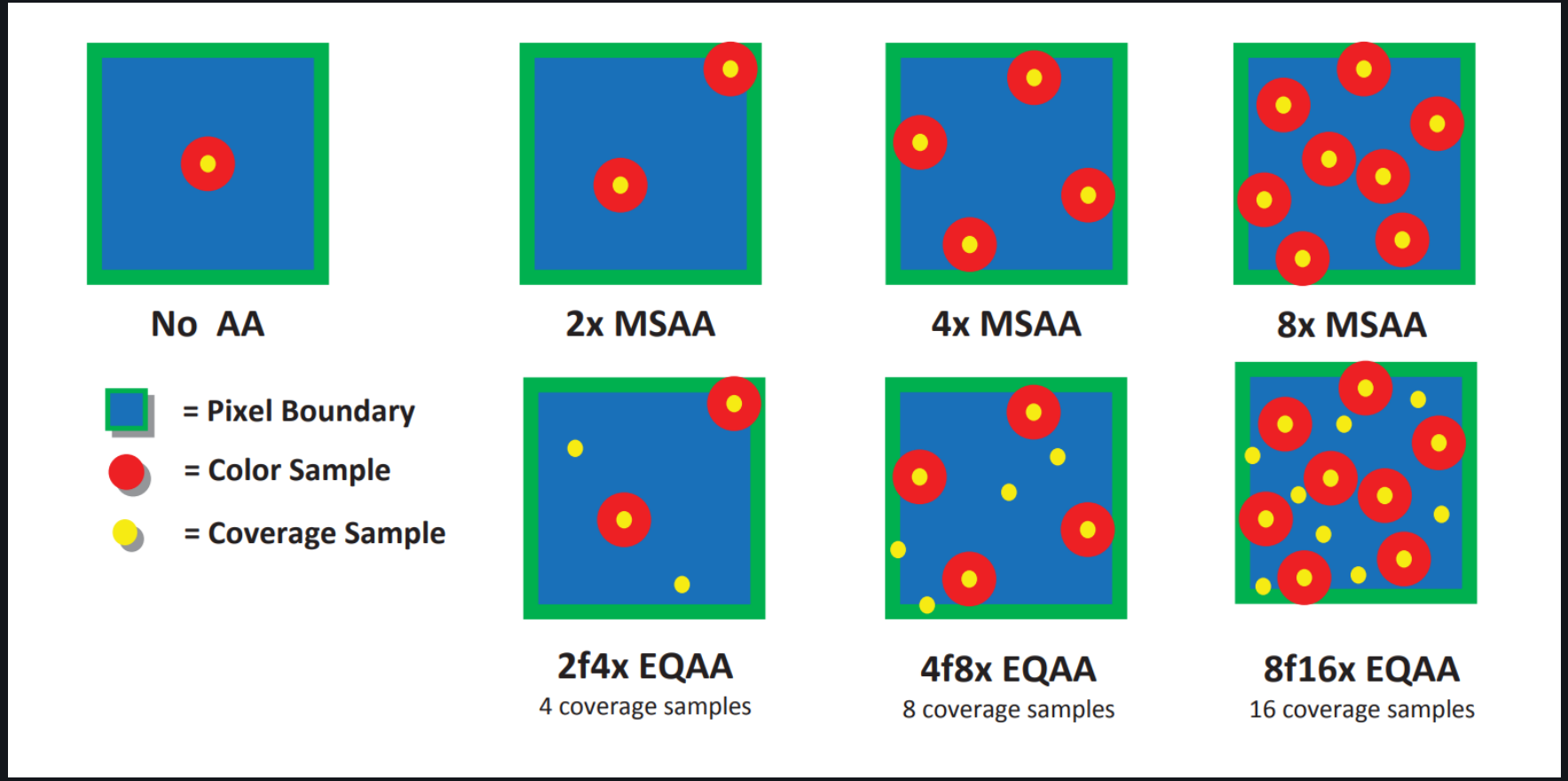
MLAA FROM 2009 TO 2017

Research Impact Retrospective

Alexander Reshetov - Jorge Jimenez

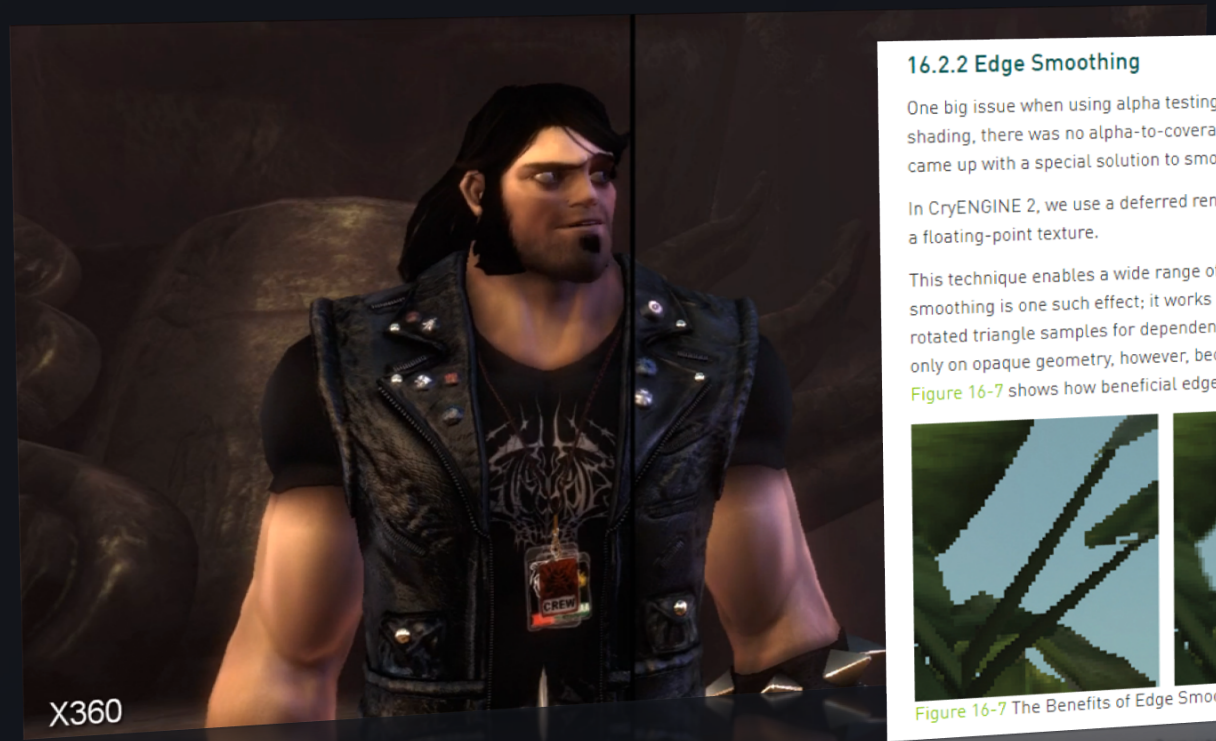
High Performance Graphics 2017

Gold Standards:
MSAA – CSAA – EQAA



Edge Detection and Blur

Information from [Leadbetter2009a]



[Sousa2007]

16.2.2 Edge Smoothing

One big issue when using alpha testing is the hard edges. At the time we developed vegetation main
shading, there was no alpha-to-coverage support in any hardware (we do now support i
came up with a special solution to smooth out the edges through post-processing.

In CryENGINE 2, we use a deferred rendering approach, by first rendering a z-pass and
a floating-point texture.

This technique enables a wide range of effects (Wenzel 2007), which require depth infor
smoothing is one such effect; it works by doing edge detection using the depth texture a
rotated triangle samples for dependent texture lookups using bilinear filtering. Edge sm
only on opaque geometry, however, because nonopaque geometry doesn't write depth in
Figure 16-7 shows how beneficial edge smoothing can be.

Figure 16-7 The Benefits of Edge Smoothing

[Shishkovtsov2004]

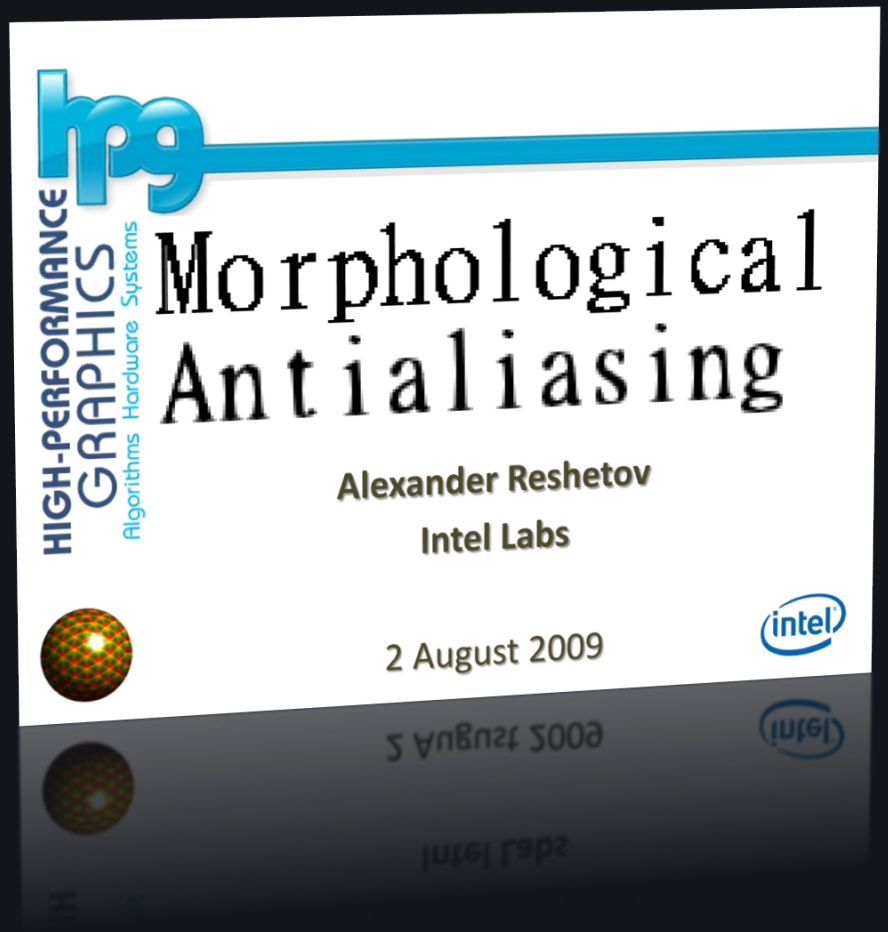
9.5 Antialiasing

A deferred renderer is just incompatible with current hardware-assisted antialiasing, unfortunately (Hargreaves and Harris 2004). Thus, antialiasing becomes solely the responsibility of the application and the shader; we cannot rely on the GPU alone. Because aliasing itself arises from the mismatched frequencies of the source signal and of the destination discrete representation, a good approximation of an antialiasing filter is just a low-pass filter, which is simple blurring. This is a zero-cost operation in the console world, where any TV display works like a low-pass filter anyway. In the PC world, we need an alternative. Our solution was to trade some signal frequency at the discontinuities for smoothness, and to leave other parts of the image intact. This was performed in a way similar to the edge-detection filters used in nonphotorealistic applications: We detect discontinuities in both depth and normal direction by taking 8+1 samples of depth and finding how depth at the current pixel differs from the ideal line passed through opposite corner points. The normals were used to fix issues such as a wall perpendicular to the floor, where the depth forms a perfect line (or will be similar at all samples) but an aliased edge exists. The normals were processed in a similar cross-filter manner, and the dot product between normals was used to determine the presence of an edge. Listing 9-2 shows the code.

