ENHANCING GRAPHICS IN UNREAL ENGINE 3 TITLES USING NEW CODE SUBMISSIONS

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AGENDA

- This presentation covers AMD code submissions that have been integrated into Unreal Engine 3
  - Tessellation
    - Phong Tessellation
    - Tessellation Optimizations
    - Performance considerations
  - Multi-monitor Support
    - Eyefinity support code
    - How to test multi-monitor support on a single monitor
  - Vertex Shader-Based Bokeh Depth Of Field (DOF)
    - Implementation
    - Performance considerations
  - Post-Process Full Screen Anti-Aliasing (FSAA)
    - MLAA support
    - Performance and quality comparison

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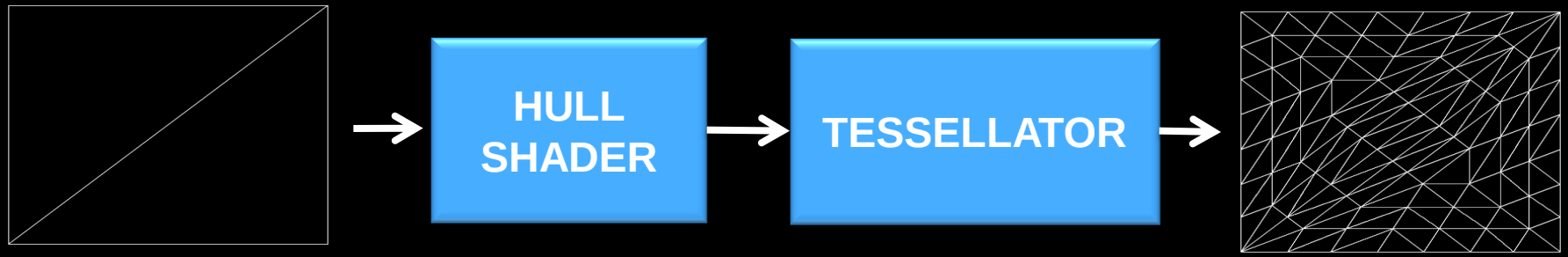
AMD

TESSELLATION

TESSELLATION TECHNIQUES

- Displacement mapping with flat tessellation
  - Requires a height map for displacement
  - Generates high-quality bumpy surface
- PN-Triangle tessellation
  - No displacement map required
  - Used to generate smooth silhouette
  - Hull shader for patch construction
- Phong tessellation
  - No extra displacement map required
  - Used to generate smooth silhouette
  - No patch construction required

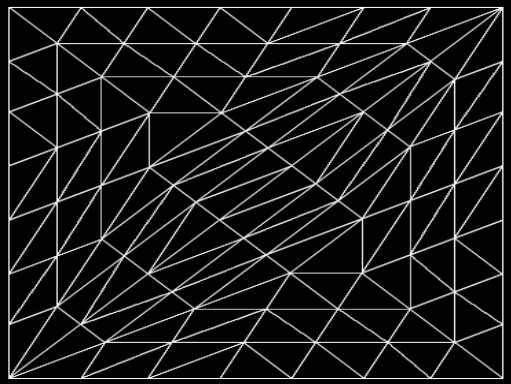
DISPLACEMENT MAPPING WITH FLAT TESSELLATION



