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Filtering Approaches for Real-Time Anti-Aliasing

http://www.iryoku.com/aacourse/

Filtering Approaches for Real-Time Anti-Aliasing

Anti-Aliasing Methods in CryENGINE 3

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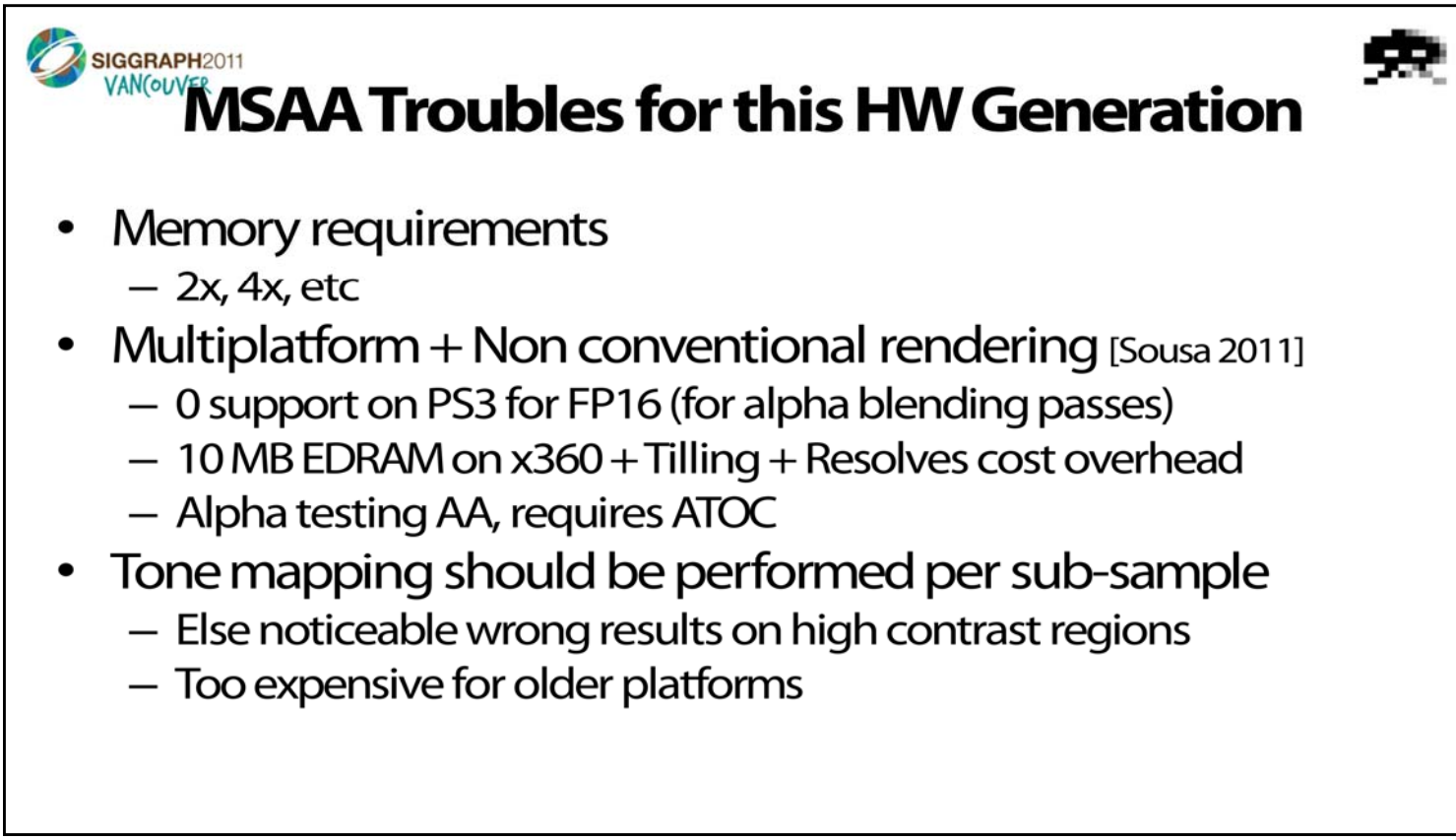
CryENGINE 3 AA Requirements

- Orthogonal and general solutions
  - No per-platform AA solution
- Play nice with HDR/Deferred techniques
- Sub-pixel accuracy is important for us
  - Schimering was the biggest offender on Crysis 1 and 2 levels
  - Crysis had imensively aliased assets: alpha tested/tiny sub-pixel details
  - HDR makes it even worse, big range of lighting contrast/color variation
- Low memory footprint
- Cost less than 2 ms on low end GPUs
  - Every ms counts for consoles



Multitude of workarounds and added complexity

Each platform with its own solution, workarounds and optimizations

Performance cost

For current Gen, situation doens't look promising...