The two detectors were then multiplied to produce a single value indicating how much the current pixel "looks like an edge." This value was used to offset four bilinear texture lookups into the composited (near-final) back buffer. The result was automatic weighting of samples with a very strong edge-detection policy that seamlessly handles edge and alpha-test/texkill aliasing without blurring other parts of the image. See Figure 9-7 for a sample result.

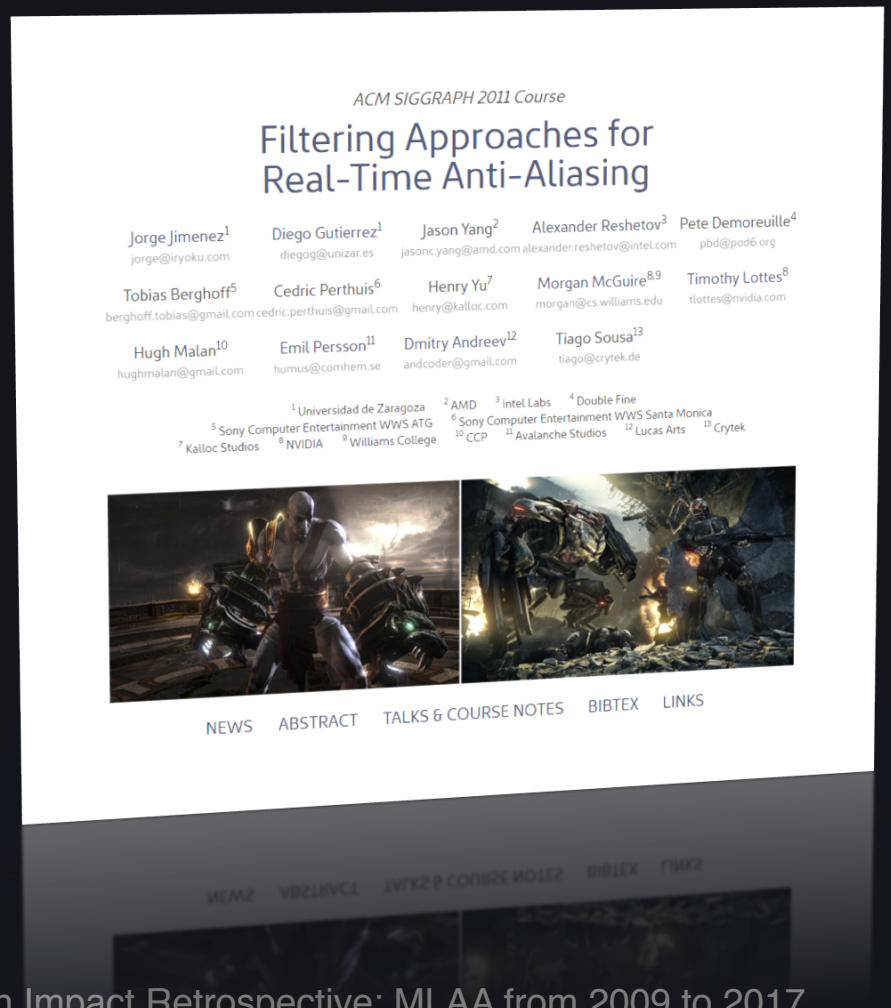
Figure 9-7 Weight Computed by the Edge-Detection Shader

Morphological Antialiasing (2009)



[Reshetov2009]

Explosion of Post-AA Techniques



[Jimenez2011a]

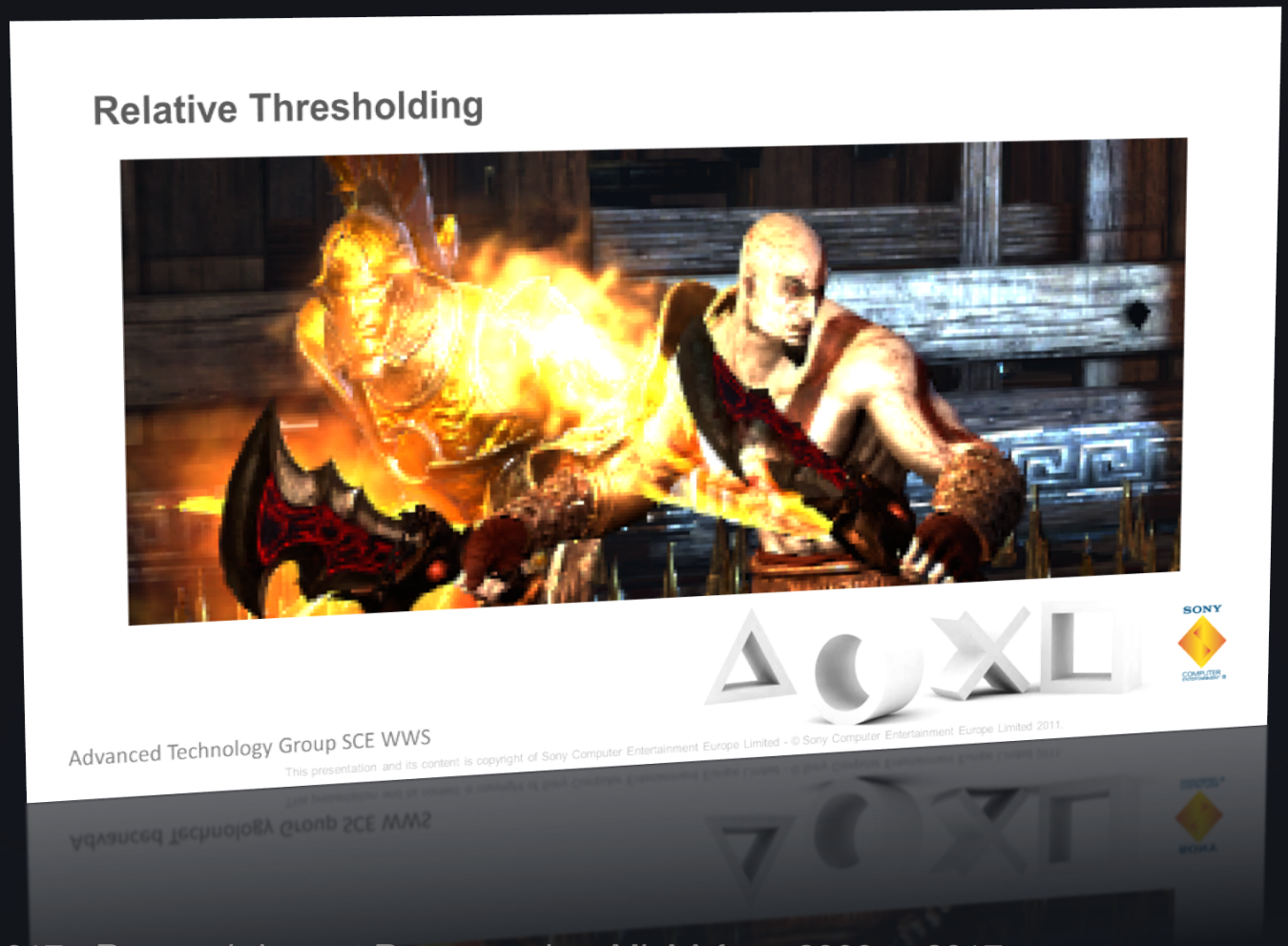
Morphological versus Edge Detect and Blur

- Morphological
  - Edge detect + Search + Blur
  - Non local information available (patterns)
- Edge Detect and Blur
  - Edge detect + Blur
  - Only local information available (neighborhood)

Saboteur (2009)

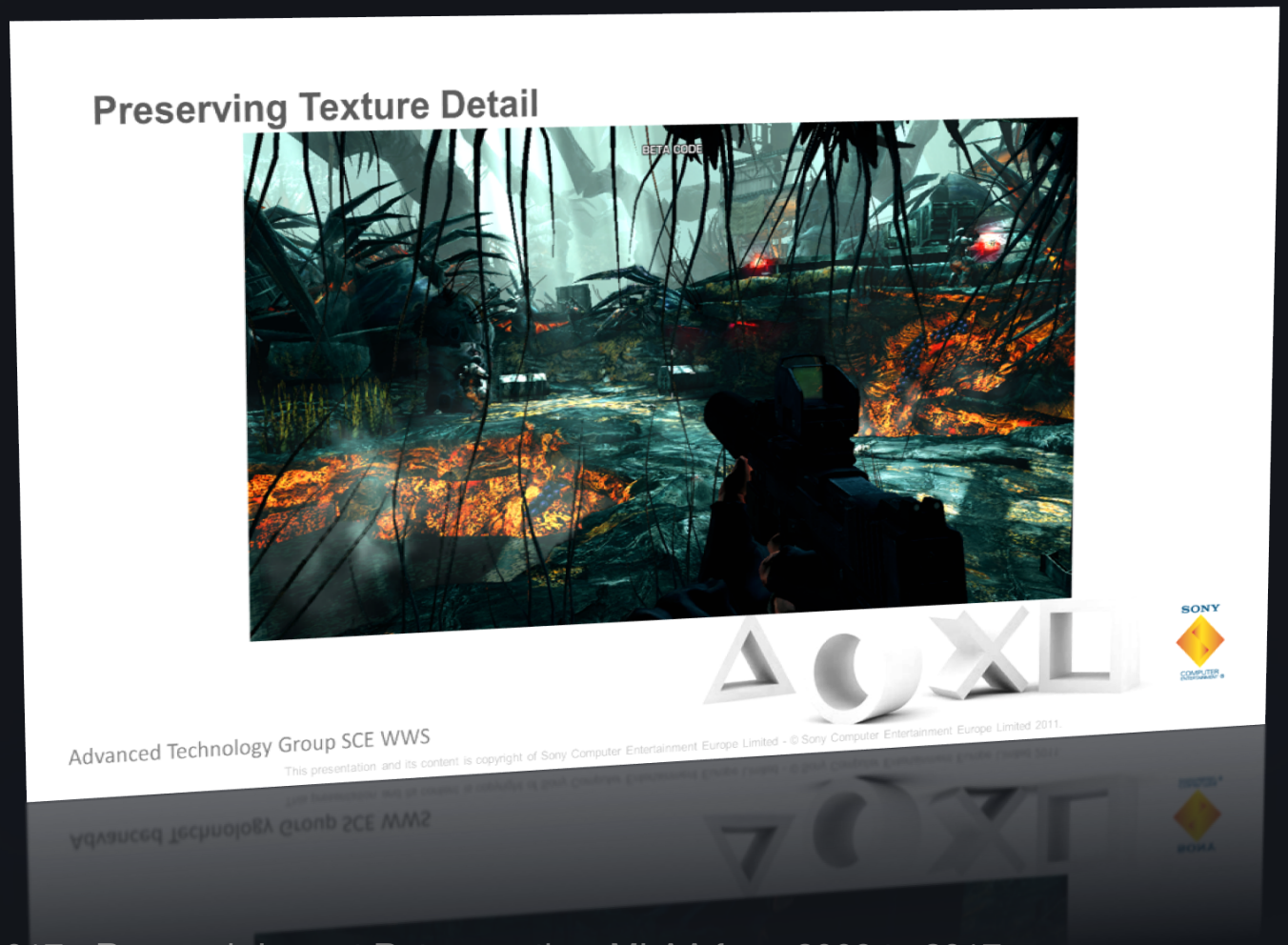
Information from [Leadbetter2009b]