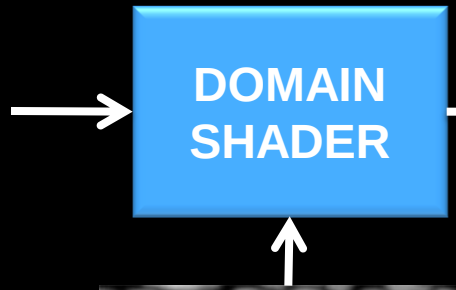
Triangle Patch Mesh

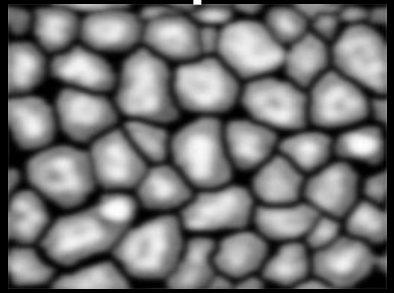
Tessellated Mesh

DISPLACEMENT MAPPING WITH FLAT TESSELLATION

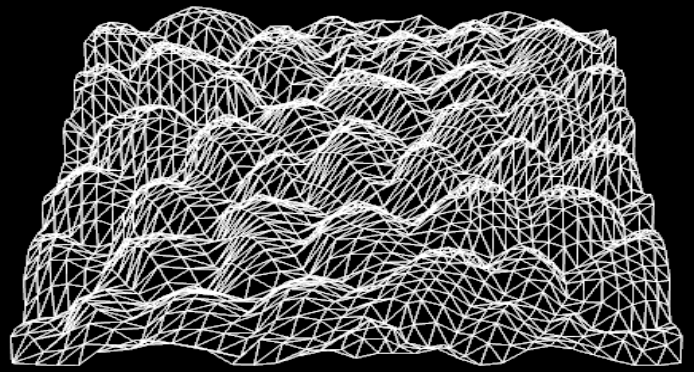


Tessellated Mesh





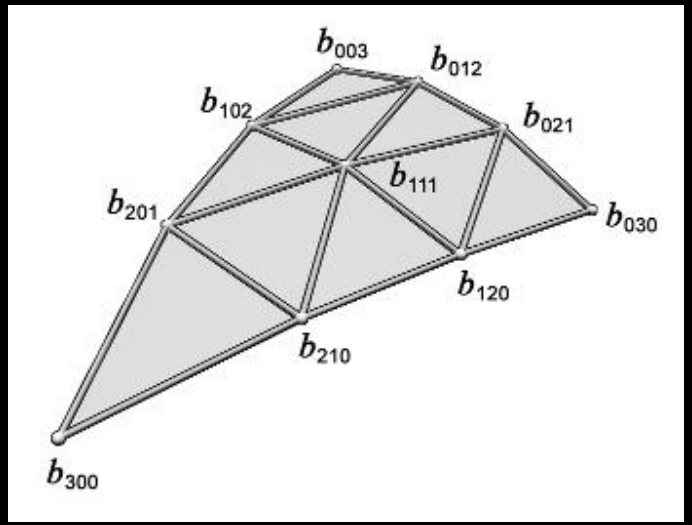
Displacement map



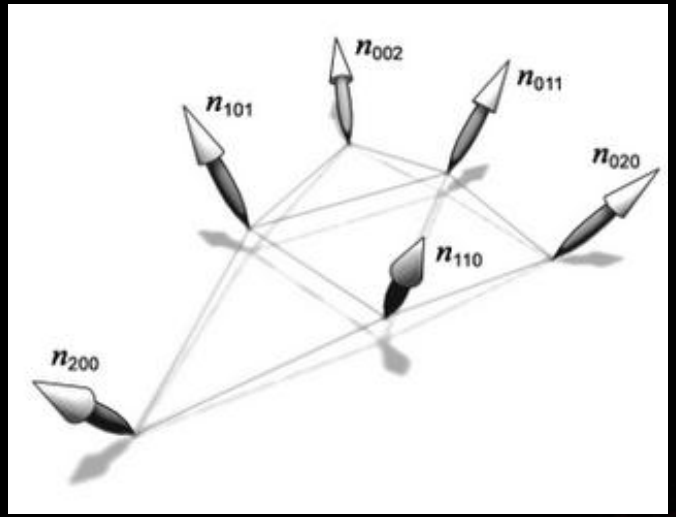
Displaced Mesh

PN-TRIANGLE TESSELLATION

- PN-triangles is a purely local scheme
- Construct a cubic Bezier patch according to the three vertex positions and normals of a triangle in the Hull shader



Control points of triangular Bezier patch

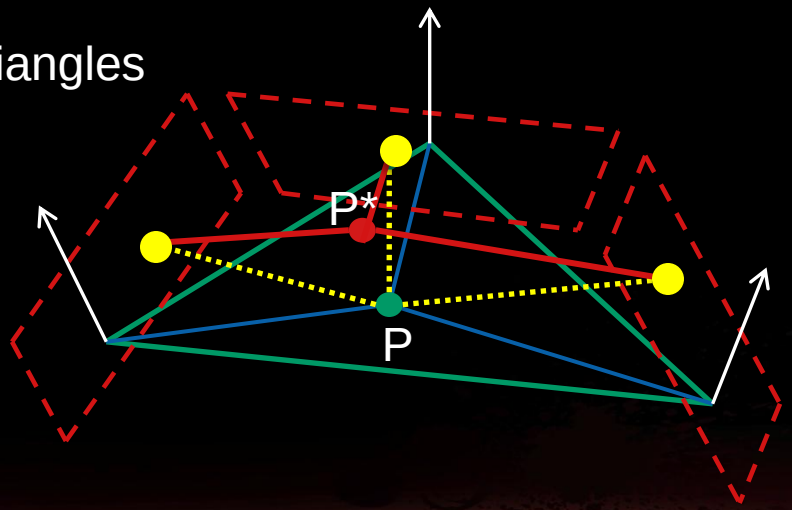


Normal component of PN-Triangle

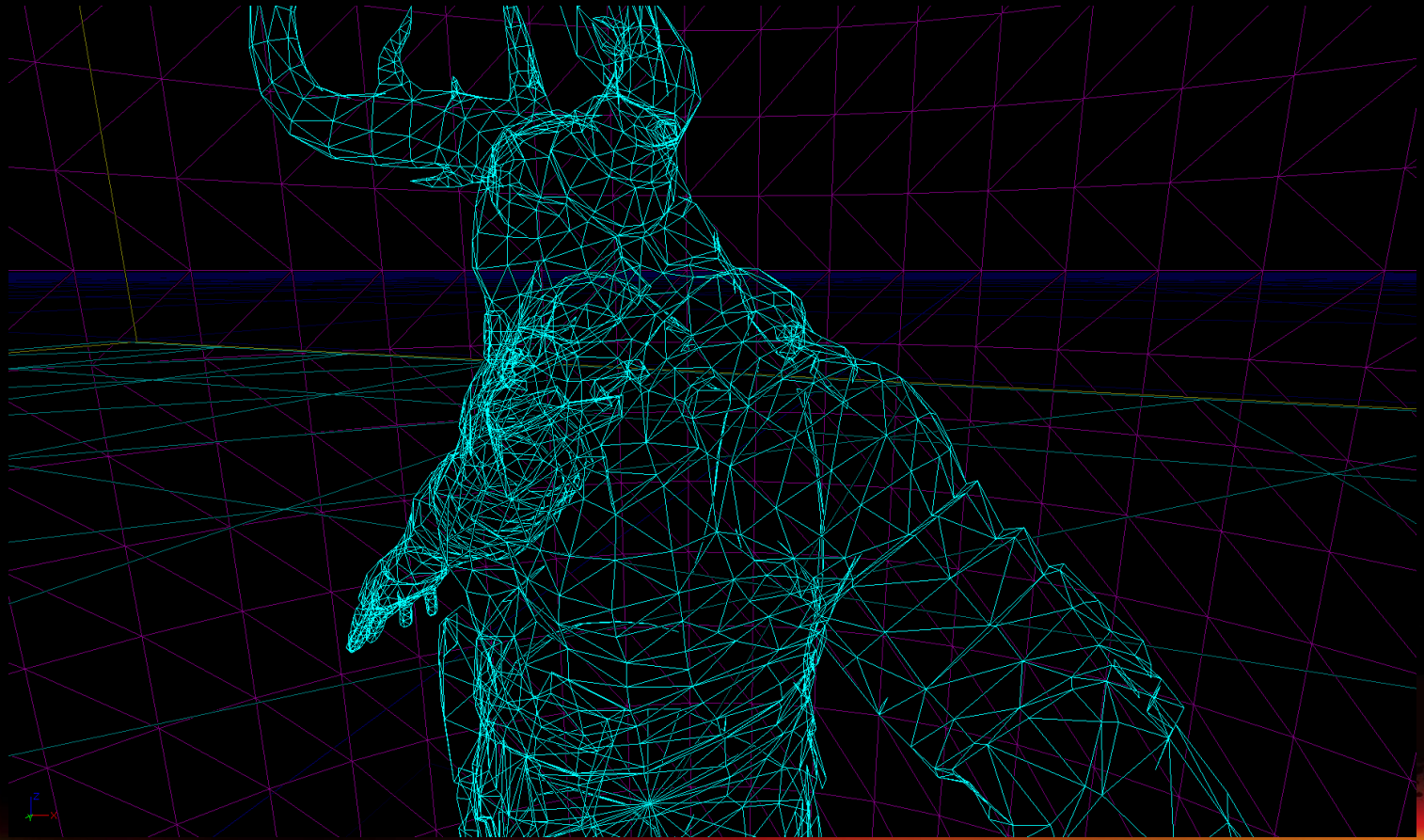
Pictures from "Curved PN Triangles" white paper, Vlachos et al.