Minimal G-Buffer

- RGBA8 World Space BF Normals + Glossiness
- Readback Z24S8 Depth + Stencil for tagging interior areas

Deferred lighting buffers

- Xbox 360: 2x RGB10F resolved to RGB10A2 for performance/memory
- PS3: 2x RGBA8 encoded in RGBK
- PC: 2x FP16

Scene buffer

- X360: RGB10F resolved to FP16 for performance
- PS3: RGBA8 encoded in RGBK for opaque, FP16 for transparents
- PC: FP16

X360: 28 MB; PS3: 31.5MB; PC: 49 MB at 720p, 110 MB at 1080p and so on.

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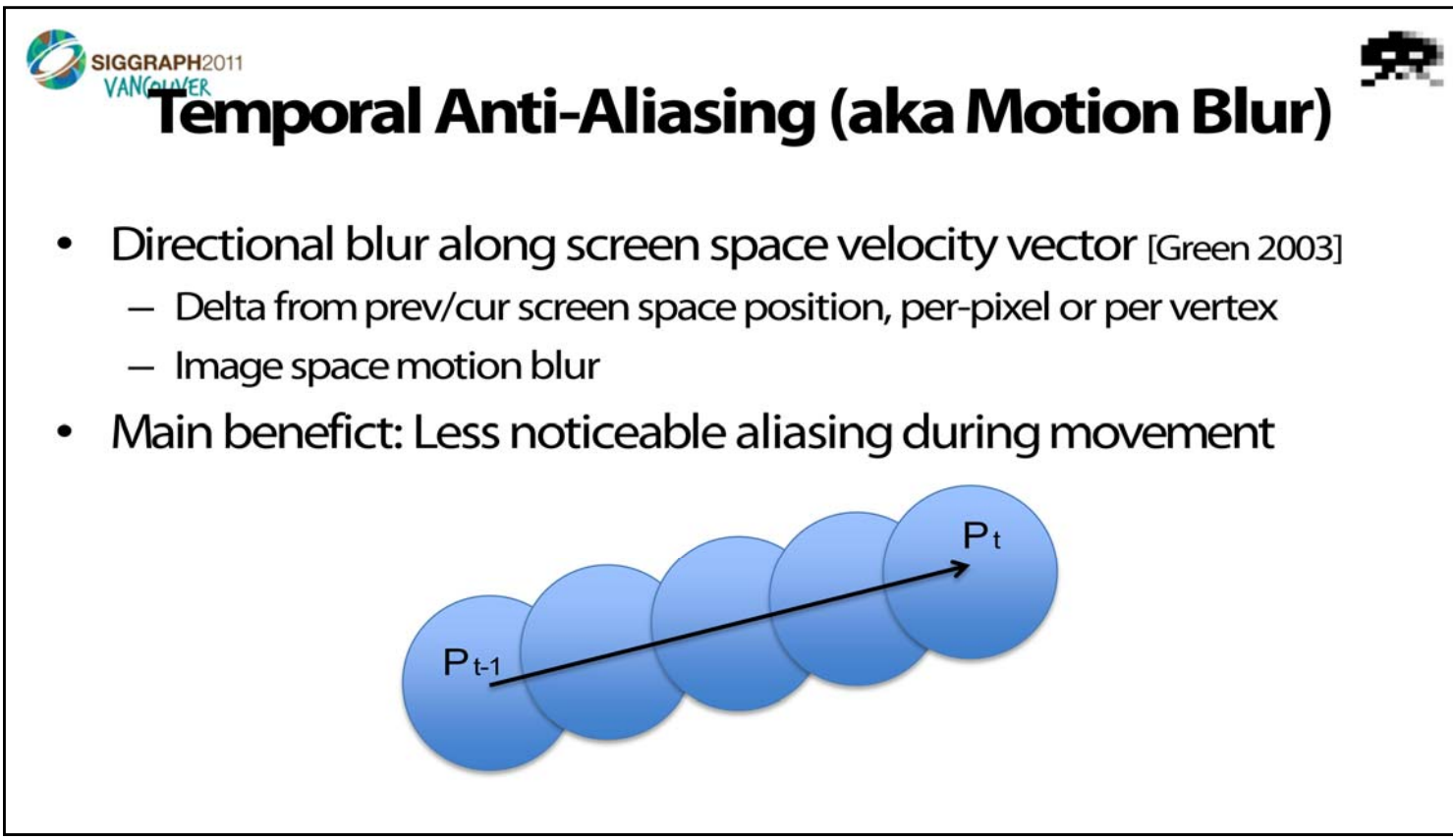
The Quest for AA Alternatives