Sony's Edge MLAA (2009)



[Perthuis2011]

Sony’s Edge MLAA (2009)

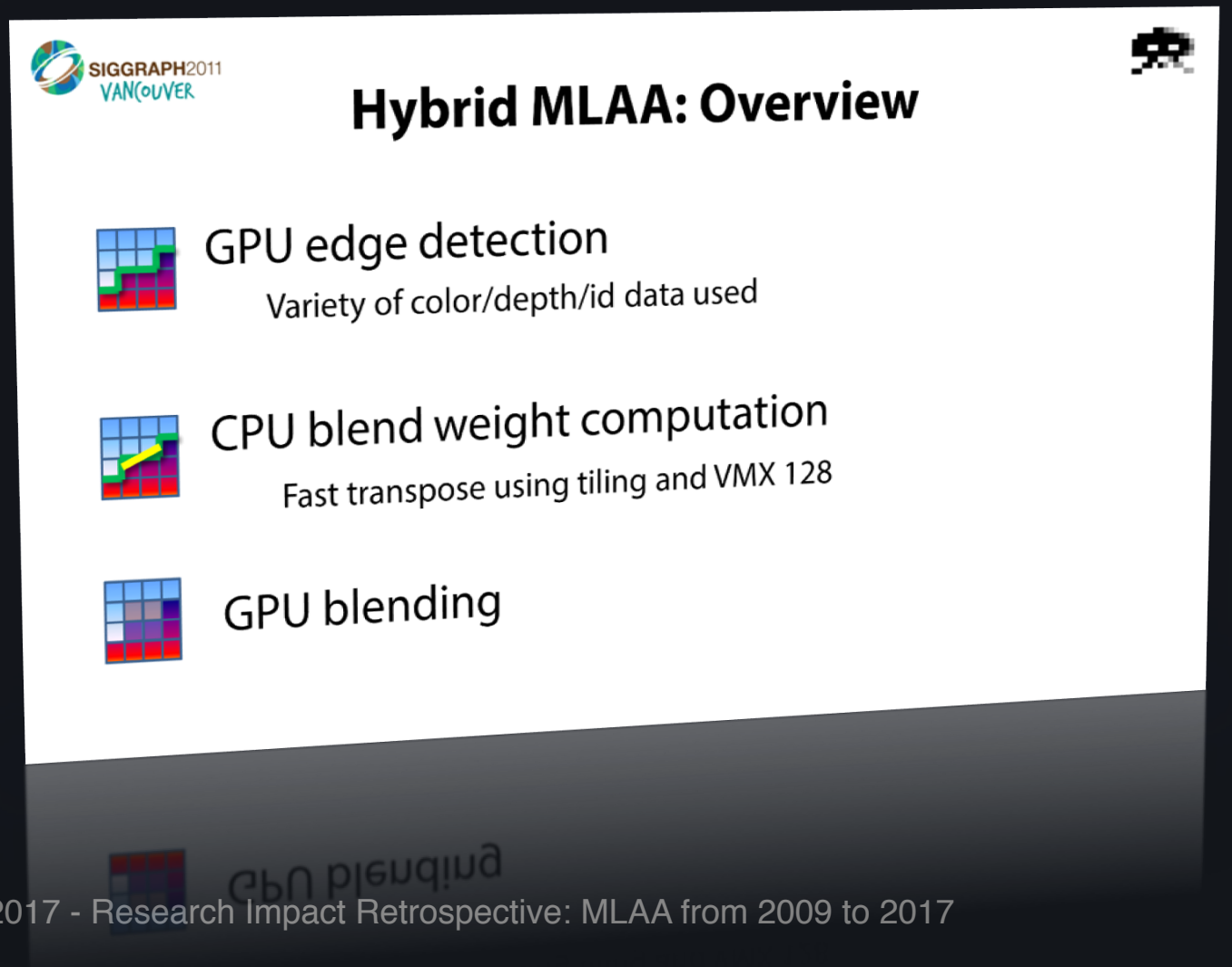


[Perthuis2011]

Double Fine's Costume Quest (2010)

[Demoreuille2011]

Double Fine's Costume Quest (2010)

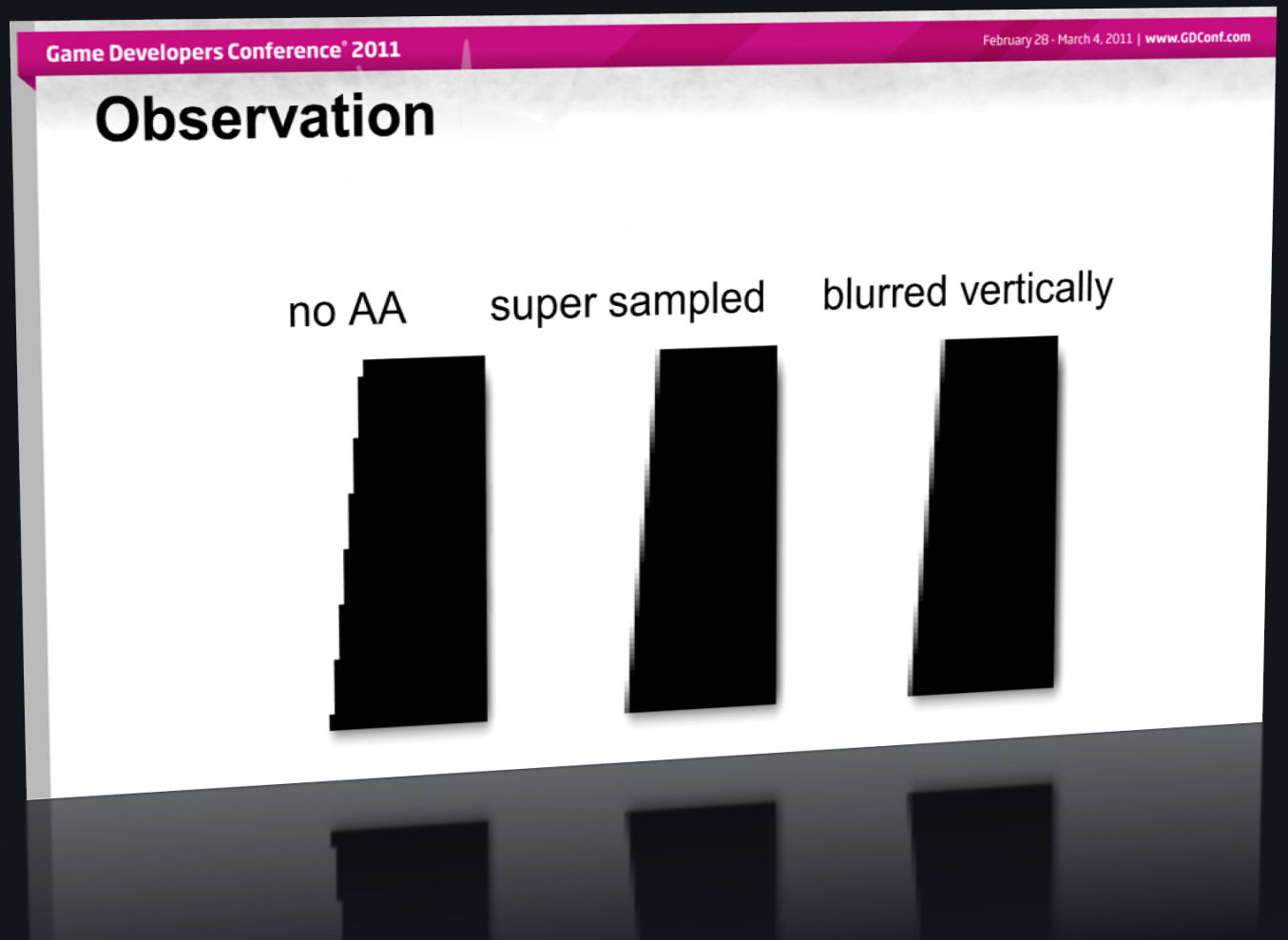


[Demoreuille2011]

Star Wars: The Force Unleashed II - DLAA (2010)

[Andreev2011]

Star Wars: The Force Unleashed II - DLAA (2010)



[Andreev2011]

FXAA Console (2010)

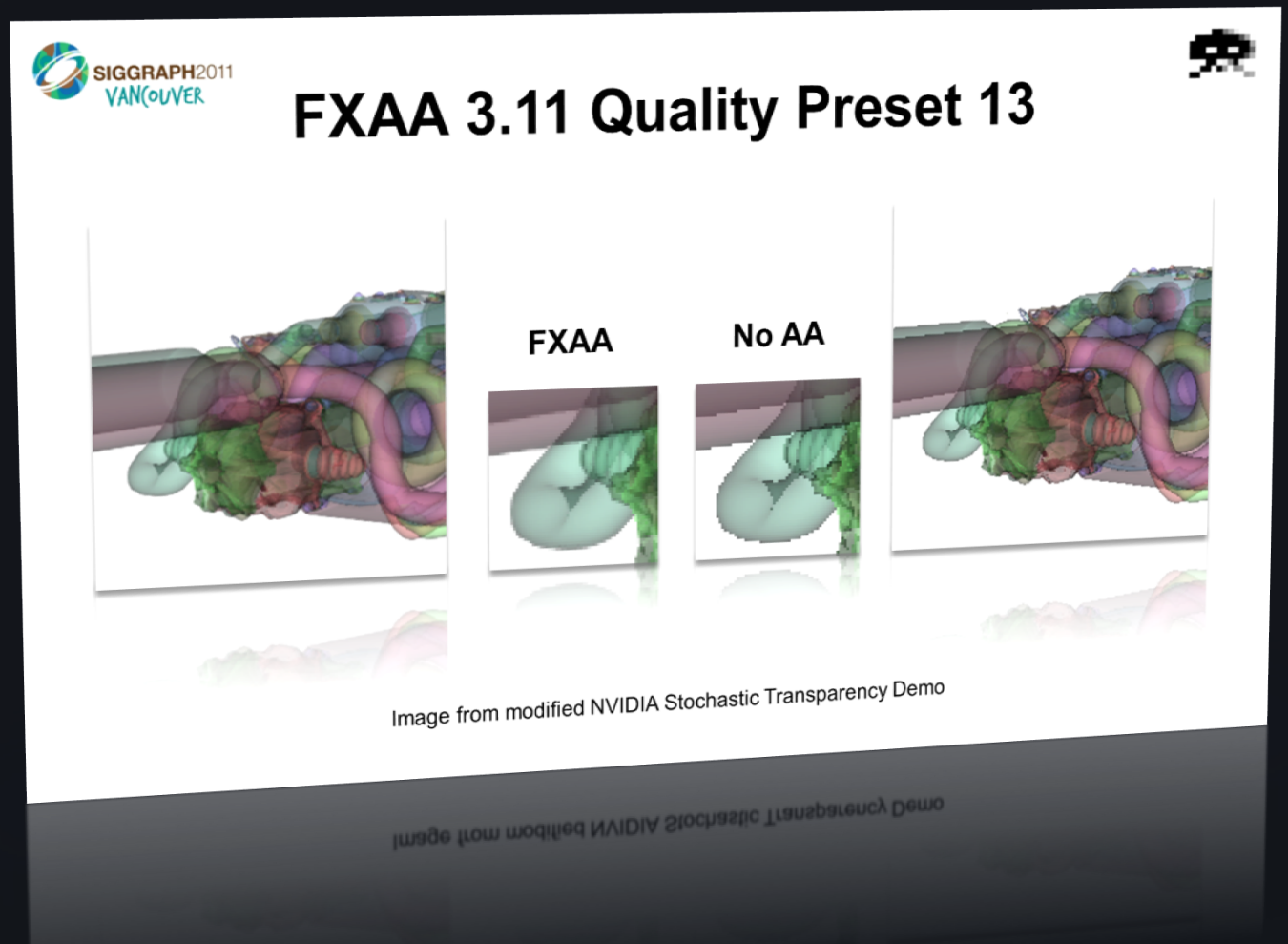
[Lottes2011]