PHONG TESSELLATION

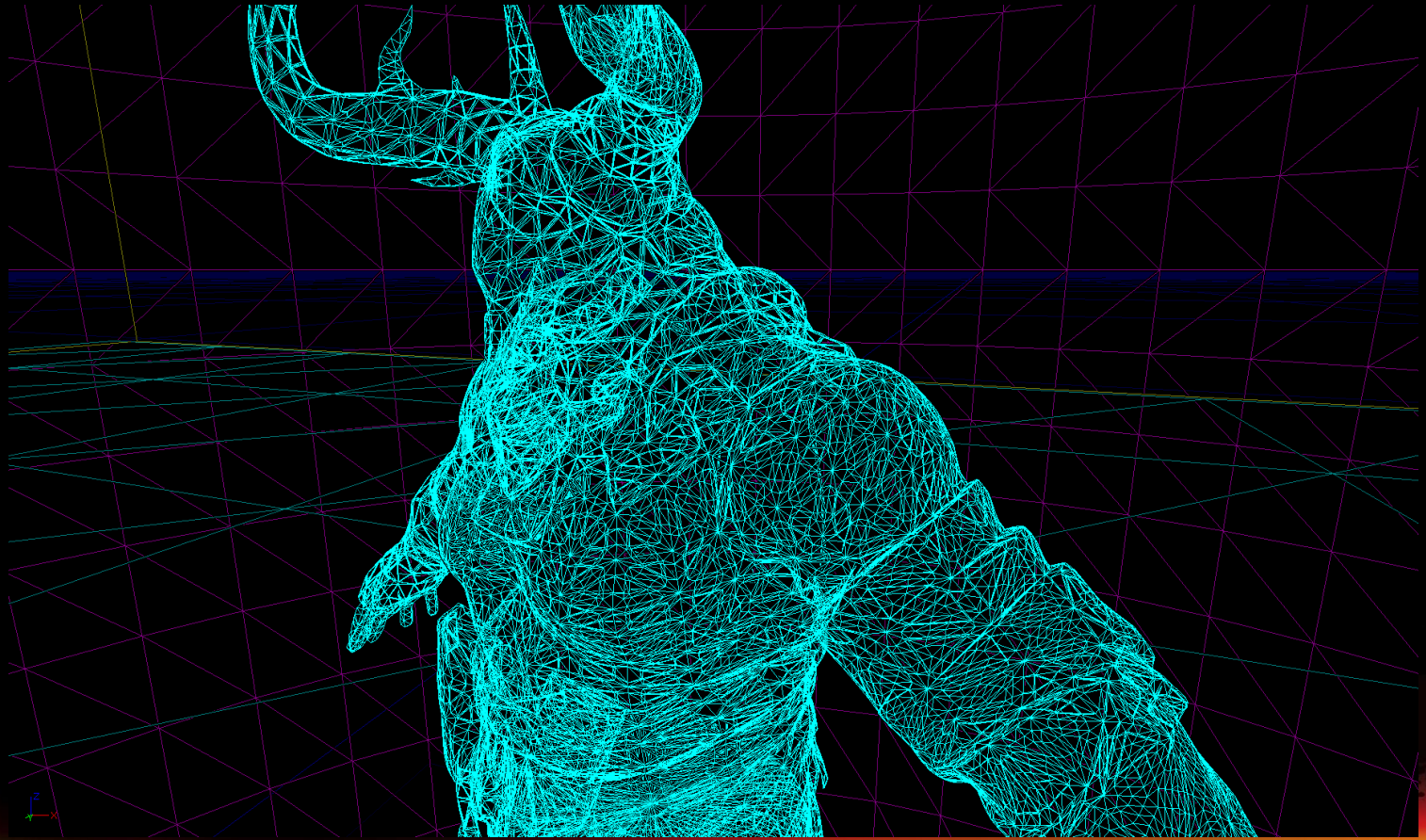
- Phong tessellation is also a purely local scheme
- No need to construct complex patch in Hull shader
  - Simple Hull shader, just pass over vertex position and normal
  - Simple shader == better performance
- Phong is simpler and more efficient than PN-Triangles
  - Yet produces very similar visual output
  - … at much better performance!