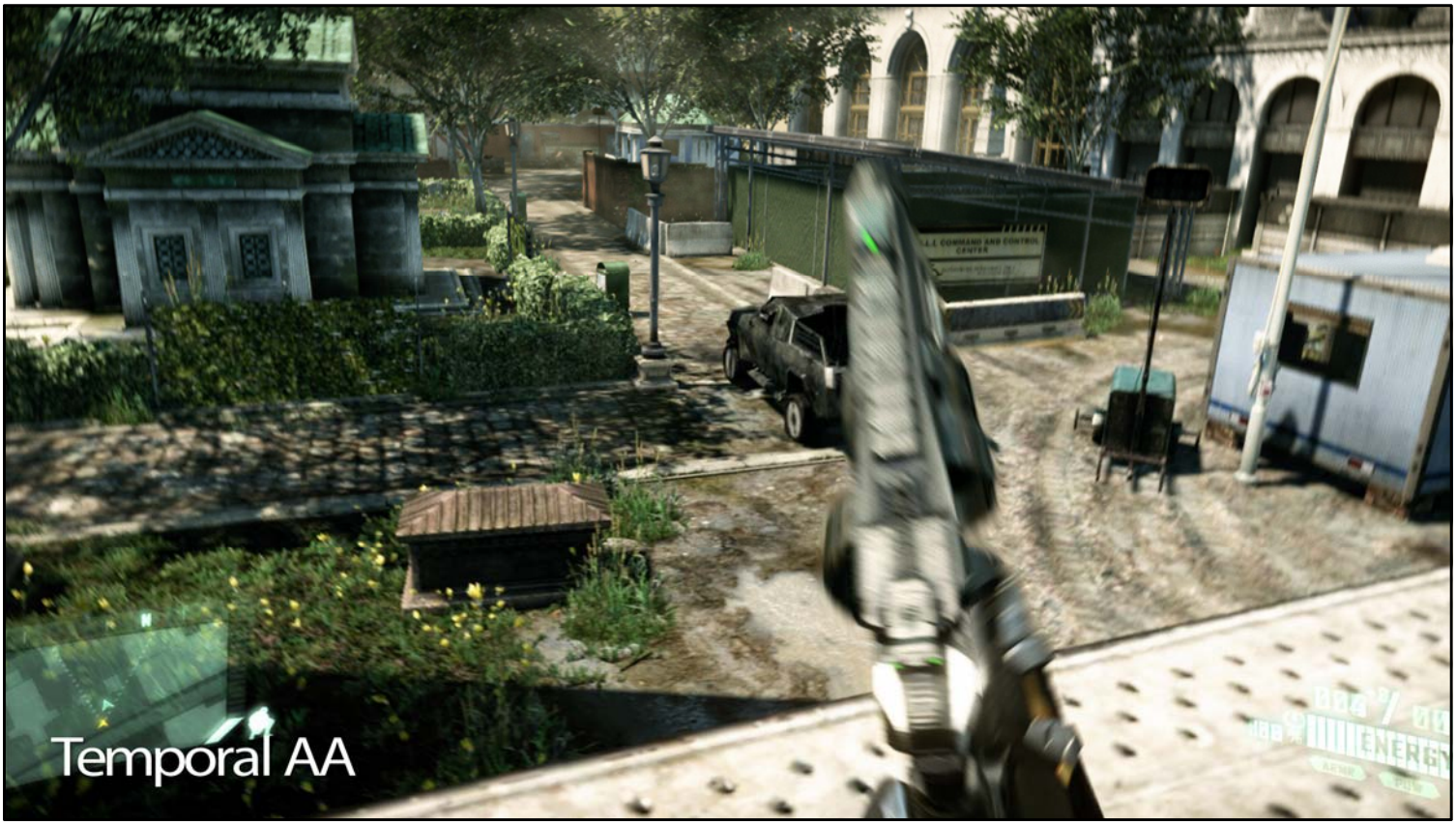
Increasingly popularity since Crysis 1 and KZ2