SIGGRAPH2011 VANCOUVER

FXAA 3.11 Console Taps

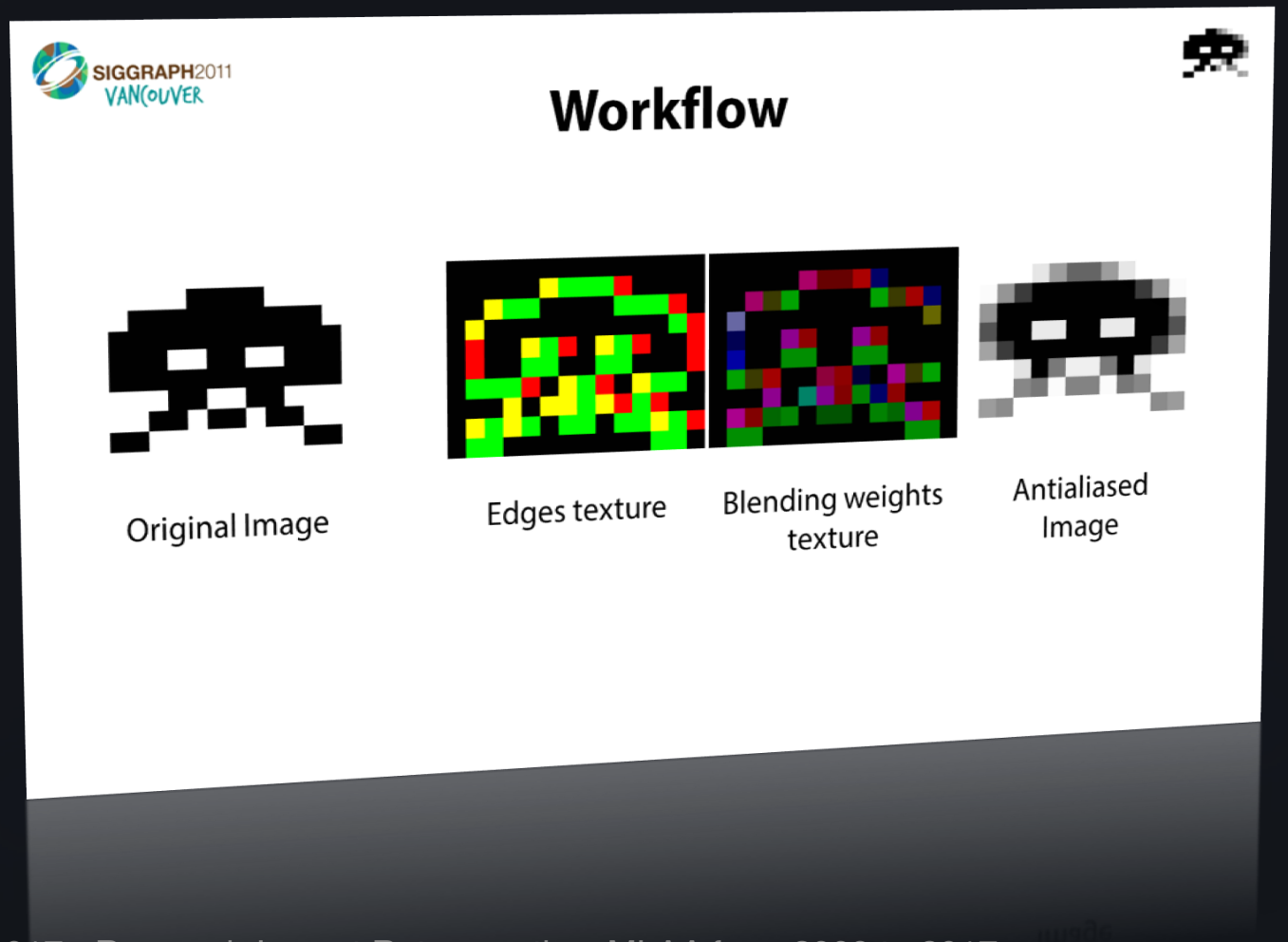
- All pixels which do not exit get this 2 tap filter
  - Direction perpendicular to local luma gradient
    - Use the four 2x2 box filtered luma values
      - dir.x = -((NW+NE)-(SW+SE))
      - dir.y = ((NW+SW)-(NE+SE))
      - dir.xy = normalize(dir.xy) * scale
- Optional extra 2 taps
  - Scale dir.xy by 1/minDir
    - minDir = min(|dir.x|, |dir.y|) * sharpness
  - Then limit filter width to 8 pixels

FXAA Quality (2010)



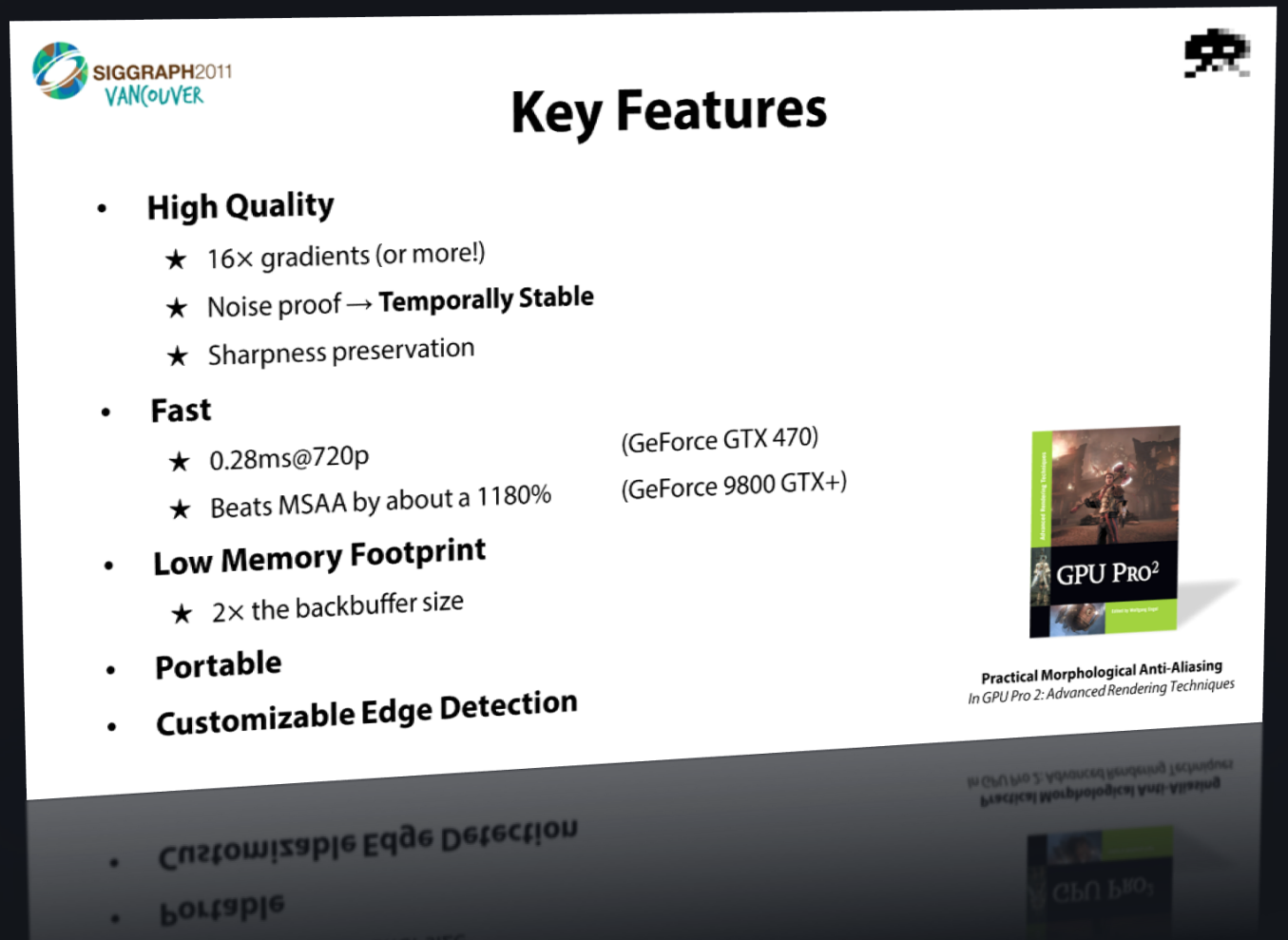
[Lottes2011]

Jimenez's MLAA (2010)



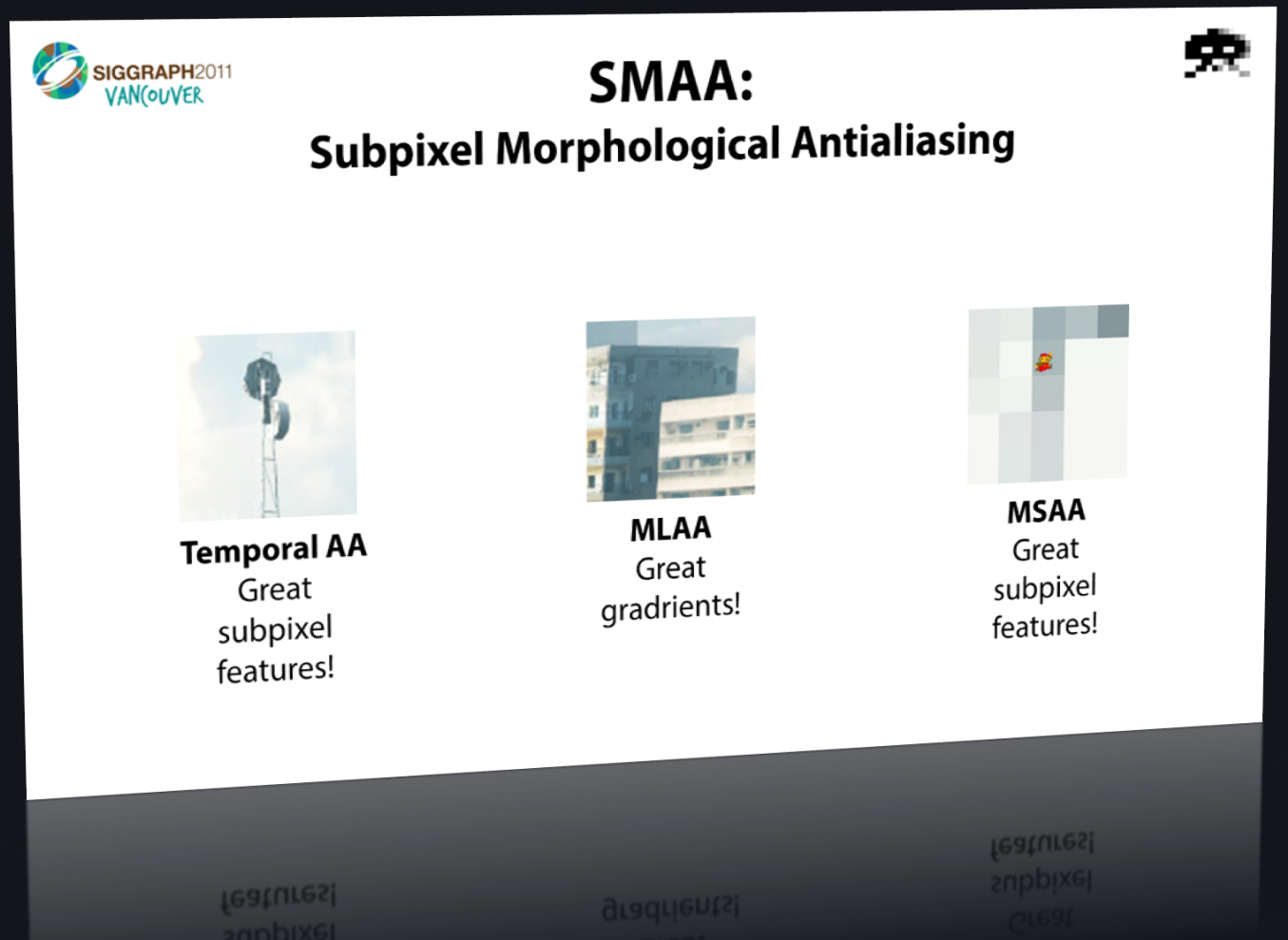
[Jimenez2011b]