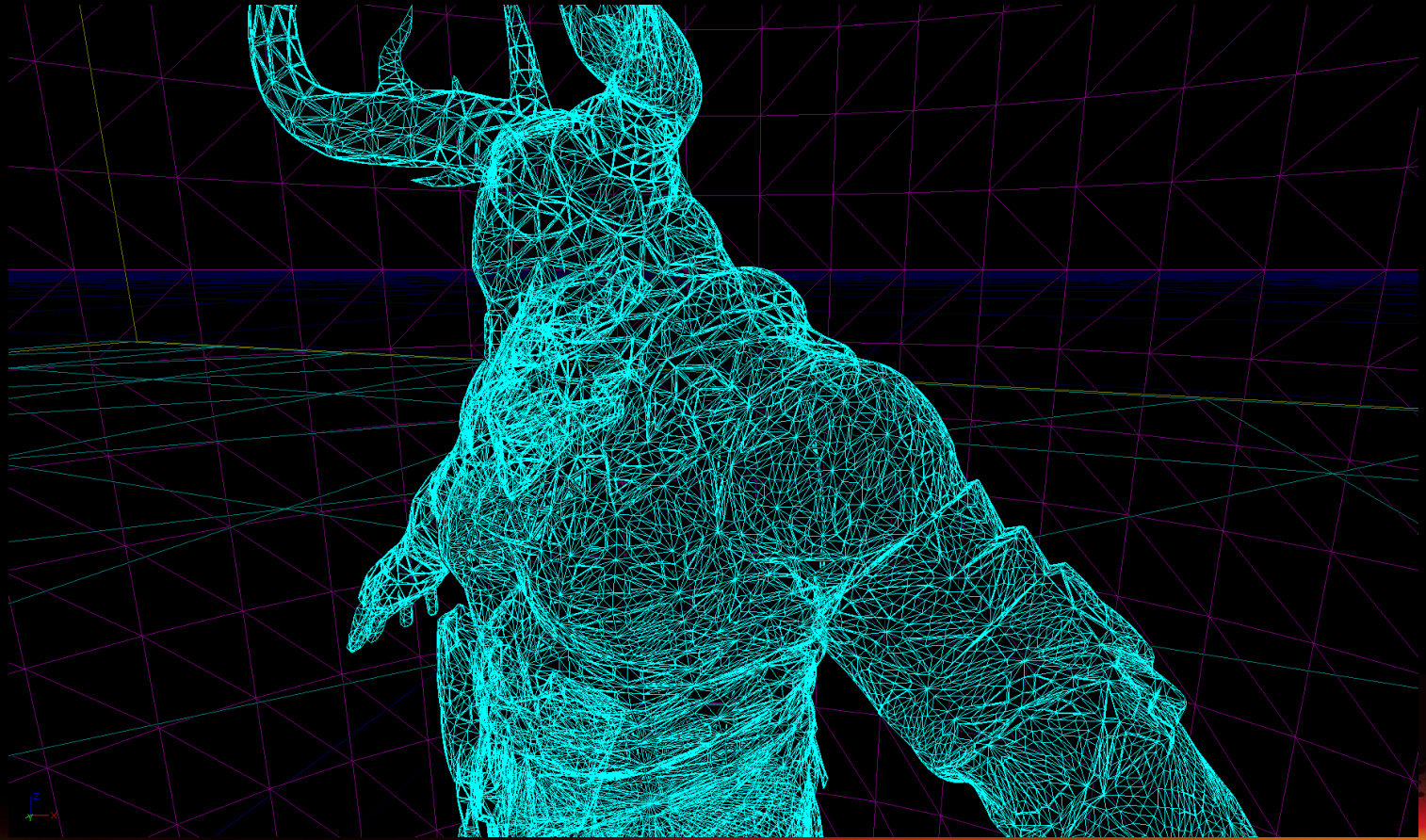
NO TESSELLATION



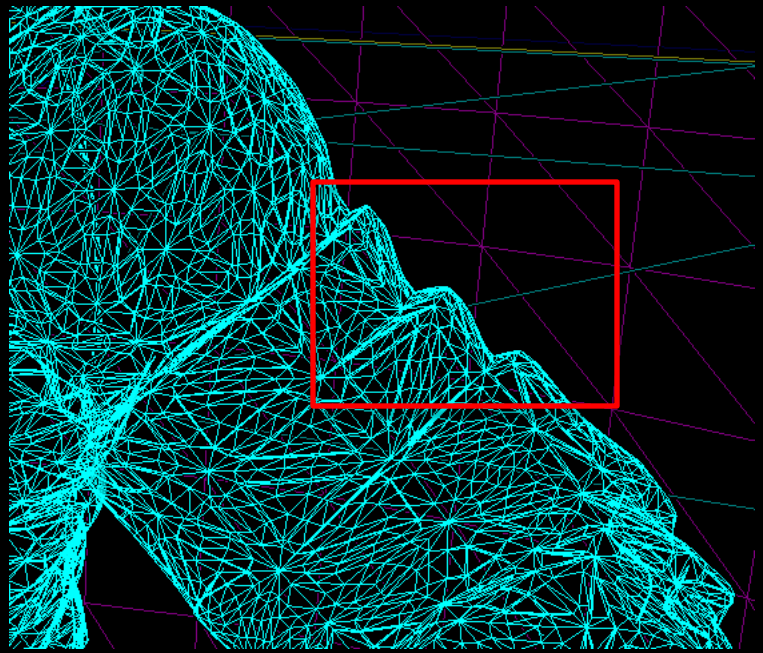
PN-TRIANGLE TESSELLATION



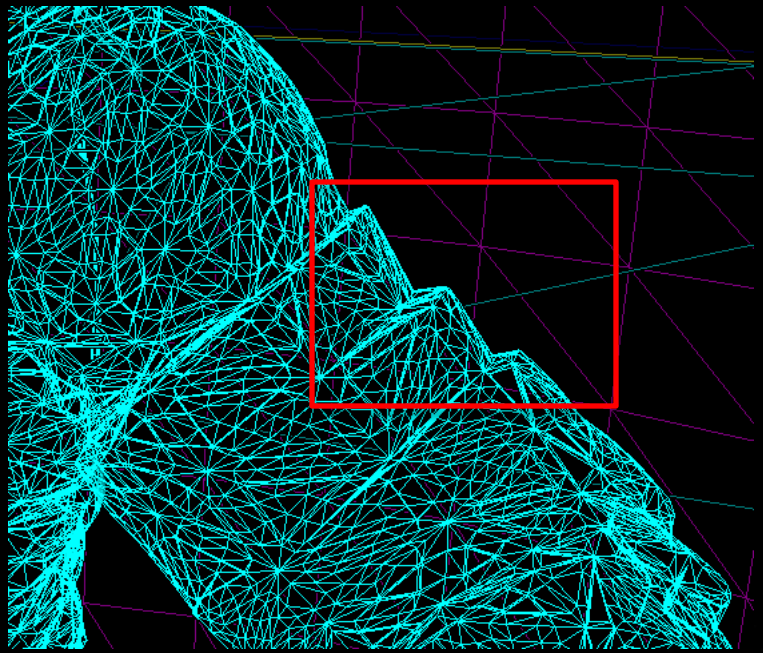
PHONG TESSELLATION



TESSELLATION COMPARISON



PN-Triangle Tessellation



Phong Tessellation

NO TESSELLATION

PN-TRIANGLE TESSELLATION

PHONG TESSELLATION

UE3 TESSELLATION FEATURES

- Tessellation modes
  - Flat Tessellation
  - PN-Triangle tessellation
  - Our submission adds Phong Tessellation mode into UE3
  - Can add displacement map to any tessellation mode
- Built-in adaptive factor based on triangle screen-space size
  - Allows constant and predictable performance
  - Avoids generation of very small triangles which are inefficient (<8 pixels)
  - More optimizations can be selected to improve performance further