Aproximated as directional blur along screen space velocity vector

Delta from prev/cur screen space position, per-pixel or per vertex

Added bonus: Great cinematic look

User for all platforms


Temporal AA

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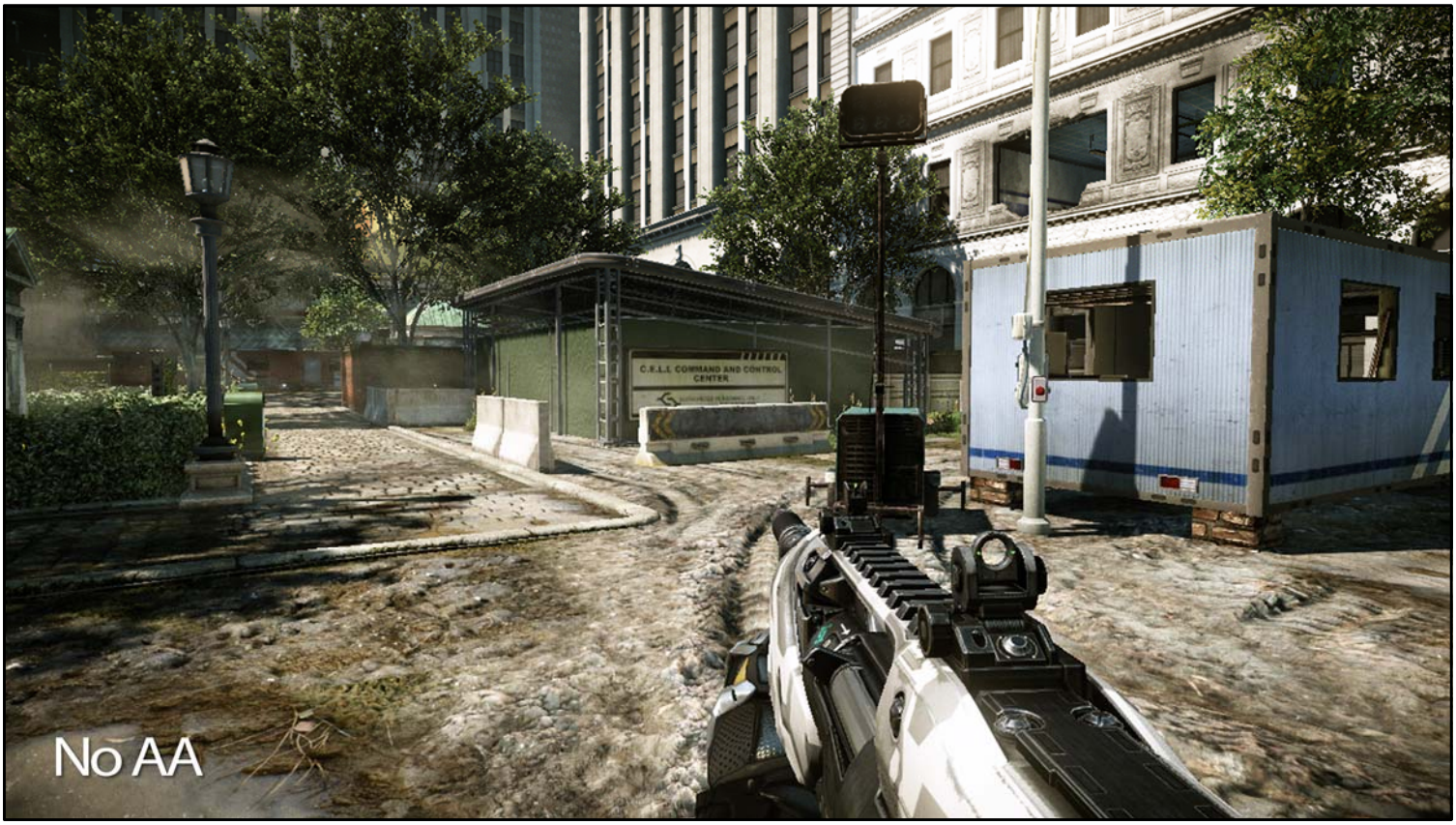
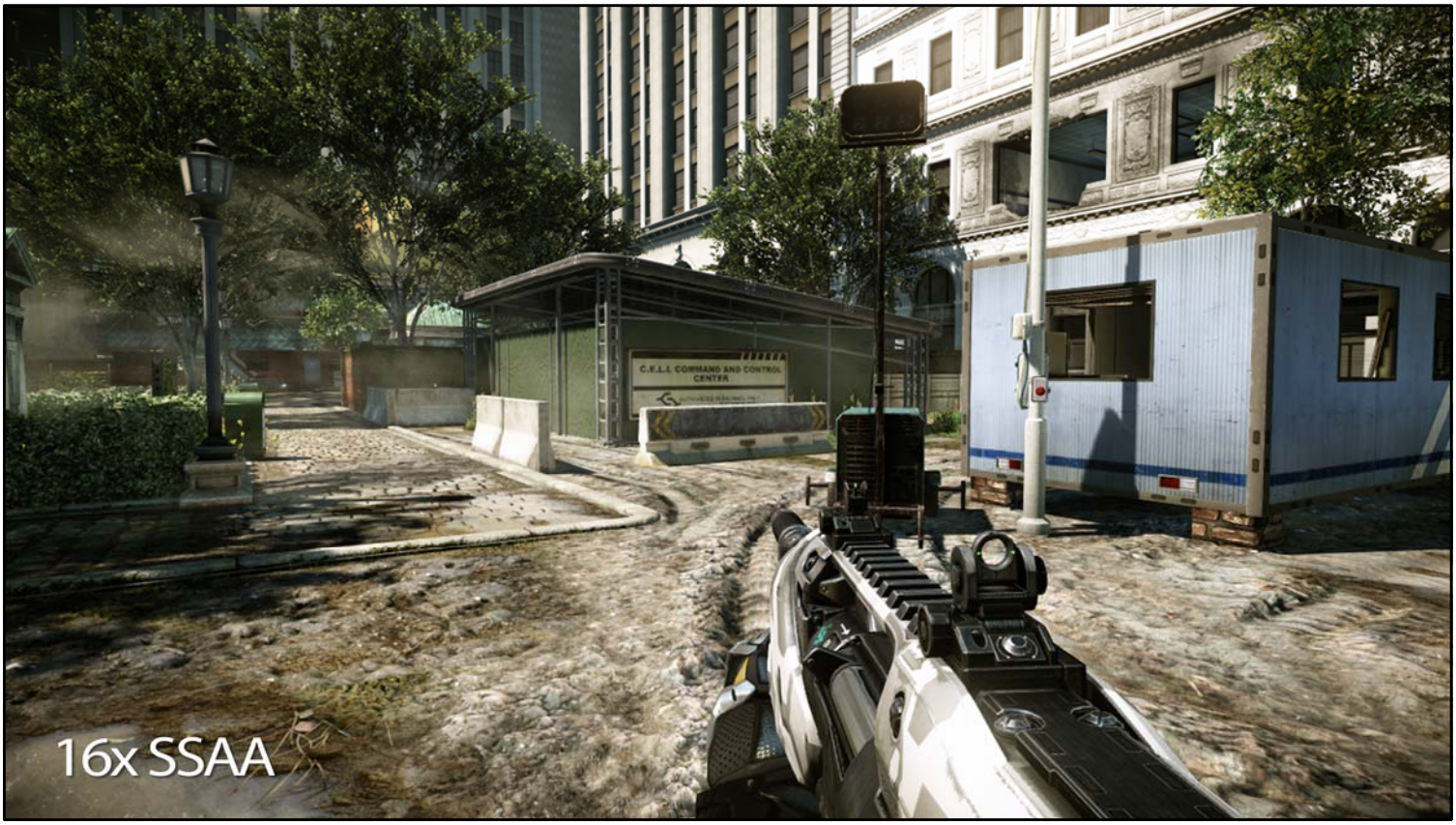
A-Buffer SSAA [Haeberli90]