Jimenez's MLAA (2010)



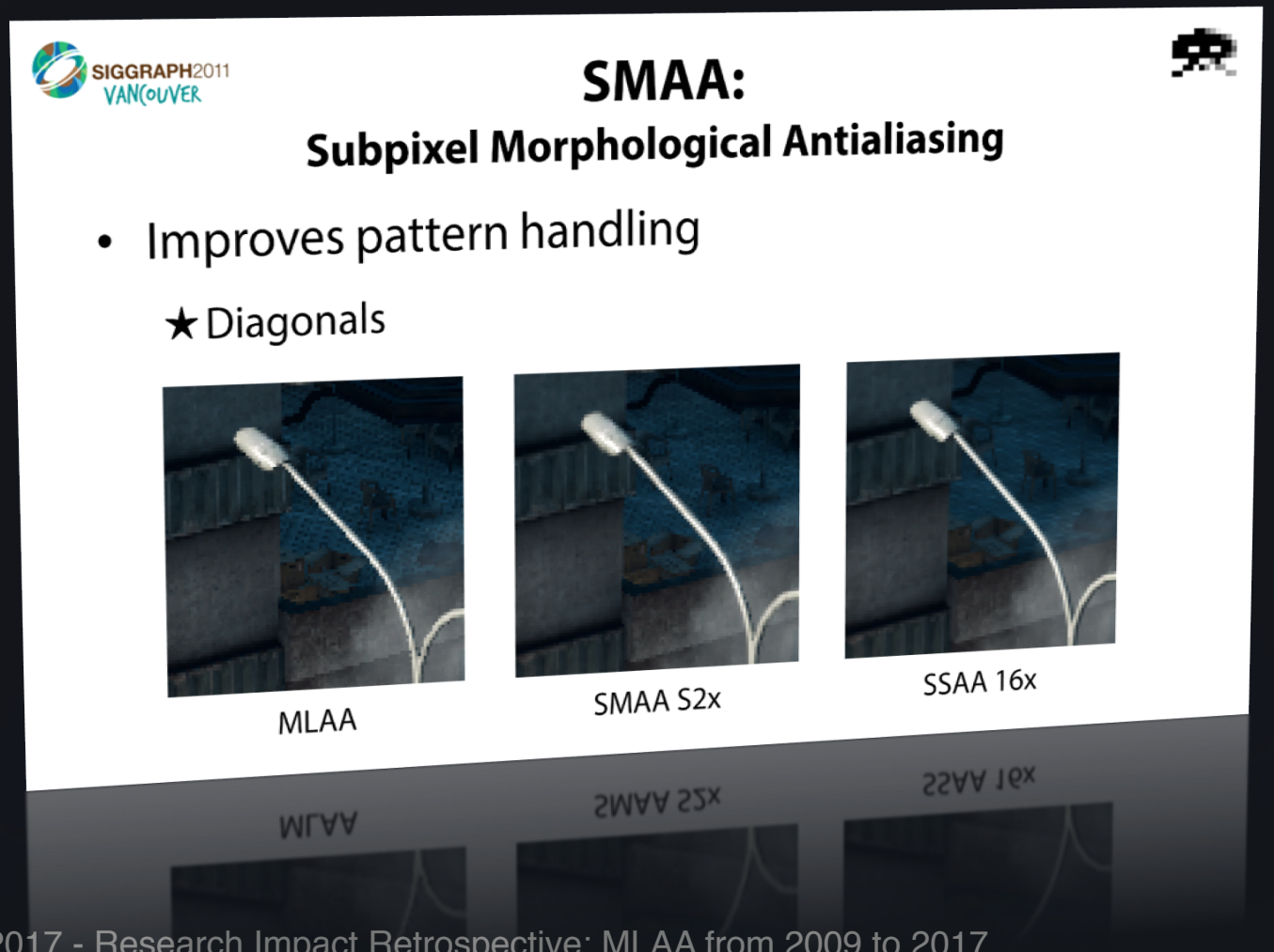
[Jimenez2011b]

SMAA (2011)



[Jimenez2011b]

SMAA (2011)



[Jimenez2011b]

FXAA / SMAA Features

FXAA Console

- Focus on ultimate performance
- Very easy to integrate
- Blurrier texture details
- Decreased temporal stability
- Worse subpixel features

FXAA Quality

- Target medium quality/performance tradeoff
- Better gradients than MSAA
- Very easy to integrate
- Blurrier texture details
- Decreased temporal stability
- Worse subpixel features

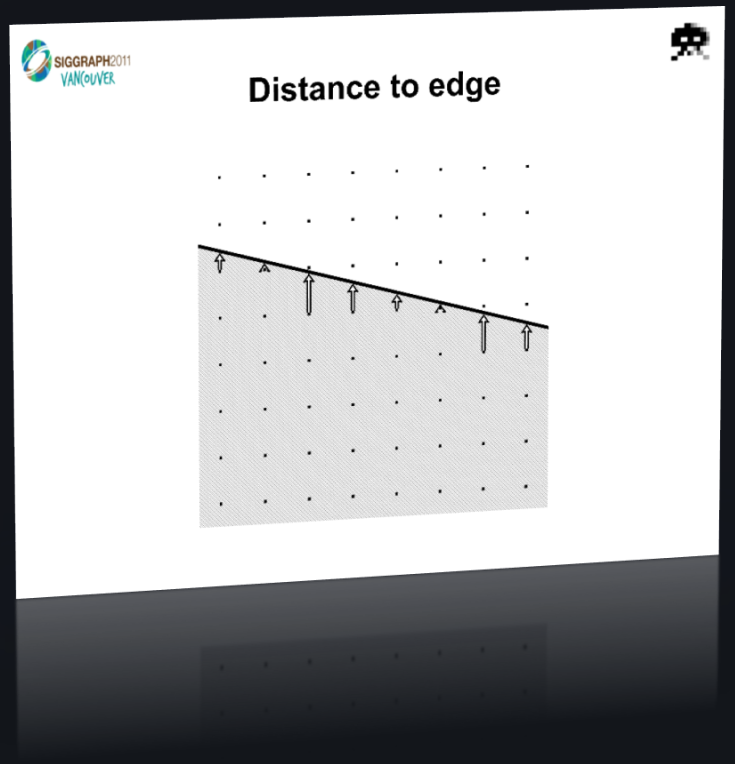
SMAA T2x

- Focus on ultimate quality
  - Sharpness
  - Extended pattern recognition
  - Optional TAA/MSAA combos for subpixel features
- Better gradients than MSAA
- More complex integration

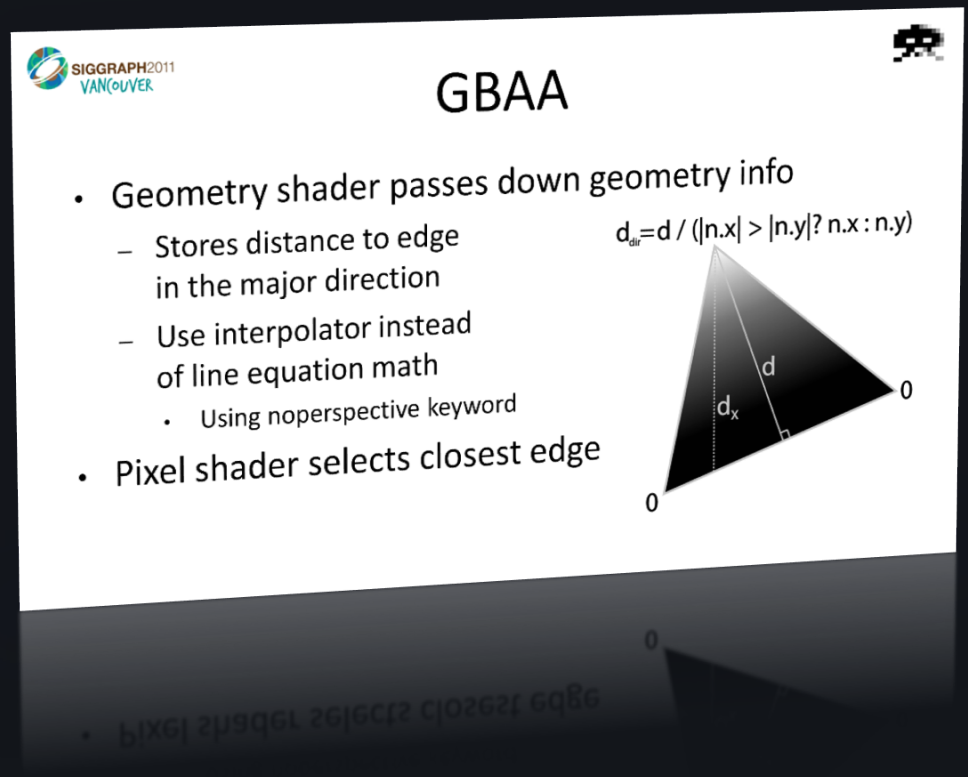
For Both FXAA/SMAA

- Not dealing with MSAA
- Compatible with deferred

DEAA & GBAA (2011)

