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GDC 10

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Tessellation Performance

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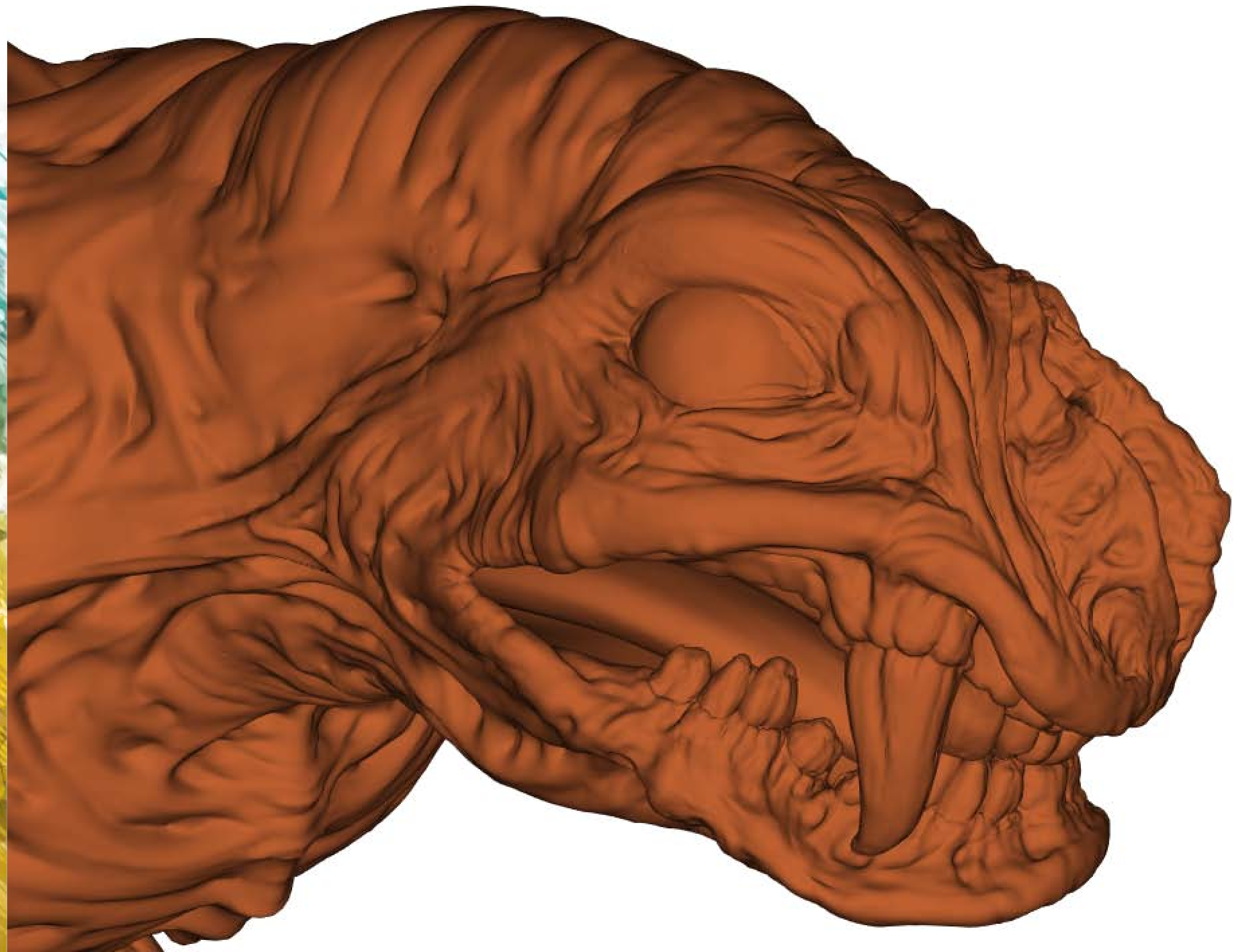
Legend

- **AMD specific**
- **NVIDIA specific**

Why Tessellate?

- Enables substantial geometric fidelity
    - GPU side expansion very efficient
- Scale performance and quality
    - Programmatic LOD control
- Compute at lower, adaptively chosen, frequency

Geometric Realism With Tessellation



Generating Geometry On-Chip

- Coarse data read through IA
  - Compact representation
- Hull shader controls expansion
- Domain shader evaluates surface

Geometry Data Flow

- Read coarse model data in VS

  Take advantage of this!

