OpenGL 4.0 Tessellation For Professionnal Applications

San Jose, CA | Sept. 21, 2010

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Agenda

- Motivation
- OpenGL 4.0 Tessellation Pipeline
- Case study
  - Massive terrain rendering

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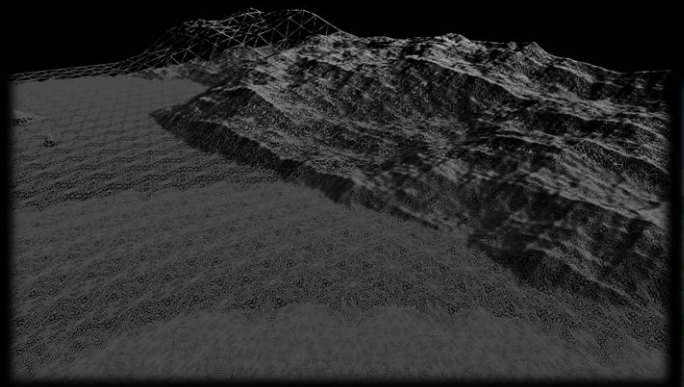
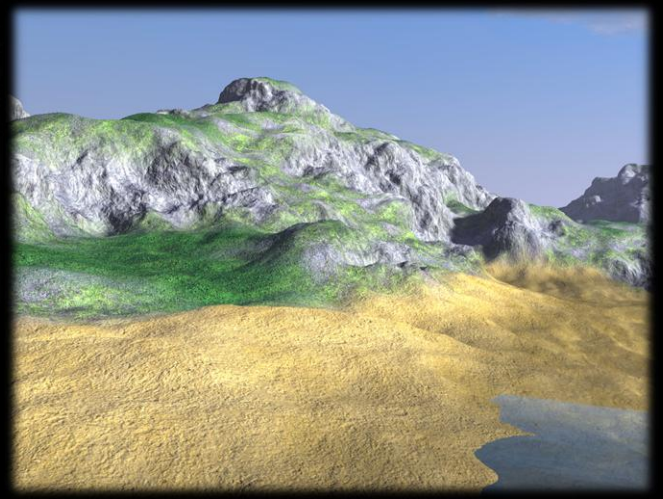
Motivation





- Visual quality
- Memory Bandwidth
- Dynamic LOD
- Perform computations at lower frequency

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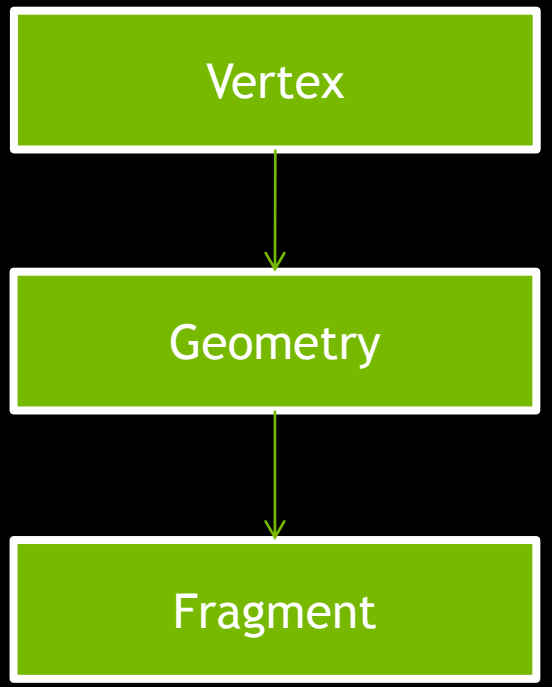
The OpenGL 3.x pipeline