- Add sub-pixel jitter to camera frustum
- Brute force: Render scene multiple times
  - N sub samples ⇔ N scene renders
- Robust and best quality
  - Also more uses besides SSAA (TSSAA/DOF/Soft-Shadows)
- Base concept used for our techniques

- Problem: Cannot afford render scene multiple times (yet)
  - Great for reference/marketing quality shots though

Alternatively, the usual approach of rendering higher resolution and downscale


C.R.I.S. COMMAND AND CONTROL CENTER
No AA


C.R.L.L COMMAND AND CONTROL CENTER
16x SSAA

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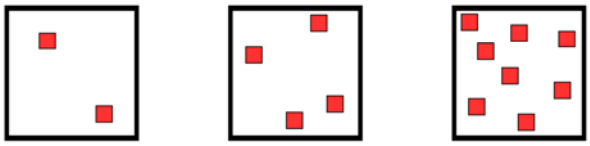
Distribute A-Buffer SSAA Overframes

- Running at 60 fps ?
  - Add sub-pixel jitter to camera frustum every frame
  - Store previous/current frame and linear blend them
  - Light-speed 2x SSAA: ~0.5 ms on current consoles
  - 2 frames ⇔ 2x SSAA, 4 frames ⇔ 4x SSAA, etc



- But... not many reach 60 fps on consoles
  - Lower fps results in extremelly noticeable image ghosting

Used in few older 60 fps games (DMC4?) , but who was first?

And even at 60 fps, still noticeable ghosting

Strafing is the worst case, we'll use if for images

Minimizing Artifacts

- Improving blending: Reprojection
  - Velocity vector fetches from previous frame sub-sample target
  - Exactly same as in TAA (but single tap)
- Deformable geometry slightly more expensive to handle
  - Output pixel velocity into a render target
  - Could not afford for vegetation
- Problem: Disocluded regions ghosting


PULL
Using reprojection

Minimizing Artifacts (2)

- Disable blending if ||V|| > 0?
  - Very rare the case when player not moving
  - And we still want AA during camera movement
- Weighting using color/edge tagging ?
  - Sub-pixel/hi frequency detail results in noticeable schimering
- Reprojection range clamping
  - Pixel weight proportional to reprojection limit
    - Eg: fBlendW = saturate(1 - (fVLen / fVMaxLen))
  - Coarse Depth stored in sub-sample buffer alpha channel
    - Mask out if fVLen > fMaxVThreshold and fCurrD > fPrevD

Disable accumulation if ||V|| > 0?

Very rare the case when player not moving

And we still want AA during camera movement

Weighting using color ?