  - Optimize models for post-transform cache
  - Do transformations and animation
  - Prepare all other per vertex attributes

VS Output

DS Output

Is Tessellation Free?

- No!
- If adding more geometry was free, we would have been doing this along time ago…☺
- Tessellation should be used where it will benefit image quality the most
- So tessellate wisely…

How Many Triangles?

Tess Factor	Triangles
1	1
3	13
5	37
7	73
9	121
11	181
13	253
15	337
…	…
64	~6000

Tessellation Factor ~ 1

- Mesh would look identical if rendered non-tessellated
- Using 3 additional pipeline stages needlessly
  - Total waste of GPU resources
- Use mesh bounding volume to calculate the average tessellation factor on the CPU
  - If ~1 render non-tessellated

Use Occlusion & Culling

- Don‘t render occluded meshes!
  - Even more important for tessellated meshes
  - Consider using occlusion queries or predicated rendering
- Use the HS to cull patches outside the view frustum
  - Set tessellation factor to 0
  - ~30% speed up in one application

Use Adaptive Tessellation Techniques Aggressively

- Consider using a combination of these techniques in your HS:
  - Distance Adaptive
  - Orientation Adaptive
  - Density Adaptive
  - Screen Space Adaptive
- Select the combination that yields the biggest win in your app
- Over-tessellation will impact both frontend and backend performance