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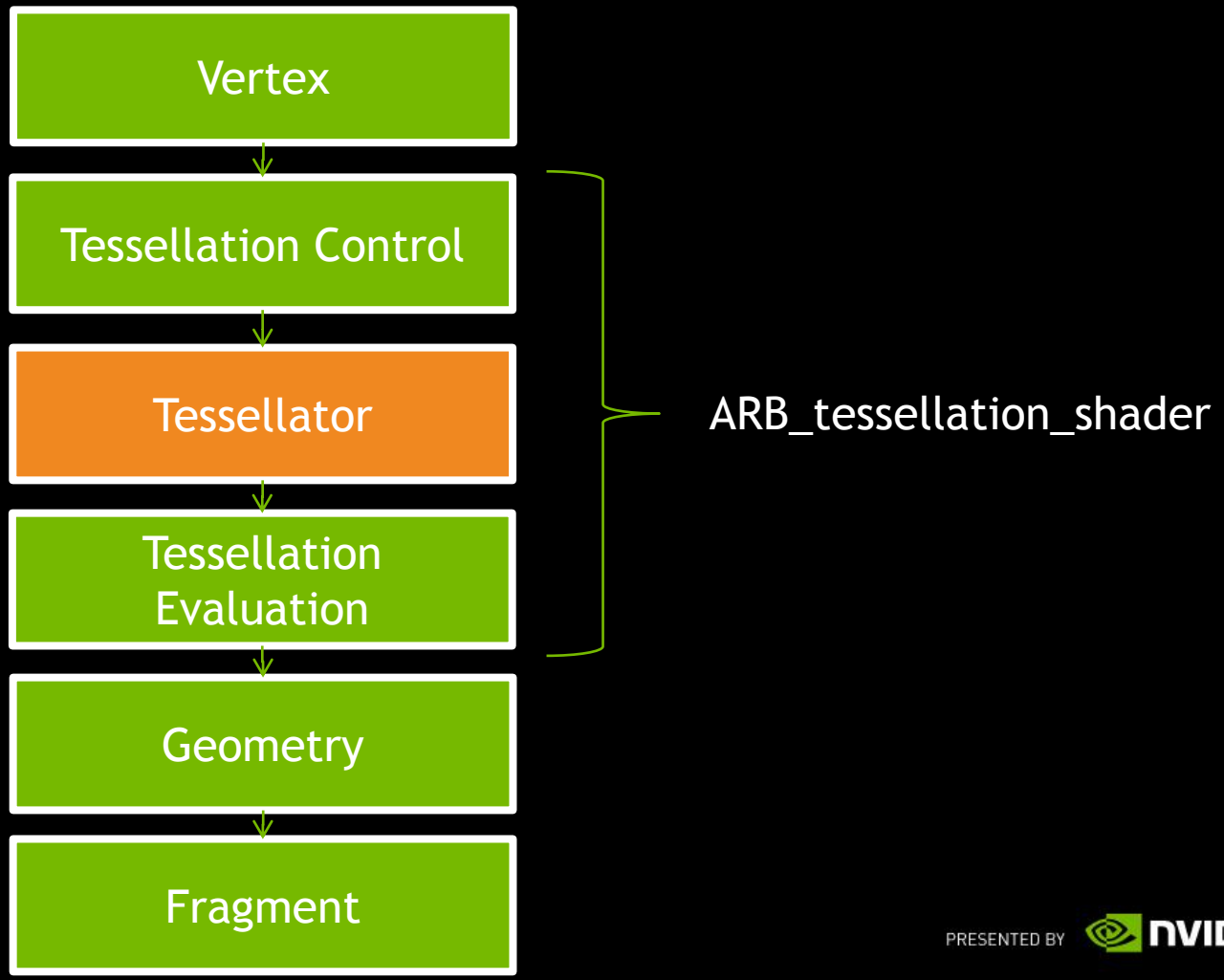
The OpenGL 4.x pipeline



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The OpenGL 4.x pipeline

- 2 new Programmable stages
  - Tessellation Control Shader (`GL_TESS_CONTROL_SHADER`)
  - Tessellation Evaluation Shader (`GL_TESS_EVALUATION_SHADER`)
- 1 new Fixed function stage
  - tessellation primitive generator aka tessellator
- 1 new primitive type
  - Patches (`GL_PATCHES`)

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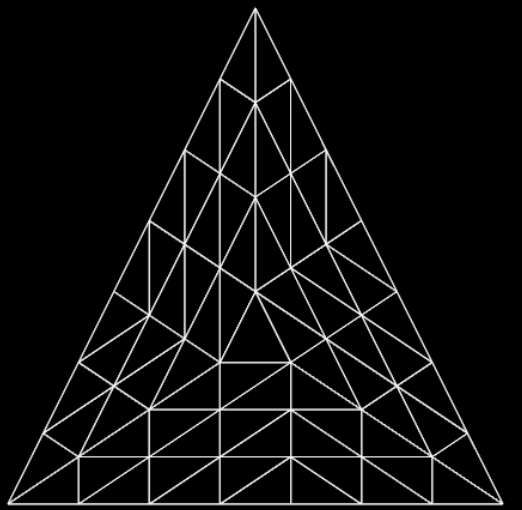
The patch primitive

- Arbitrary number of vertices (1 to 32)
  - `glPatchParameteri(GL_PATCH_VERTICES, patchVCount)`
- Only primitive type allowed when a tessellation control shader is active
- No implied geometric ordering



