fractional_odd_spacing* : let *n* = next-lower *odd* integer (for 4.6, that is 7); make segment size segments and split the remaining space in 2.
  - *fractional_even_spacing* : same as odd, but *n* is next-lower *even* integer
  - get smoother transitions between levels
- http://www.geeks3d.com/20130128/know-your-opengl-tessellation-spacing-modes/

Tessellation Coordinates

- Similar to texture coordinates
- Depend on data type: line, triangle, quad
- triangles use *barycentric* coordinates
  - represent any point inside by linear combination of vertex coordinates
  - subdivision points inside triangle can be defined on an *abstract* triangle with these coordinates and later transformed by actual Cartesian coordinates.



Triangle Barycentric Coordinates

- Given triangle defined by $\mathbf{v_0}$, $\mathbf{v_1}$, $\mathbf{v_2}$ where $\mathbf{v_i}=(\mathbf{x_i}, \mathbf{y_i})$
- Can represent every point in triangle with

$$x = \lambda_0 x_0 + \lambda_1 x_1 + \lambda_2 x_2$$
$$y = \lambda_0 y_0 + \lambda_1 y_1 + \lambda_2 y_2$$

  where $\lambda_0 + \lambda_1 + \lambda_2 = 1$
- Given Cartesian coordinates, can get barycentric:

$$\lambda_0 = ((y_1-y_2)(x-x_2)+(x_2-x_1)(y-y_2))/\det(T)$$
$$\lambda_1 = ((y_2-y_0)(x-x_2)+(x_0-x_2)(y-y_2))/\det(T)$$
$$\lambda_2 = 1 - \lambda_0 - \lambda_1$$

where $T = \begin{vmatrix} x_0-x_2 & x_1-x_2 \\ y_0-y_2 & y_1-y_2 \end{vmatrix}$

Tessellation Level Specifications

- Inner level[2] = [2.0, 4.0]
  - *quad*: *u* direction edges split into 2 parts, *v* into 4
  - *triangle*: all edges split into 2; 2nd element not used
- Outer level[4] = [2.0, 3.0, 4.0, 5.0]
  - *quad*: left edge split in 2 parts, bottom into 3, right into 4, and top into 5.
  - *triangle*: edge between (0,0,1) and (0,1,0) split into 2
    edge between (0,0,1) and (1,0,0) split into 3
    edge between (1,0,0) and (0,1,0) split into 4
    (last value not used).

http://www.informit.com/articles/article.aspx?p=2120983

Tessellation Primitive Generator

- Fixed-function stage: not programmable by user,
- User provides parameters (directly or via a shader)
  - tessellation levels
  - spacing parameters for tessellated vertices
  - data type: triangles, quads, isolines, points
- Determines **only**
  - # vertices to generate, their order, primitive type
- It does not use the actual input vertex information
  - all output is relative to an abstract normalized (0,1) primitive object

Tessellation Control Shader (TCS)

- Processes exactly one vertex of a patch
- Can communicate with other TCS instances for same patch
  - can share information
  - must synchronize
  - share output information
- Outputs (mostly) go directly to the Tessellation Evaluation Shader (TES)
  - patch output inner and outer tessellation levels goes to the tessellation primitive generator

Tessellation Evaluation Shader (TES)

- Input
  - abstract patch from tessellation primitive generator
  - actual vertex data for **entire** patch (from TCS or VS)
- Output
  - A single vertex from the tessellation
- Assumption: not verified
  - if a patch has 6 vertexes, 16 TES instances are created and all patch data and each knows which it is supposed to produce as output.

Geometry Shader

- Geometry shader takes input after vertex processing (including tessellation) and prior to vertex post-processing
- Geometry shader input: OpenGL *Primitive* stream
  - points
  - lines, lines_adjacency
  - triangles, triangle_adjacency
- Note that geometry shader has the **entire** triangle, not just 1 vertex at a time.
- Each geometry shader only processes 1 kind of Primitive

•http://web.engr.oregonstate.edu/~mjb/cs519/Handouts/geometry_shaders.1pp.pdf

Stencil Buffer

- Like a depth buffer where values act like a cardboard stencil, that can either allow colors through, prevent them.
- OpenGL's stencils have more options than cardboard!

•https://open.gl/depthstencils