Sub-pixel/hi frequency detail results in noticeable schimering

Reprojection range clamping ? (used for Crysis 2)

Pixel weight proportional to reprojection limit

Eg: fBlendW = saturate(1 - (fVLen / fVMaxLen))

Coarse Depth stored in sub-sample buffer alpha channel

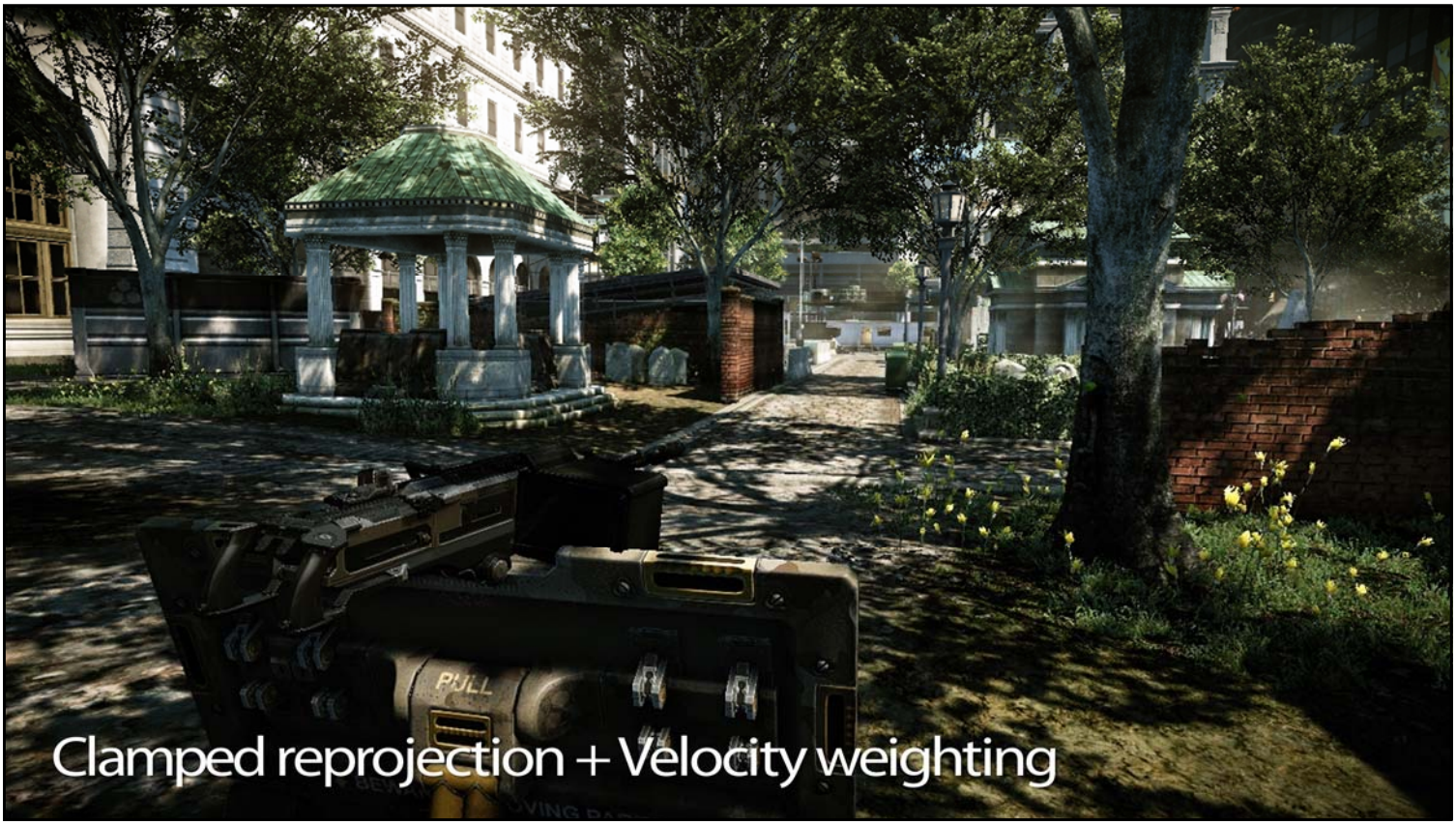
Mask out if fVLen > fMaxVThreshold and fCurrD > fPrevD

8 bit insufficient to cover large range, limited to nearby


Clamped reprojection (used in Crysis2)

Minimizing Artifacts (3)

- Store ||V|| in sub-sample buffer alpha channel
  - Weight: abs(fPrevLenV – fCurrLenV) / fVMaxLen