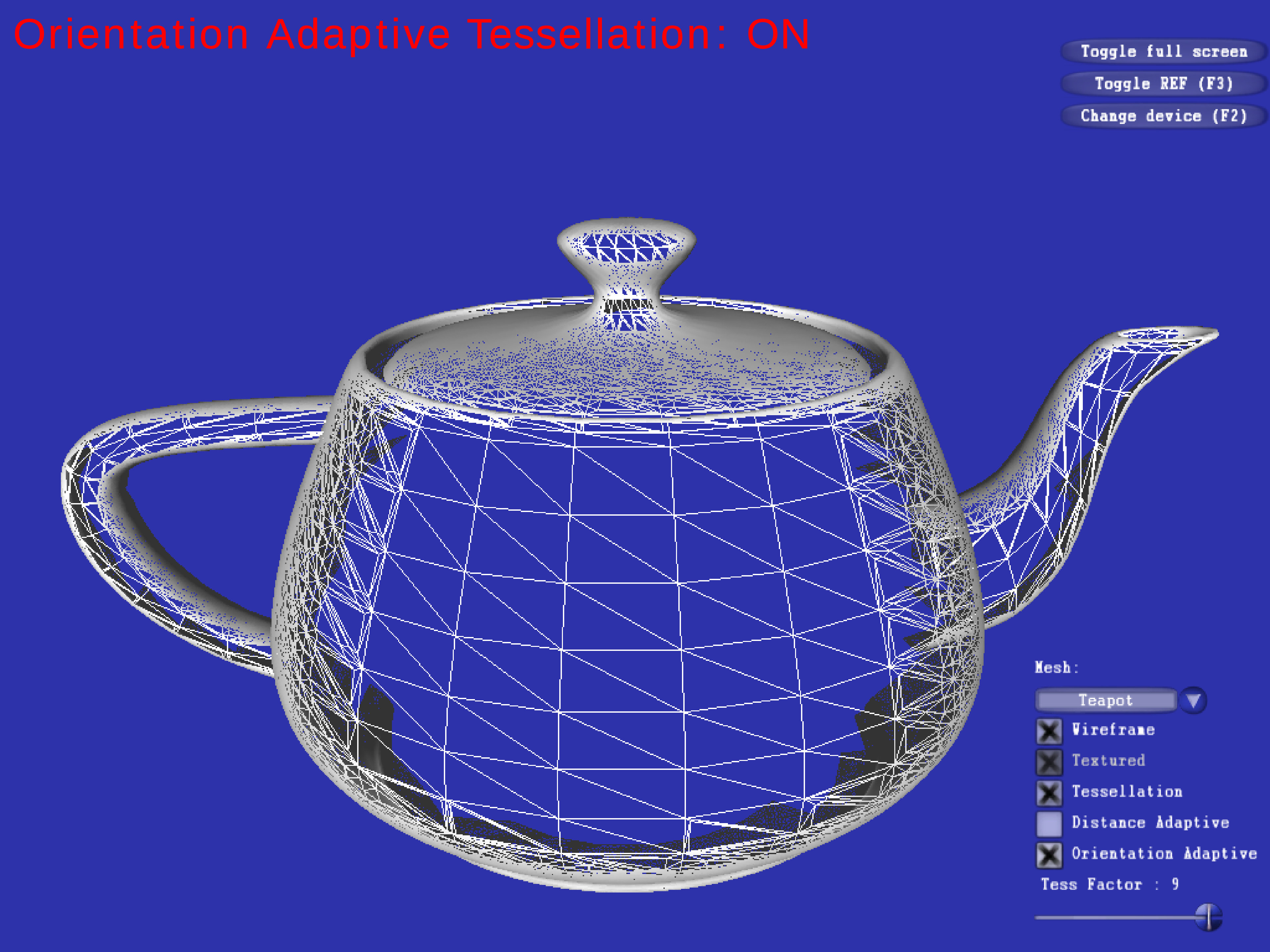
Distance Adaptive Tessellation

- Use the HS to determine the edge tessellation factors based on distance from view point
- If using a CPU check on the bounding volume to switch tessellation off:
  - HS should use the same falloff values to avoid tessellation popping