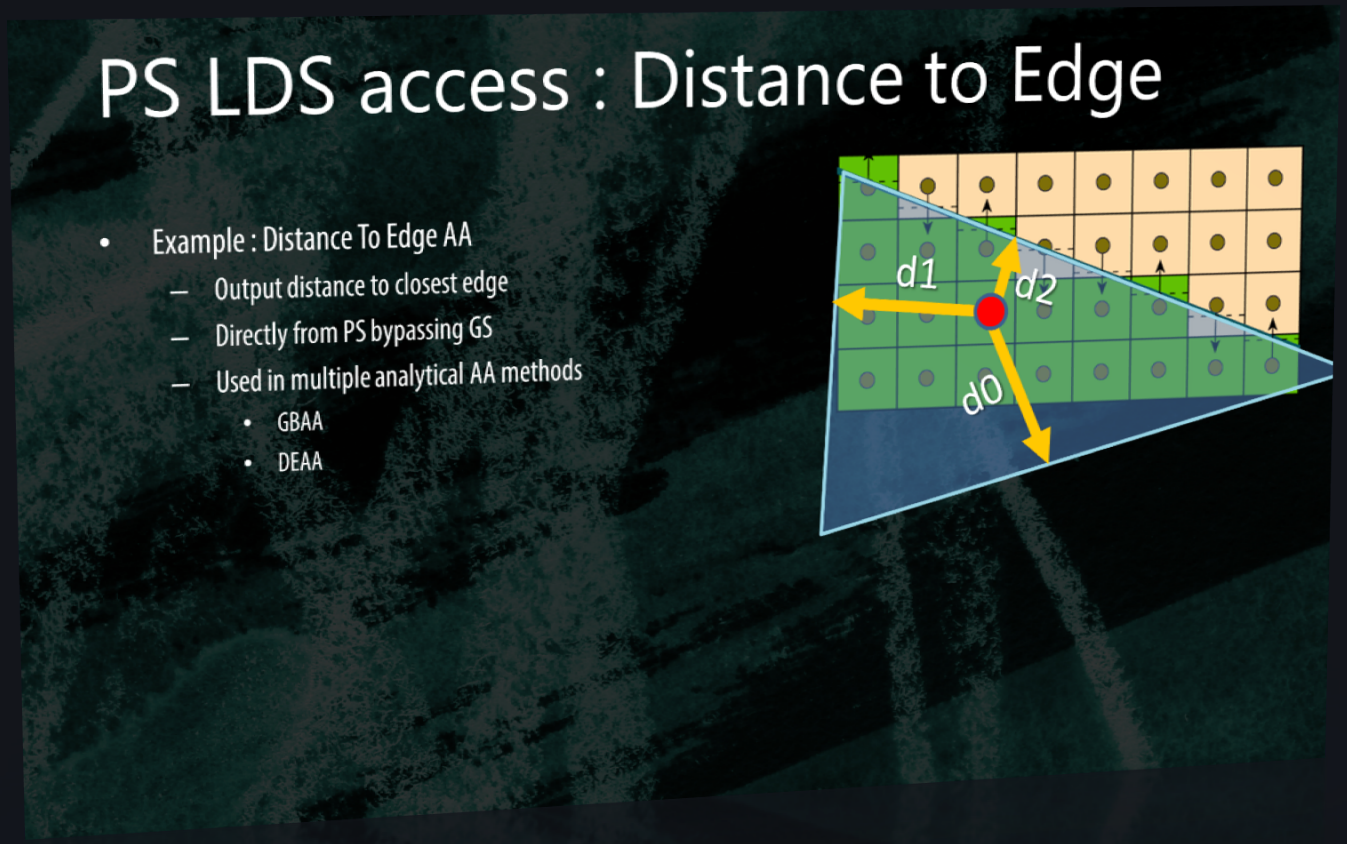


[Malan2011]



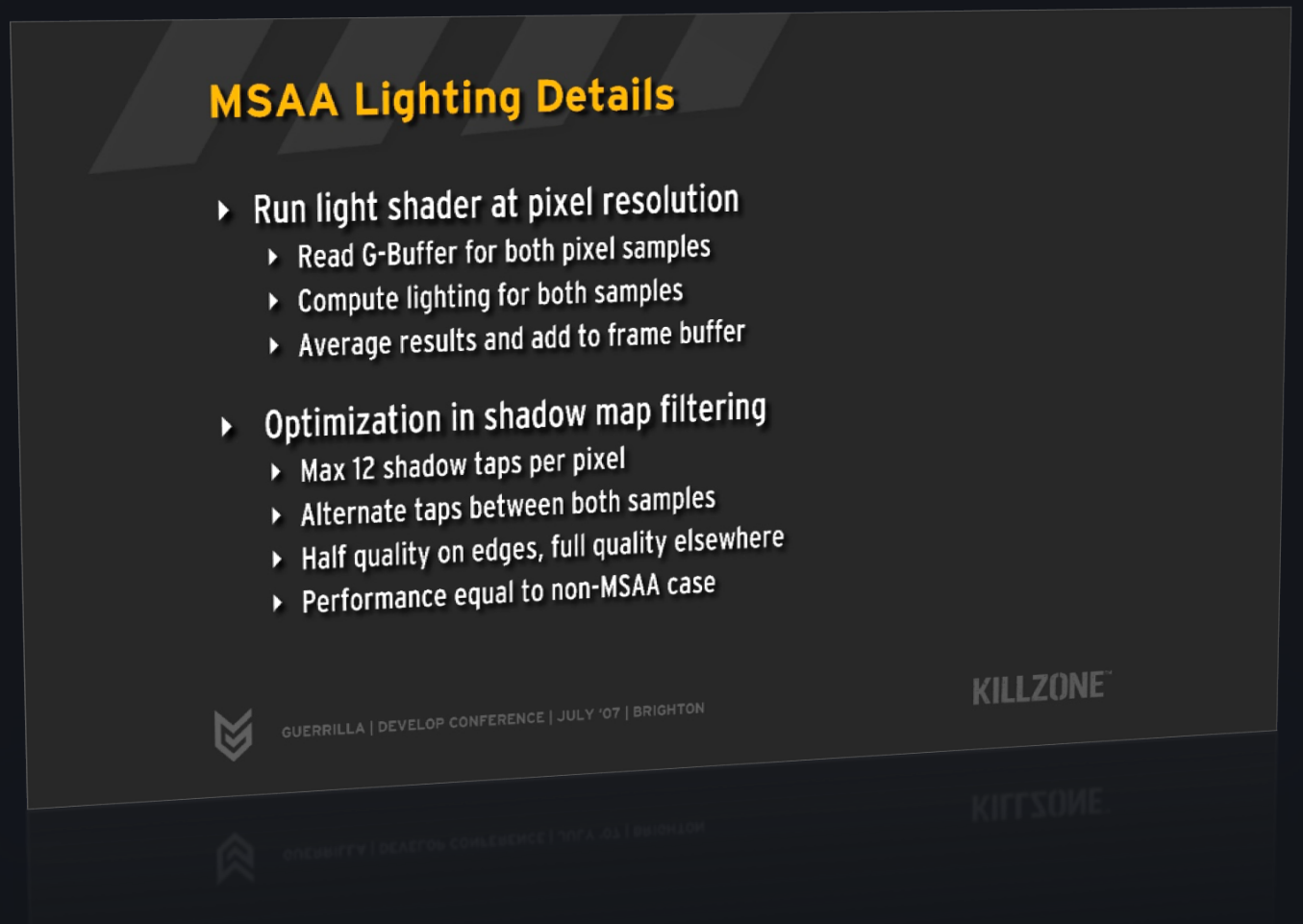
[Persson2011]

Low Level Optimizations for GCN [Drobot2014]



[Drobot2014a]

Killzone AA Transition



[Valient2007]

Uncharted 4 (2016)

Temporal AA

Accelerating Real-Time Shading with Reverse Reprojection Caching [Nehab2007]

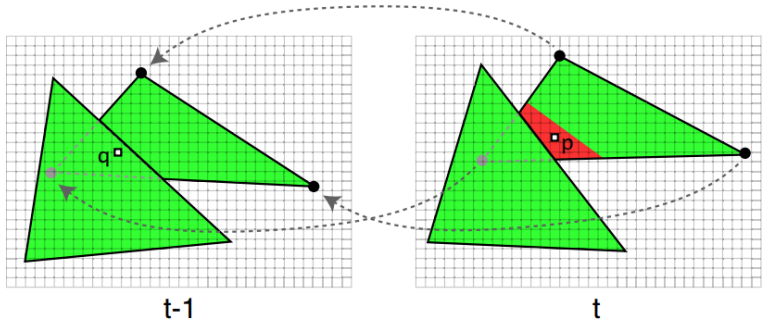


Figure 4: ***Left:*** *Shading calculations and pixel depths in frame $t-1$ are stored in screen-space buffers.* ***Right:*** *In the next frame, each vertex is also transformed by the model, camera and projection matrices (along with any animation parameters) at time $t-1$. These values become per-vertex attributes that undergo perspective-correct interpolation, giving each pixel access to its position in the cache. To detect cache misses, we compare the reprojected depth of a pixel p to the depth stored at its position in the cache at q.*

[Nehab2007]

Gran Turismo PSP (2009)

Information from [Greer2009]

Slow Motion

Full Speed, as observed on a PSP

Halo Reach (2010)

Information from [Leadbetter2010]

Crysis 2 [2011]

[Sousa2011]

SMAA (2011)

[Jimenez2012]

SMAA: Enhanced Subpixel Morphological Antialiasing

Jorge Jimenez[1] Jose I. Echevarria[1] Tiago Sousa[2] Diego Gutierrez[1]

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[2]Crytek GmbH, Germany

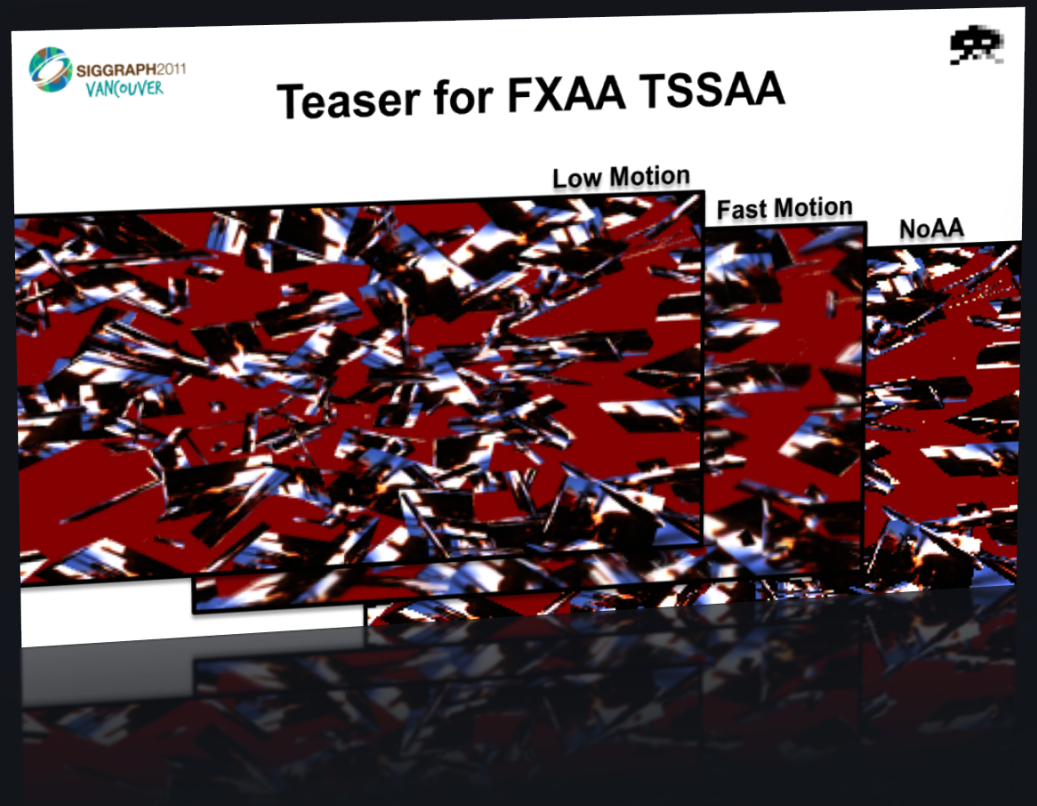
Figure 1: *Example of SMAA 4x integrated in the* Crysis 2 *game. The insets show the differences between MLAA [JME*11], our novel SMAA T2x and 4x algorithms and MSAA 8x as reference. For 1080p frames, the average cost of SMAA T2x is 1.3 ms and 2.6 ms for SMAA 4x, measured on a NVIDIA GeForce GTX 470.*