TESSELLATION PERFORMANCE

AMD

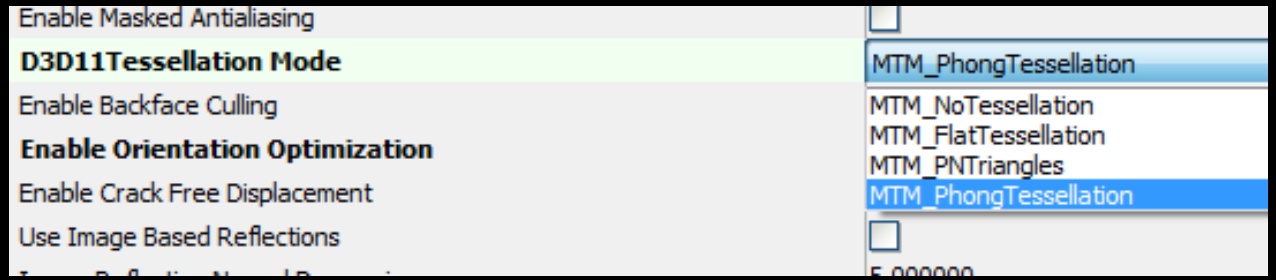
- Tessellation is not free!
  - Use with caution otherwise it can impact performance considerably
  - Should only be used where image quality can be improved
- Adaptive tessellation keeps tessellation requirements reasonable
  - Vary tessellation factors based on real-time metrics
  - UE3 implements screen-space adaptive optimization
- More aggressive optimizations are required to keep performance up

MORE AGGRESSIVE OPTIMIZATIONS

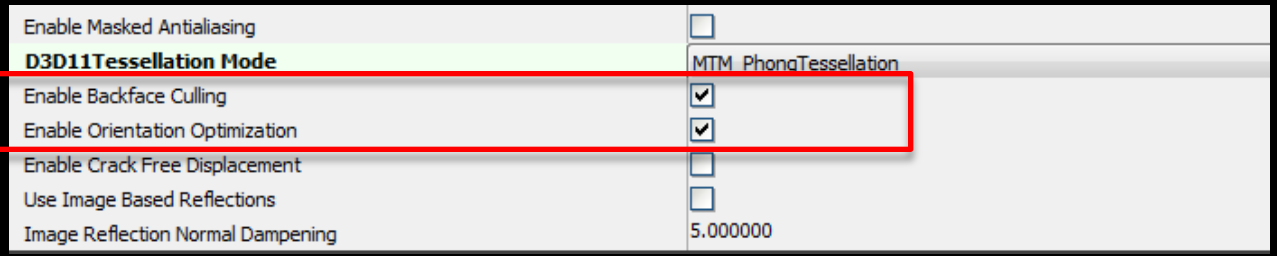
AMD

- Backface culling
  - Set tessellation factor to 0 on back-facing (i.e. invisible) triangles
  - Warning: some back facing triangle still contribute to a silhouette!
- View frustum culling
  - Don‘t waste tessellation power on invisible triangles
  - Set tessellation factor to 0 if the *whole* triangle patch is outside the view frustum
- Orientation-Adaptive Tessellation
  - Only silhouette patches contribute to silhouette enhancement
  - Silhouette patches therefore get higher tessellation factors

MATERIAL EDITOR



New Phong tessellation mode



Two new optimization options for all tessellation modes

UDKENGINE.INI

- Two new variables in UDKEngine.ini
  - TessellationBackfaceCullingThreshold
    - **If (dot(N, V) < -TessellationBackfaceCullingThreshold)**
      Tessellation factor = 0;
  - TessellationOrientationThreshold
    - **EdgeScale = 1.0f – abs(dot(N, V));**
    - **Tessellation factor =**
      (EdgeScale – TessellationOrientationThreshold) /
      (1.0 – TessellationOrientationThreshold);

PHONG TESSELLATION

No Tessellation

Phong Tessellation with backface culling and orientation adaptive factor

REAL-TIME DEMO

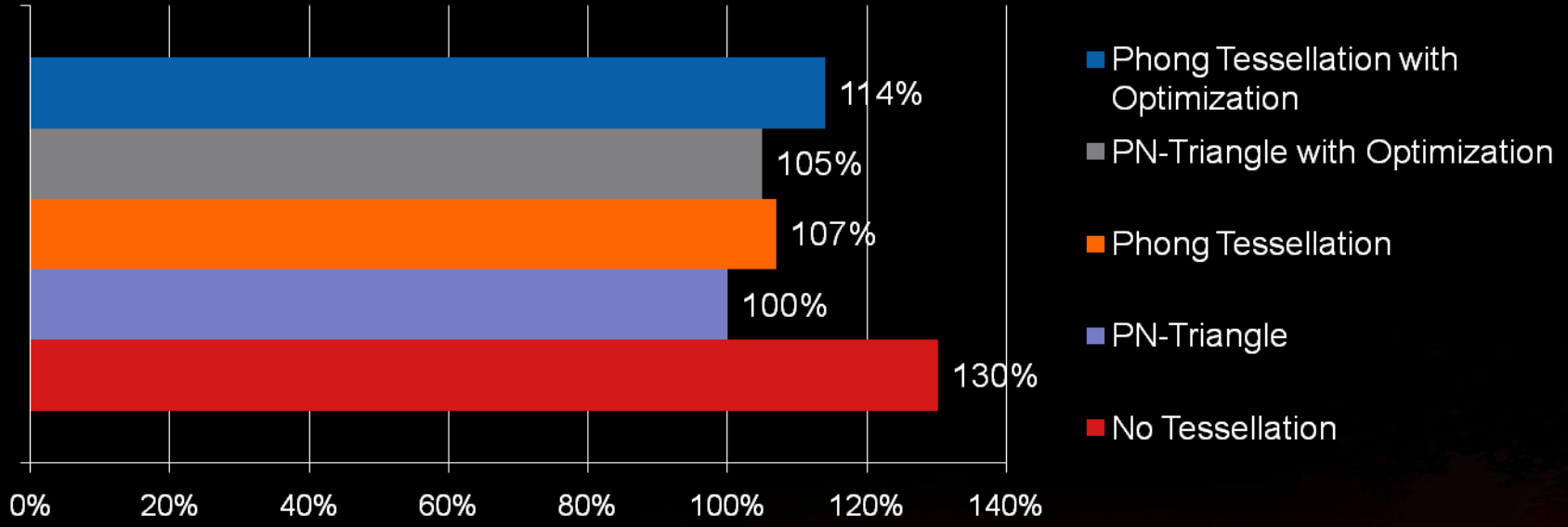
- How to activate Phong tessellation and optimizations in material editor
- Show real-time orientation adaptive optimization demo in UE3 editor

PERFORMANCE NUMBERS

- Tessellation performance on AMD Radeon HD6970

  BackfaceCullingThreshold=0.6

  OrientationThreshold=0.0



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MULTI-MONITOR

WHY SUPPORTING MULTI-MONITOR

AMD

- Multi-monitor configurations are becoming more common as a result of the affordability of LCD monitors!