Clamped reprojection + Velocity weighting

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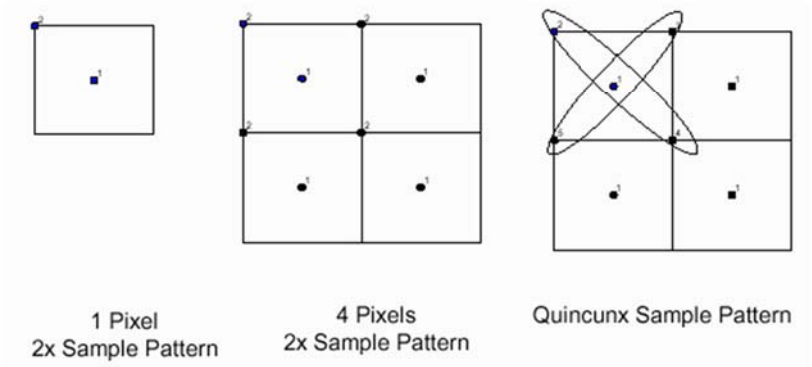
Example Code

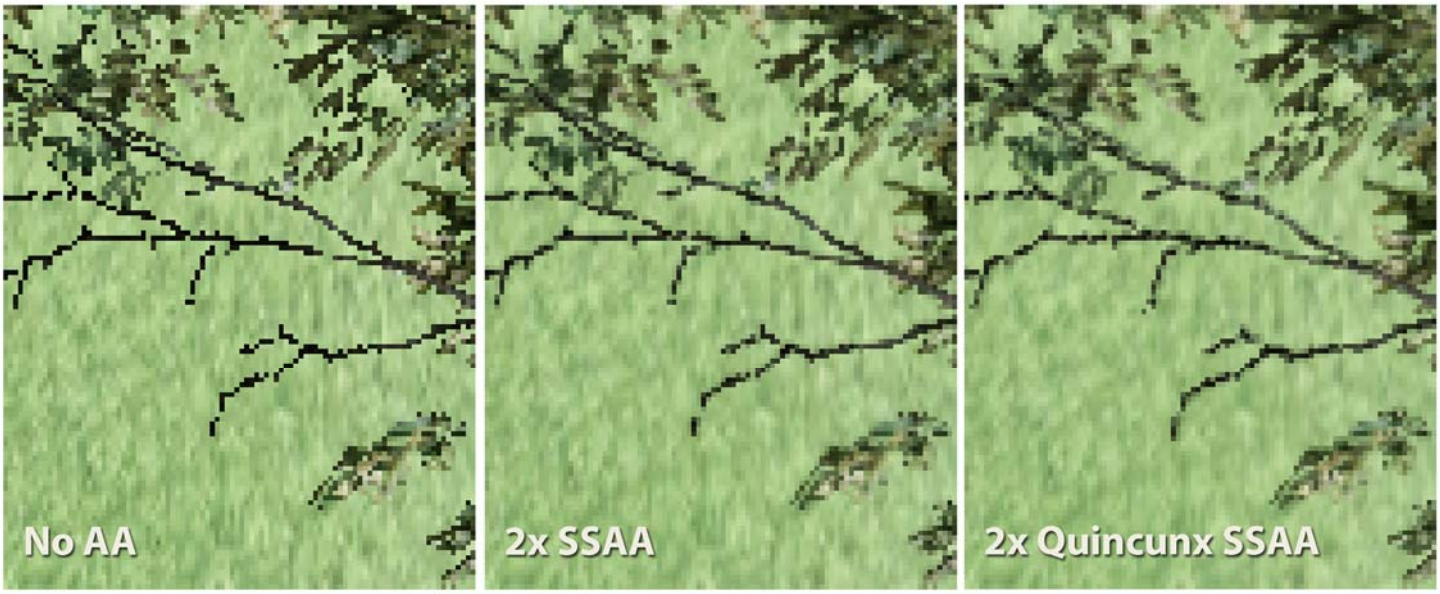
```
float fDepth = GetLinearDepth(sDepth, tcBase.xy );
float3 vPosWS = WorldViewPos.xyz + IN.vCam.xyz * fDepth;

float4 vPrevPos = mul(mViewProjPrev, float4(vPosWS, 1.0 ));
vPrevPos /= vPrevPos.w;

float2 vVelocity = vPrevPos.xy - tcBase.xy;
half4 cObjVelocityParams = tex2D(sObjVelocity, tcBase.xy) ;
half2 vObjVelocity = DecodeMotionVector( cObjVelocityParams );

vVelocity = cObjVelocityParams.w? vObjVelocity : vVelocity;
float fVLenSq = dot(vVelocity.xy, vVelocity.xy) + 1e-6f;
vVelocity /= fVLenSq;

half4 cCurr = tex2D(sCurrFrame, tcBase.xy)
half4 cPrev = tex2D(sPrevFrame, tcBase.xy + vVelocity * min(fVLenSq, fVMaxLen) );

half fBlendW = 0.5 - 0.5 * saturate(fVLenSq / fVMaxLen );
fBlendW *= saturate(1 - (abs(cCurr.a - cPrev.a) * fVWeightScale  );

OUT.Color = lerp(cCurr, cPrev, fBlendW);
```