Crysis 3 - SMAA (2013)

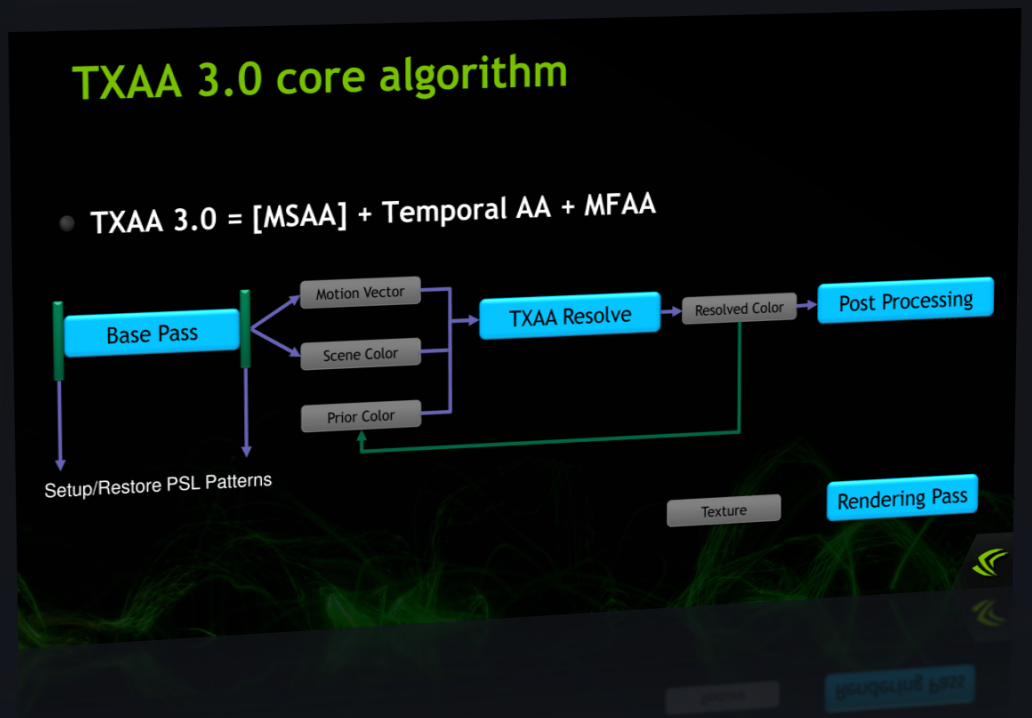
Assassins Creed 4 and Ryse - SMAA (2013)

The Last Guardian (2016)

Lottes' TSSAA & TXAA (2011)



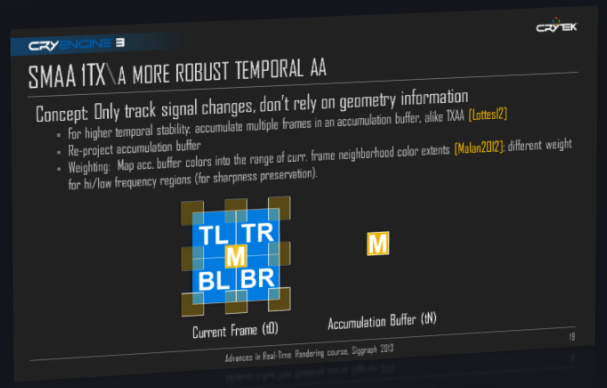
[Lottes2011]



[Cao2016]

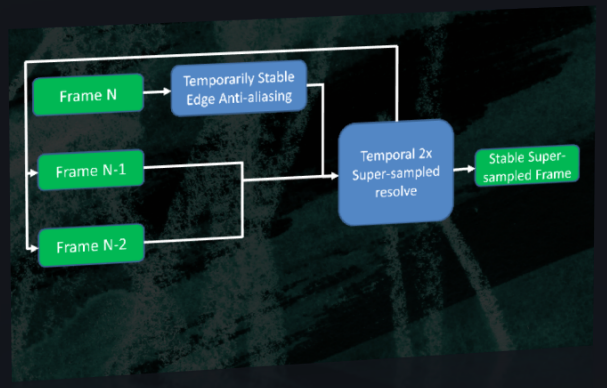
Evolution

[Sousa2013]

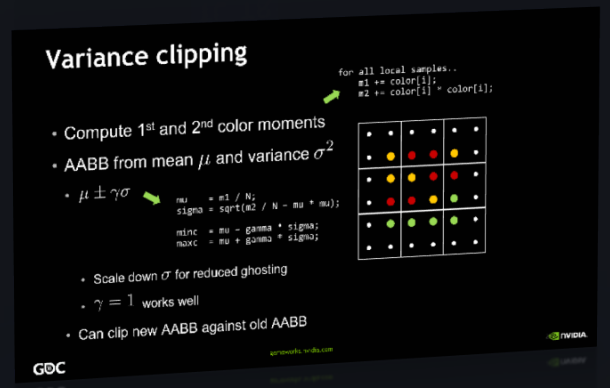


[Karis2014]

[Drobot2014b]



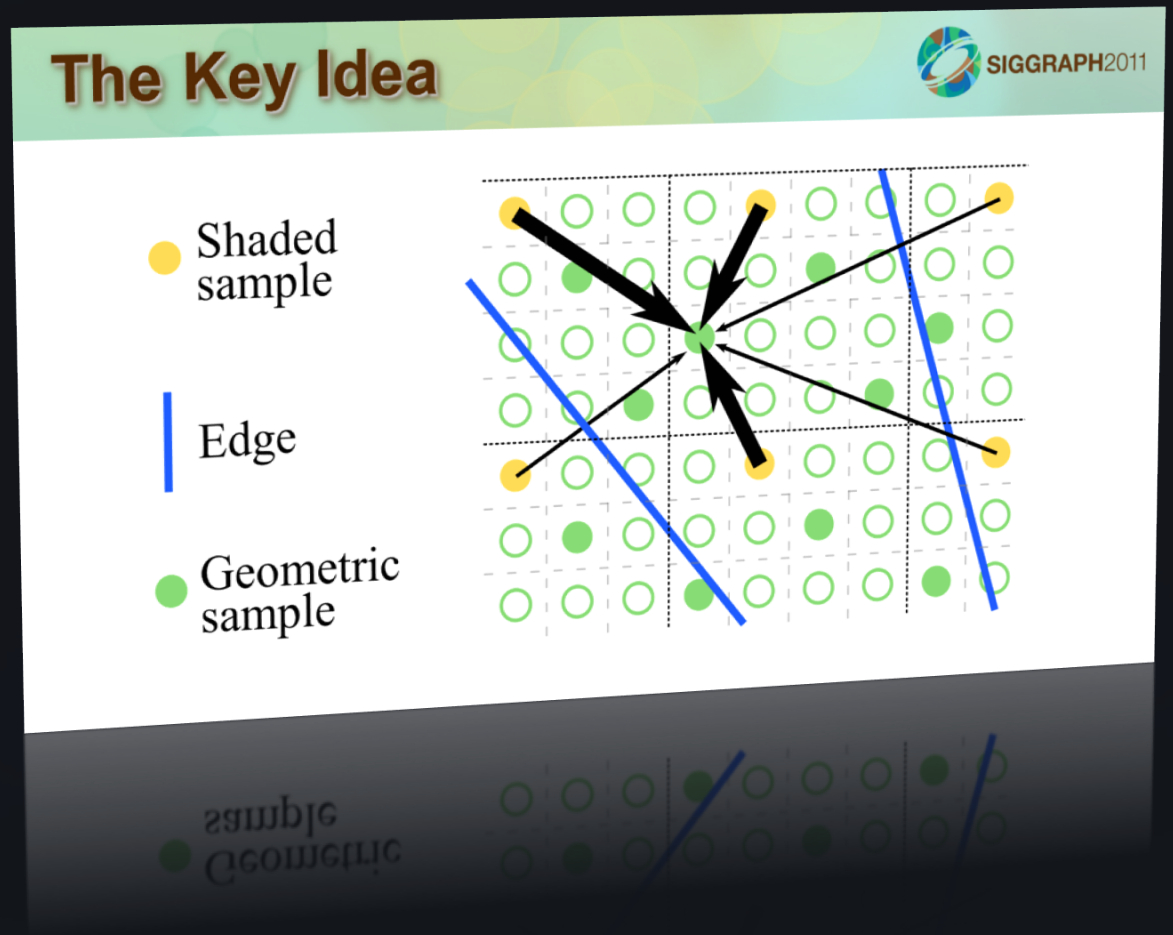
[Salvi2016]



[Jimenez2016]