- Technically easy to support in your titles (with some extra care for HUD)
  - Multi-Monitor is "just" a single larger render target from the programmer's perspective

- AMD's code submission for Eyefinity makes it even easier
  - Developers are able to test multi-monitor on a single monitor system

SINGLE MONITOR VS. MULTI-MONITOR

HOW TO SUPPORT MULTI-MONITOR

AMD

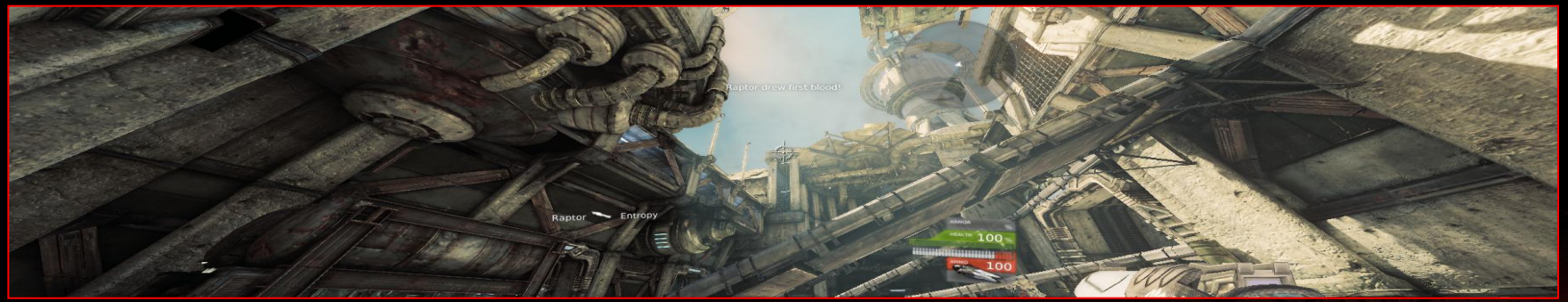
- Don’t block any special aspect ratio resolution (i.e. 5760x1200)
  - Game should be flexible with its supported resolutions
- Expand Field of View according to the resolution
  - Most common Multi-Monitor resolution is 3:1 landscape
  - Set vertical axis to a fixed FOV and let horizontal FOV expand with resolution
- Place HUD to the middle monitor
- Cut-scenes and movies should be played on the middle monitor and retain their original aspect ratio
  - Use bConstrainAspectRatio property of camera to keep the right aspect ratio for your movie
  - FOV expansion will be disabled if bConstrainAspectRatio is TRUE

WHAT AMD HAS DONE FOR YOU

- Use “AllowAMDEyefinity“ in UDKEngine.ini to enable Eyefinity support
- Expand FOV according to the resolution
  - Use "EyefinityFOVThreshold" in UDKEngine.ini to limit the Max FOV in X axis
- Place HUD to the middle monitor
  - Only works on Gfx HUD component
  - It detects the Eyefinity mode then place Gfx HUD component against middle monitor automatically
- Test multi-monitor support on a single monitor
  - Programmer fills out the window resolution and monitor configuration in C++ code
  - This feature is only activated on debug version
  - Convenient feature for developers if they don't have access to all Eyefinity configurations

SAMPLE SCREENSHOTS

SAMPLE SCREENSHOTS



REAL-TIME DEMO

- Demonstrate UDKGame without Eyefinity support
- Demonstrate how to test Eyefinity support on a single monitor machine

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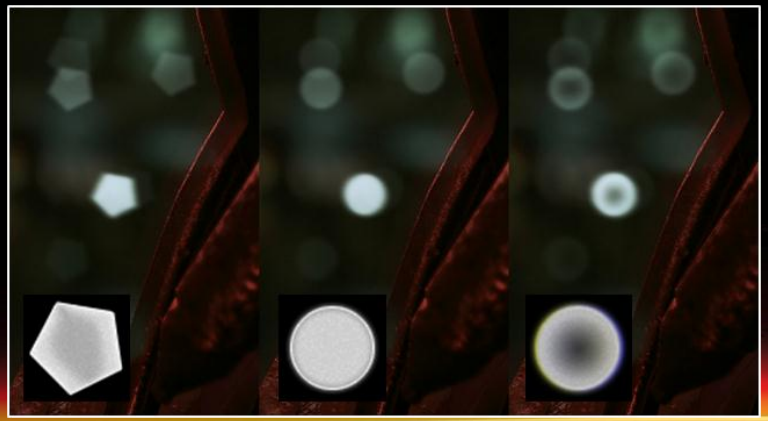
VERTEX SHADER BASED BOKEH DEPTH OF FIELD

BOKEH DEPTH OF FIELD (DOF) IN UE3

- New stunning UE3 post-processing effect introduced last GDC
- In photography, **Bokeh** is the blur in out-of-focus areas of an image.
- UE3 Bokeh DOF uses the Geometry Shader (GS) to generate a massive number of point sprites to simulate Bokeh
  - Generates 1 to 4 Bokeh point sprites for every 4 pixels of half-resolution image
- UE3 renders Bokeh DOF into two layers (foreground and background) to avoid artifacts
- DirectX® 11 only



BOKEH DOF CODE SUBMISSION

AMD

- Generating a massive number of point sprites in the GS impacts performance!
- We moved it to the Vertex Shader (VS)
  - Performance improvement is quite large on some hardware
  - Visual results unchanged
- Now supports DirectX 9 level hardware after moving it to the VS
  - Cost a bit more video memory in DX9 mode to store vertex IDs
- Video memory footprint is the same in DirectX 11 mode
  - No actual vertex buffer is needed
- Triangle and Quad Bokeh supported

VERTEX IDS

DirectX 11:

- Use system-generated vertex IDs (SV_VertexID)
- Bind NULL Vertex Buffer
  - Vertices are generated in the vertex shader without buffer input

DirectX 9:

- Generate a vertex buffer with vertex ID attributes to emulate same functionality
- Generate (HalfResX/2)*(HalfResY/2)*3*4 vertices (for triangle Bokeh)
  - (HalfResX/2)*(HalfResY/2)*6*4 vertices for quad bokeh
- A new vertex buffer is created on resolution change