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OpenGL Tessellation - Setup

```
char *tcsSource; // Null terminated string
GLuint tcs = glCreateShader(GL_TESS_CONTROL_SHADER);
glShaderSource(tcs, 1, tcsSource, NULL);
glCompileShader(tcs);
glAttachShader(program, tcs)
```

```
char* tesSource; // Null terminated string
GLuint tes = glCreateShader(GL_TESS_EVALUATION_SHADER);
glShaderSource(tes, 1, tesSource, NULL);
glCompileShader(tes);
glAttachShader(program, tes);
```

```
glLinkProgram(program);
```

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Tessellation Control Shader (TCS)

- Runs once for each vertex
- Computes LOD per patch
  - `gl_TessLevelOuter[4]`
  - `gl_TessLevelInner[2]`
- Optional
  - If not present tessellation level will be set to their default value
  - Default value can be changed using:
    - `glPatchParameterfv(GL_PATCH_DEFAULT_OUTER_LEVEL, outerLevels)`
    - `glPatchParameterfv(GL_PATCH_DEFAULT_INNER_LEVEL, innerLevels)`

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Tessellation Control Shader (TCS)

- Patch discarded if
  - gl_TessLevelOuter[x] <= 0 (Usefull for Culling)
  - gl_TessLevelOuter[x] = NaN

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Tessellation Control Shader : Sample

```
layout(vertices = 3) out;
uniform float tessLevelOuter;
uniform float tessLevelInner;
void main()
{
  gl_TessLevelOuter[0] = tessLevelOuter;
  gl_TessLevelOuter[1] = tessLevelOuter
  gl_TessLevelOuter[2] = tessLevelOuter;
  gl_TessLevelInner[0] = tessLevelInner;
  gl_out[gl_InvocationID].gl_Position =  gl_in[gl_InvocationID].gl_Position;
}
```

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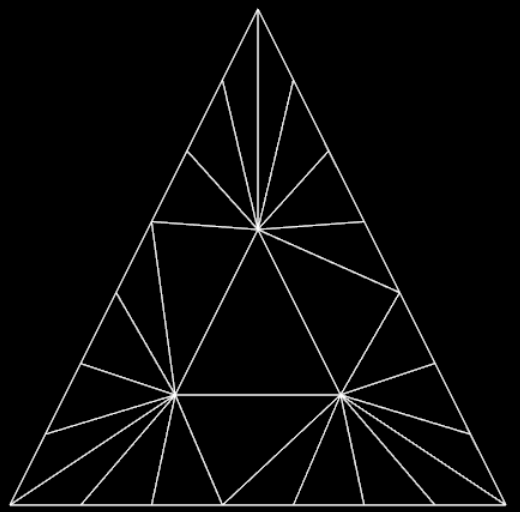
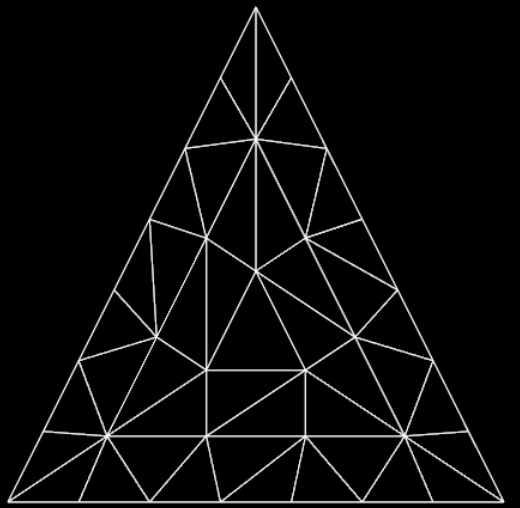
Tessellator

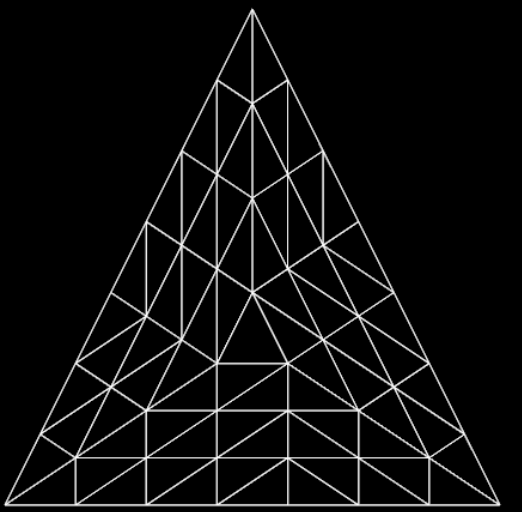
- Uses tessellation levels to decompose a patch into a new set of primitive
- Each vertex is assigned a (u, v) or (u, v, w) coordinate



Outer = 3
Inner = 3



Outer = 5
Inner = 5



Outer = 7
Inner = 7

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Tessellation Evaluation Shader (TES)