Temporal Upsampling and 4k Reconstruction

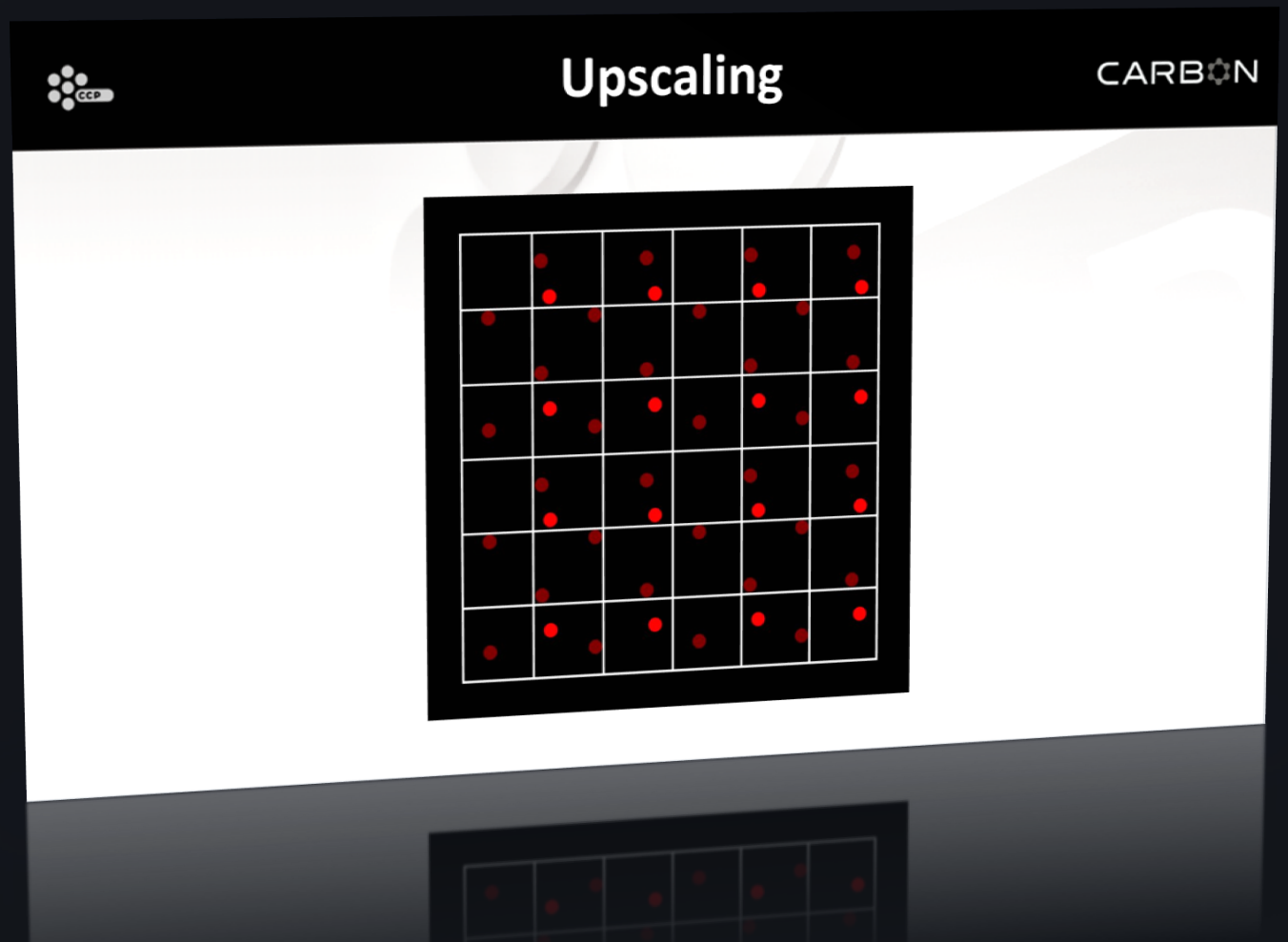
SRAA (2011)



[McGuire2011]

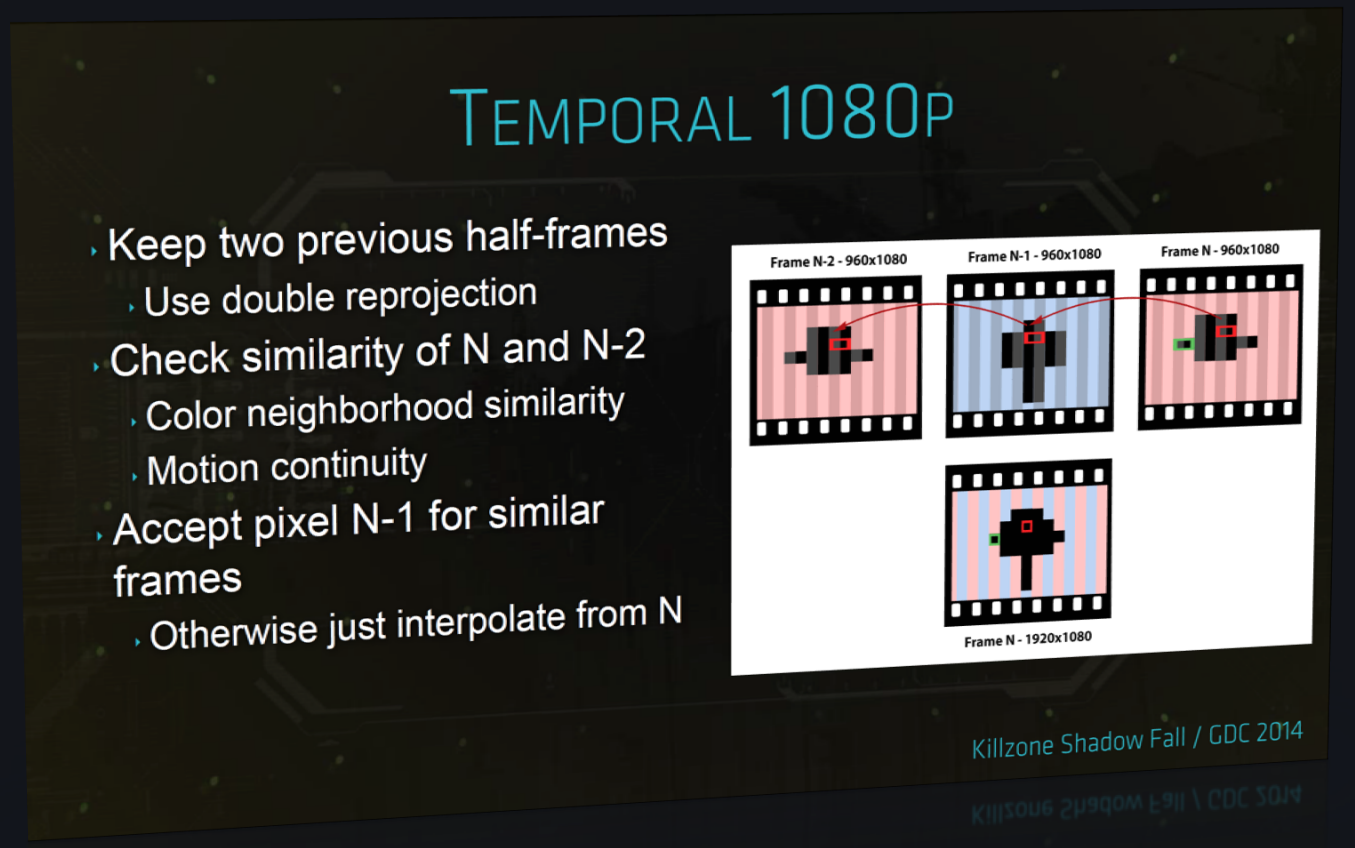
Infamous Second Son (2014, patched for 4k)

Dust Experimental Temporal Upsampling (2012)



[Malan2012]

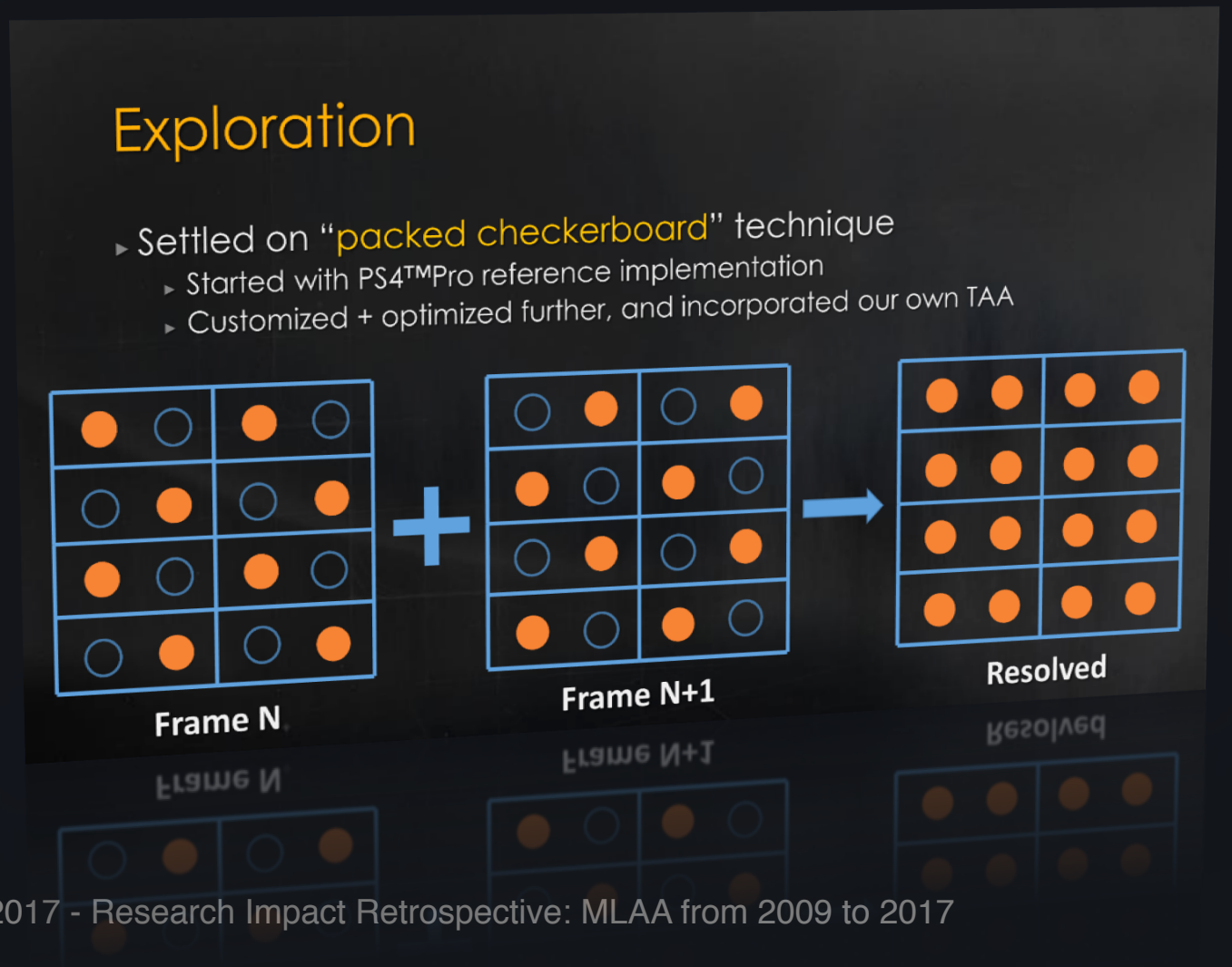
Killzone Shadow Fall (2014)



[Valient2014]

Battlefield 1 (2016) and Mass Effect Andromeda (2017)

[Wihlidal2016]



Dynamic Antialiasing

- [Jimenez2017] Dynamic Antialiasing in Call of Duty: Infinite Warfare
  - Combines dynamic resolution with temporal upsampling
  - Always outputs 1080p frames, with varying degrees of AA depending on load

- Advances in Real-Time Rendering in Games: Part I
  - Monday 11:40 am

Summary

- MLAA questioned the status quo.
- MLAA went against the trend.
- MLAA possibly slowed down MSAA and hardware antialiasing advances.
- Unreal Engine added support for MSAA.
- Interesting tradeoffs to be found on hybrid solutions.

Summary

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Q&A - Acknowledgements

Special thanks to Peter-Pike Sloan

References

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- [Cao2016] Advanced Ambient Occlusion, Shadow and Anti-Aliasing in NVIDIA GameWorks
- [Demoreuille2011] Hybrid CPU/GPU MLAA on the Xbox-360
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- [Drobot2014b] Hybrid Reconstruction Antialiasing
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- [Leadbetter2009b] http://www.eurogamer.net/articles/digitalfoundry-saboteur-aa-blog-entry
- [Leadbetter2010] http://www.eurogamer.net/articles/digitalfoundry-halo-reach-tech-interview?page=2
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- [Reshetov2009] Morphological Antialiasing
- [Salvi2016] An Excursion in Temporal Supersampling
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- [Valient2014] Real-Time Global Illumination and Reflections in Dust 514
- [Wihlidal2016] 4k Checkerboard in Battlefield 1 and Mass Effect Andromeda