IMPLEMENTATION

AMD

- Render the vertex buffer (NULL on DX11) as a triangle list
- Use vertex ID to compute current Bokeh ID
  - Triangle number = (VertexID/3). (VertexID%3) is local triangle vertex index
  - If using quads: Quad number = (VertexID/6). (VertexID%6) is local quad vertex index
- Compute the Bokeh position and texture coordinates in Vertex Shader
  - For NULL Bokeh: place all vertices at the same position to skip rendering
  - (VertexID%12) to get the vertex index ID in a Bokeh group
    - Place all last 9 vertices at the same position to eliminate 3 triangles
  - (VertexID%24) for quad

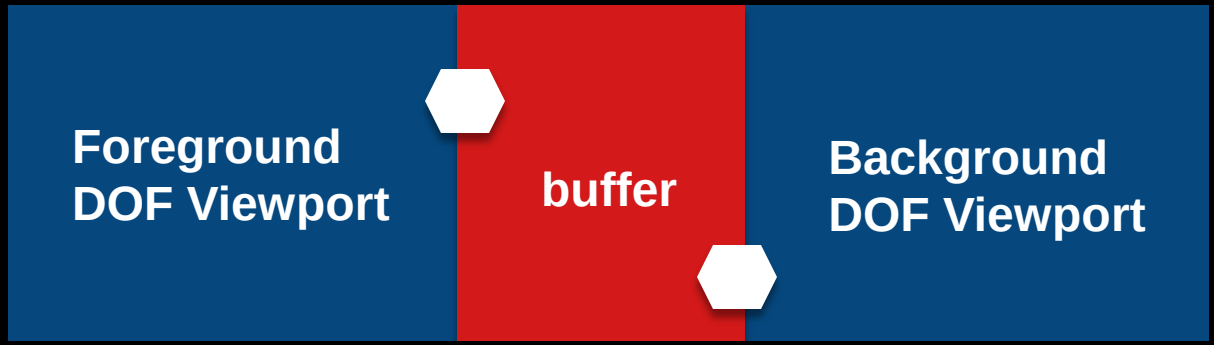
IMPLEMENTATION

- Shift and scale vertex position to simulate multiple viewports in DX11
  - Original code uses multi-viewport to render both foreground and background Bokeh into a single render target

  - Use clip() in pixel shader to simulate viewport clipping
    - Compute the clip distance in Vertex Shader

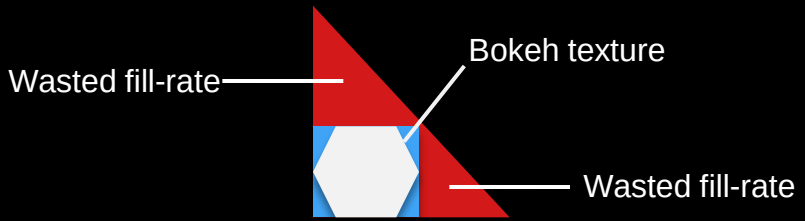
IMPLEMENTATION

- Alternate solution for simulating viewport clipping
  - Create a bigger render target with buffer in the middle
  - Faster, no clipping is needed
  - Costs a little more video memory
  - Bokeh may cross the buffer if it's bigger than the buffer



TRIANGLE OR QUAD?

- Should one use a triangle or quad to represent a point sprite?
- Using triangles can reduce vertex processing cost by 50% compared to using quads
- But triangle point sprite may not be a good solution for big Bokeh shapes
  - Rasterization/fill-rate power will be wasted on invisible pixels (red area)



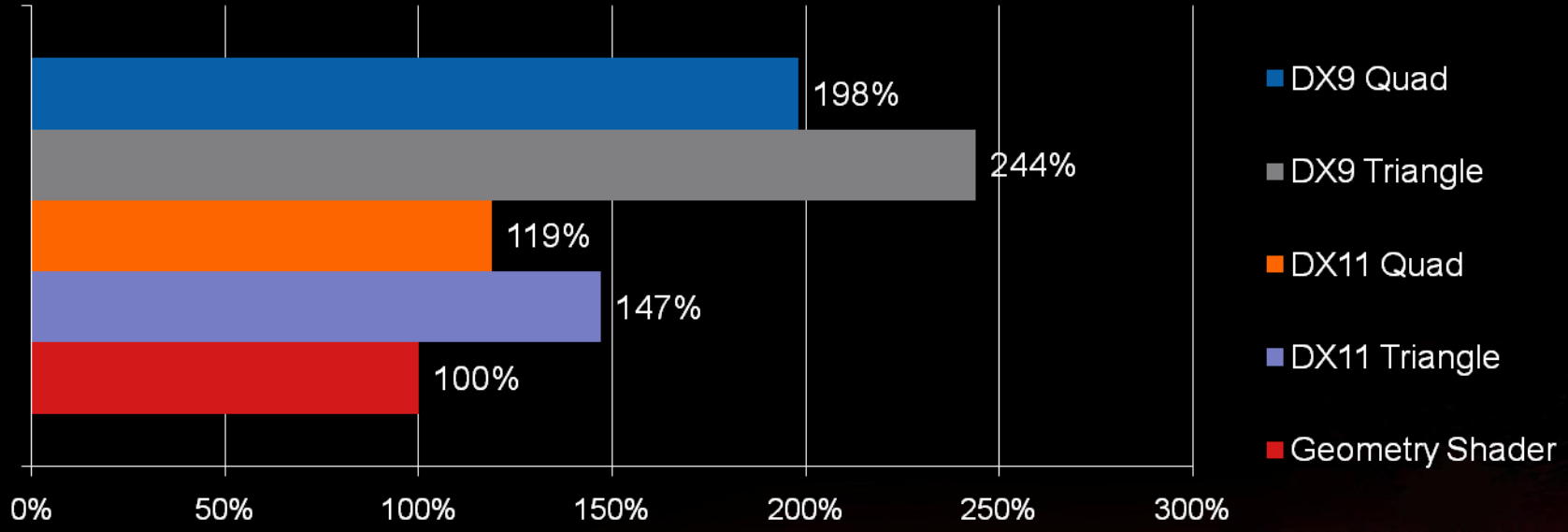
- We implemented both
- Simply use preprocess in C++ code to switch
  - #define __TRIANGLE_BOKEH__ 1

PERFORMANCE NUMBER

Performance test map : EpicCitadel
Small Bokeh setting (not fill-rate bound for triangle Bokeh)