- Compute the position of each vertex produced by the tessellator
- Control the tessellation pattern
- Can specify orientation of generated triangles
  - ccw (default)
  - cw
- Capable of generating points instead of lines or triangles
  - point_mode

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TES: Layout

- equal_spacing
  - `tessLevel = clamp(tessLevel, 1, maxTessLevel)`
  - Rounded to nearest integer
- fractional_even_spacing
  - `tessLevel = clamp(tessLevel, 2, maxTessLevel)`
  - Rounded to next even integer
- fractional_odd_spacing
  - `tessLevel = clamp(tessLevel, 1, maxTessLevel - 1)`
  - Rounded to next … odd integer ☺

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Tessellation Evaluation Shader : Sample

```
layout(triangles, equal_spacing, ccw) in;


void main()
{
  gl_Position = vec4(gl_In[0].gl_Position.xyz * gl_TessCoord.x +
     gl_In[1].gl_Position.xyz * gl_TessCoord.y +
     gl_In[2].gl_Position.xyz * gl_TessCoord.z +
     1.0);
}
```

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Tessellation Schemes

- Flat
- PN Triangles
- Gregory Patches

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Water-tight tessellation

- Cracks may occur due to floating point precision
  - `a + b + c != c + b + a`
- Use GLSL `precise` qualifier
  - Ensure computations are done in their stated order

```
precise out vec4 position;

out vec4 position;
precise position; // make existing variable precise
```

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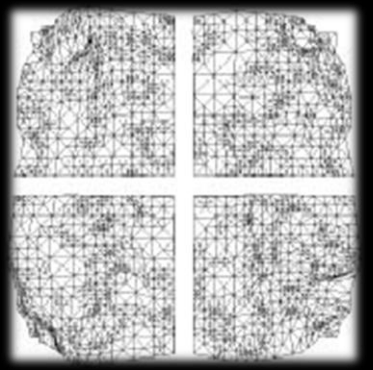
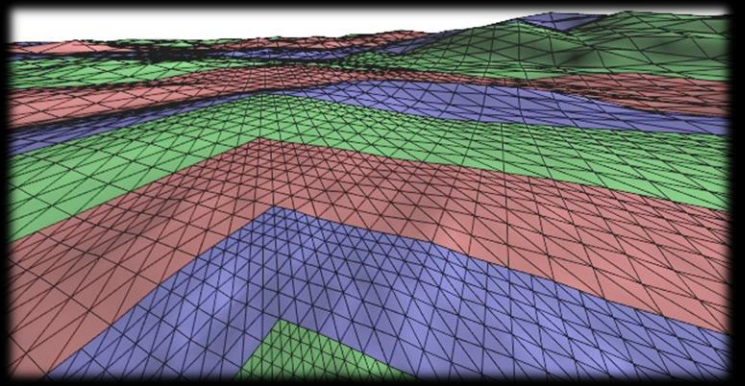
Case Study: Massive Terrain Rendering

- ROAM
- Geometry Clipmaps
- Chunked LOD
- …





- So many algorithms, why do we need tessellation ?

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Case Study: Massive Terrain Rendering

- Dataset
  - ~600MB : space required to store earth elevation data with a km precision
  - 600GB+ : current publicly available resolution (30m SRTM)
- Enhance existing algorithms
  - “Hybrid“ Chunked LOD
    - Static chunk of terrain can be replaced by a grid of GL_PATCHES

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Tessellation heuristics (TCS)

- Distance adaptive tessellation
  - Use the TCS to determine the edge tessellation level based on the distance to the viewpoint
- Orientation adaptive tessellation
  - Compute the dot product of the average patch normal with the eye vector (can be done offline, using CUDA)
- Screenspace adaptive tessellation
  - Compute edge midpoint screen space error metric
  - Use edge bounding sphere for rotation invariant heuristic

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Performance Considerations

- Tessellation pipeline is not free !
- Avoid running tessellation shaders when not necessary
  - “Cache” tessellation results using Transform Feedback
    - Don’t forget to switch to GL_TRIANGLES when disabling tessellation

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Frutum & Occlusion Culling

- Consider using the Tessellation Control Shader to Cull patches not in frustum
  - gl_TessLevelOuter[x] = 0
  - Don’t forget to take displacement into consideration
- Don’t render occluded patches
  - Use occlusion queries

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Other use cases

- High quality rendering
- Vector Rendering
- Hair Rendering

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Conclusion

- OpenGL tessellation pipeline can greatly enhance the visual quality of your application
- Can adapt to existing rendering pipelines
- Implement efficiently
- Great for Simulators and GIS applications

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Questions ?

Thank you

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