Distance Adaptive Tessellation: OFF

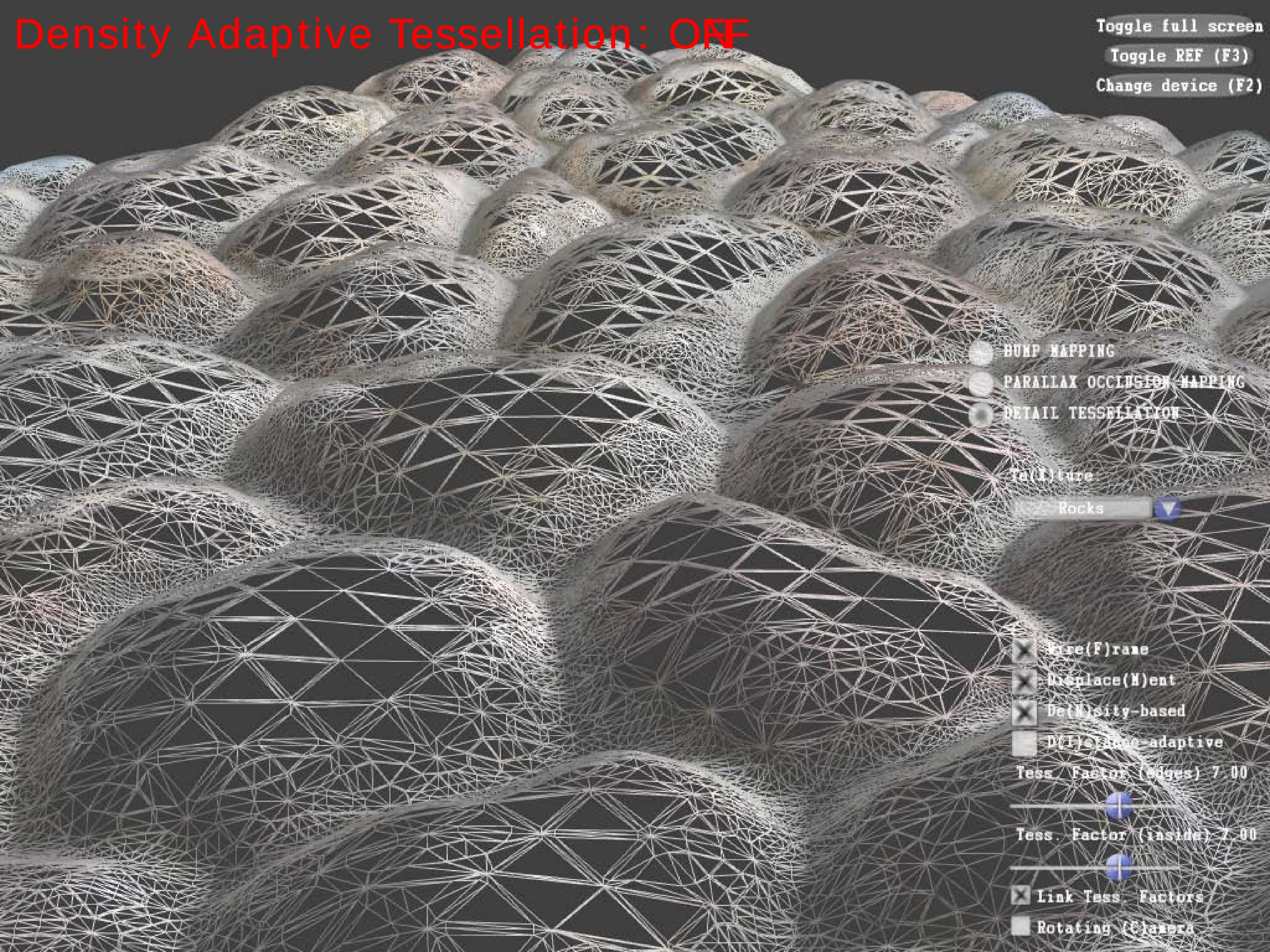
Orientation Adaptive Tessellation

- Compute dot product of average edge normal with view vector
- Back facing patches either:
  - Use lower tessellation factors
  - Get culled altogether
- Silhouette patches use higher factors
  - EdgeScale = 1.0f – abs(dot(N, V));
- Perfect for PN-Triangles
  - ~3x gain at tessellation factor 9


Orientation Adaptive Tessellation: ON
Toggle full screen
Toggle REF (F3)
Change device (F2)
Mesh:
Teapot
Wireframe
Textured
Tessellation
Distance Adaptive
Orientation Adaptive
Tess Factor : 9

Density Adaptive Tessellation

- Pre-compute tessellation factors from displacement maps
- Calculate gradients from height values
- Create a buffer of patch edge tessellation factors
- Sample buffer in your HS to determine tessellation factor



Density Adaptive Tessellation: OFF
Toggle full screen
Toggle REF (F3)
Change device (F2)
BUMP MAPPING
PARALLAX OCCLUSION MAPPING
DETAIL TESSELLATION
Te(X)ture
Rocks
Wire(F)rame
Displace(M)ent
De(N)sity-based
D(I)stance-adaptive
Tess. Factor (edges) 7.00
Tess. Factor (inside) 7.00
Link Tess. Factors
Rotating (C)amera

Screen Space Adaptive Tessellation

- Triangles under 8 pixels are not efficient
- Consider limiting the global maximum TessFactor by screen resolution
- Consider the screen space patch edge length as a scaling factor
  - Watch out for patches at a skew angle to the camera
  - May need to tweak how this works

Draw Tessellated Meshes Together

Bad ☹	Good ☺
Draw	Draw
Draw_Tessellated	Draw
Draw	Draw_Tessellated
Draw_Tessellated	Draw_Tessellated
…	…

- Toggling tessellation is a large state change
- Minimize these transitions

Consider Using Stream Out

- If you render tessellated meshes multiple times consider streaming out the tessellated mesh
  - Shadow map slices
  - Lighting passes
- Then render multiple times through the non-tessellated pipeline
  - Make sure you measure, this may not help performance!

General Rules

- Compute complex things as early in the pipeline as possible
  - VS possible?
  - HS possible?
  - DS possible?
  - If not, then PS
- Try to minimize number of attributes coming to PS stage

Hull Shader Tips : 1

- A long HS can affect performance at low tessellation factors
  - Keep simple
  - Move work to the VS if possible
- Minimize vertex data passed from the VS
- Minimize data passed to the DS
- Specify maxtessfactor() with HS
  - May help the driver to optimize the workload

Hull Shader Tips : 2

- Use a PASS-THROUGH Control Point Phase
  - Only requires 1 HW thread

Shading in the Domain Shader

- Can hoist lower-frequency computation from PS to DS
  - E.g. ambient/volumetric lighting
  - Test to see if this is a performance win – it may well not be!
- This often works best with uniform sampling of surface
  - Tessellation with uniform screen space triangle sizes
  - Aim for rasterizer "sweet spot"

Shading in the Domain Shader

- Example: underwater caustics

Shading in the Domain Shader

- Example: Fourier Opacity Maps

Domain Shader Tips

- A long DS can dominate performance at high tessellation factors
  - Keep simple
- Calculate mip level for sampling displacement maps
  - Avoid thrashing the texture cache
- Minimize data passed to GS / PS

Summary

- Tessellation can be a big quality and performance win
- Use occlusion & culling
- Disable tessellation if not needed
- Aggressively use adaptive tessellation techniques
- Keep HS and DS stages as simple as possible
- Use this killer DX11 feature to make games look awesome…☺

Questions?

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