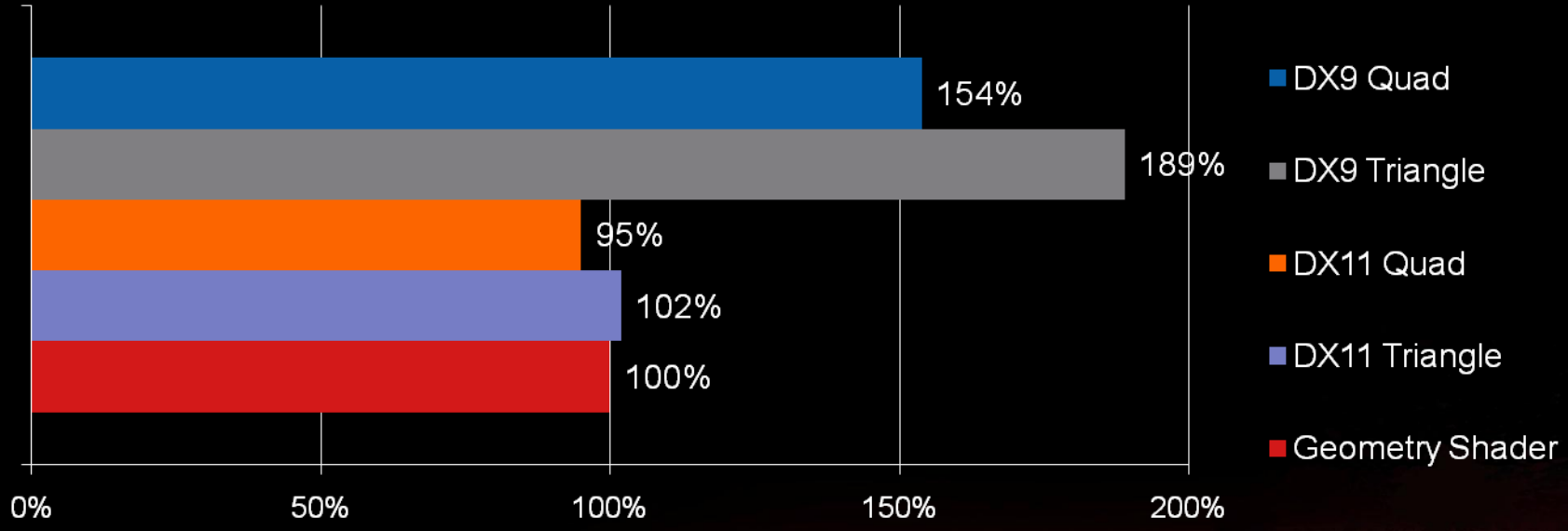
PERFORMANCE NUMBER

- Bokeh DOF on AMD Radeon HD 6970 @ 1920x1080



PERFORMANCE NUMBER

- Bokeh DOF on GTX 580 @ 1920x1080



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POST-PROCESS FULLSCREEN ANTI-ALIASING (FSAA)

POST-PROCESS FSAA

- Why using Post-Process Fullscreen Anti-Aliasing?
  - MSAA doesn't work for deferred shading when using DX9 level hardware
  - MSAA is expensive with deferred shading (performance and memory footprint)
  - MSAA doesn't work with transparent textures (alpha-tested)
  - Post-Process FSAA does not add any complexity to the rendering pipeline
  - Easy to change, modify or optimize without adverse effects on other rendering stages
  - It can also work with MSAA
- UE3 supports two types of post-process FSAA since the July 2011 build
  - Fast Approximate Anti-Aliasing (FXAA)
  - Morphological Anti-Aliasing (MLAA)

COMPARISON

COMPARISON

No AA

MLAA

FXAA OVERVIEW

AMD

- Single-pass post-processing
- No extra render target required
- Tends to detect too many edges and prone to blur non-edge pixels

MLAA OVERVIEW

- Three passes post-processing
  - 1st Pass : Detect edges
  - 2nd Pass : Compute edge length
  - 3rd Pass : Blend edge color according to the edge type and length
- Needs two extra render targets
  - One is for storing edge mask
  - One is for storing edge length
- Can detect edges pretty well so that only edge pixels are anti-aliased
- Adjustable edge detection level
  - It's good for performance tuning

FXAA AND MLAA COMPARISON – EDGE DETECTION

Edge pixels detected by MLAA (in red)

Edge pixels detected by FXAA (in red)

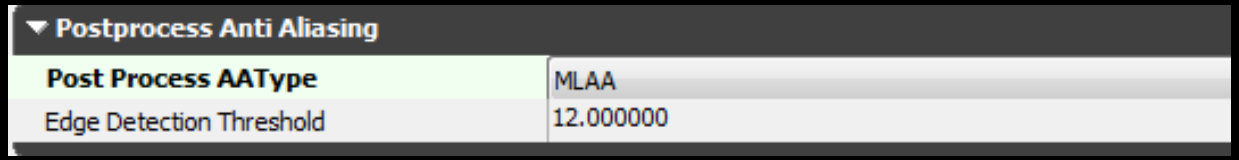
FXAA AND MLAA COMPARISON – EDGE DETECTION (ZOOMED-IN)

Edge pixels detected by MLAA (in red)

Edge pixels detected by FXAA (in red)

UE3 POSTPROCESS AA

- UE3 supports both from July 2011 build
- Can be activated in uberpostprocess node



- MLAA needs to be activated from UDKEngine.ini file
  - bAllowPostProcessAA = True
  - Default is OFF
- Good AA solution for deferred shading
- Supports both DX9 and DX11

CONCLUSION

- Tessellation
  - New Phong tessellation mode which generates similar visual output to PN-Triangle but at much better performance
  - New optimization options for all tessellation modes
- Multi-monitor
  - Automatic FOV expansion and HUD placement
  - Simulate multi-monitor on single monitor system
- Vertex Shader Based Bokeh DOF
  - Huge performance improvement
  - Support both DirectX 9 and DirectX 11
- Post-processing FSAA
  - Already in UE3 since the July 2011 build
  - More efficient option over MSAA when using deferred shading

QUESTIONS?

- Send your feedback/suggestion to owen.wu@amd.com

CODE SUBMISSION DOWNLOAD LINKS

- https://udn.epicgames.com/pub/Three/LicenseeCodeSubmissions/Eyefinity.rar
- https://udn.epicgames.com/pub/Three/LicenseeCodeSubmissions/VSBokehDOF.rar

REFERENCES

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