2x Quincunx SSAA

- Improving quality with 2 sub-samples
  - Bilinear fetch to one of sub-samples
  - "Aproximate" 4x SSAA



2x Quincunx SSAA



Distributed A-Buffer SSAA: Caveats

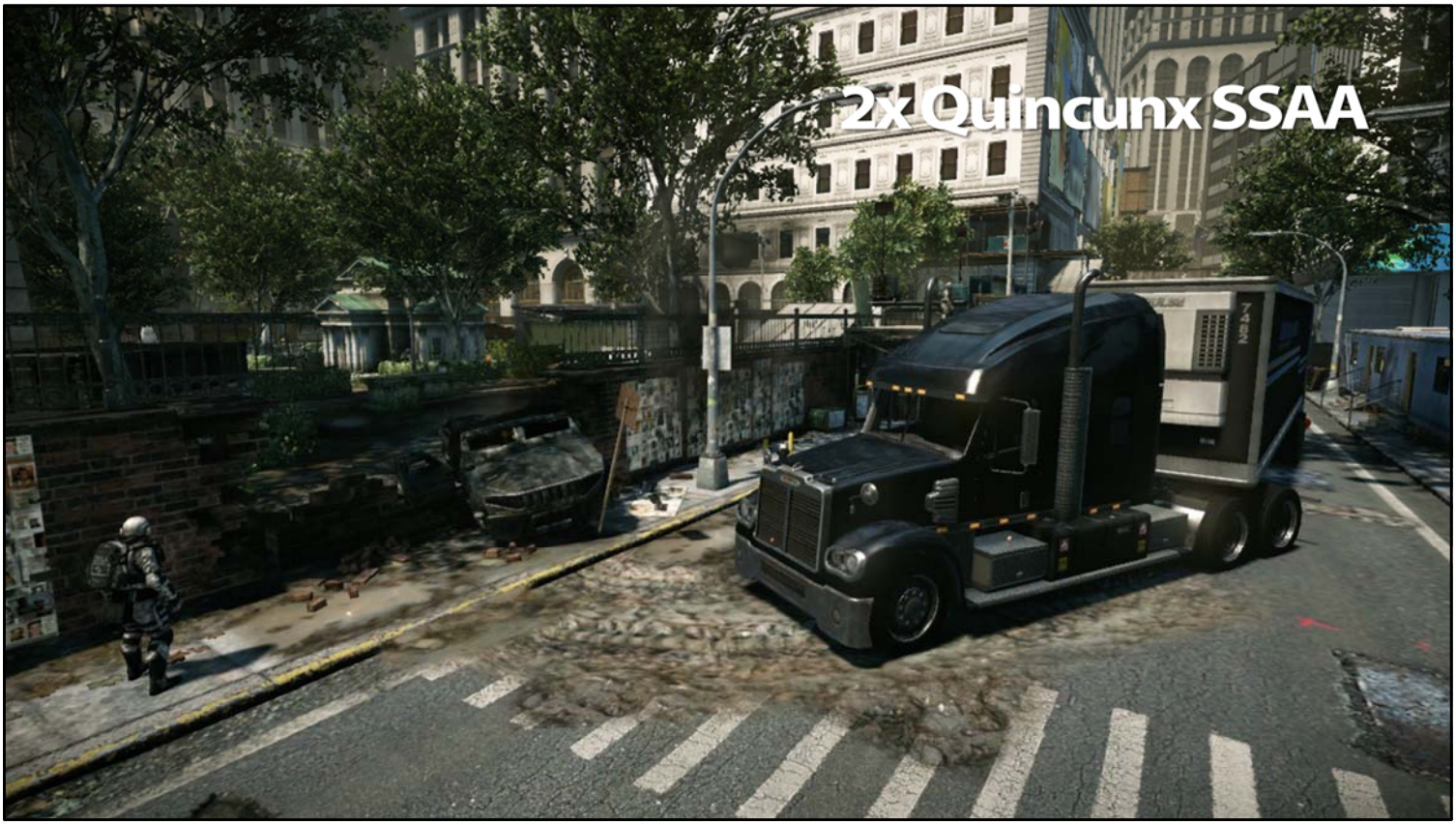
- Not temporally stable
  - No AA on disocluded regions
  - Input signal changes (color/lighting), no robust solution yet
- Alpha blending problematic
  - Withouth OIT, only possible to handle correctly for first hit
  - Additional overhead
- Multi-GPU
  - Additional frame latency to address
  - For Crysis 2, we switched to Nvidia's FXAA when in MGPU
    - Schimering was again, biggest complain from MGPU users

Future Work

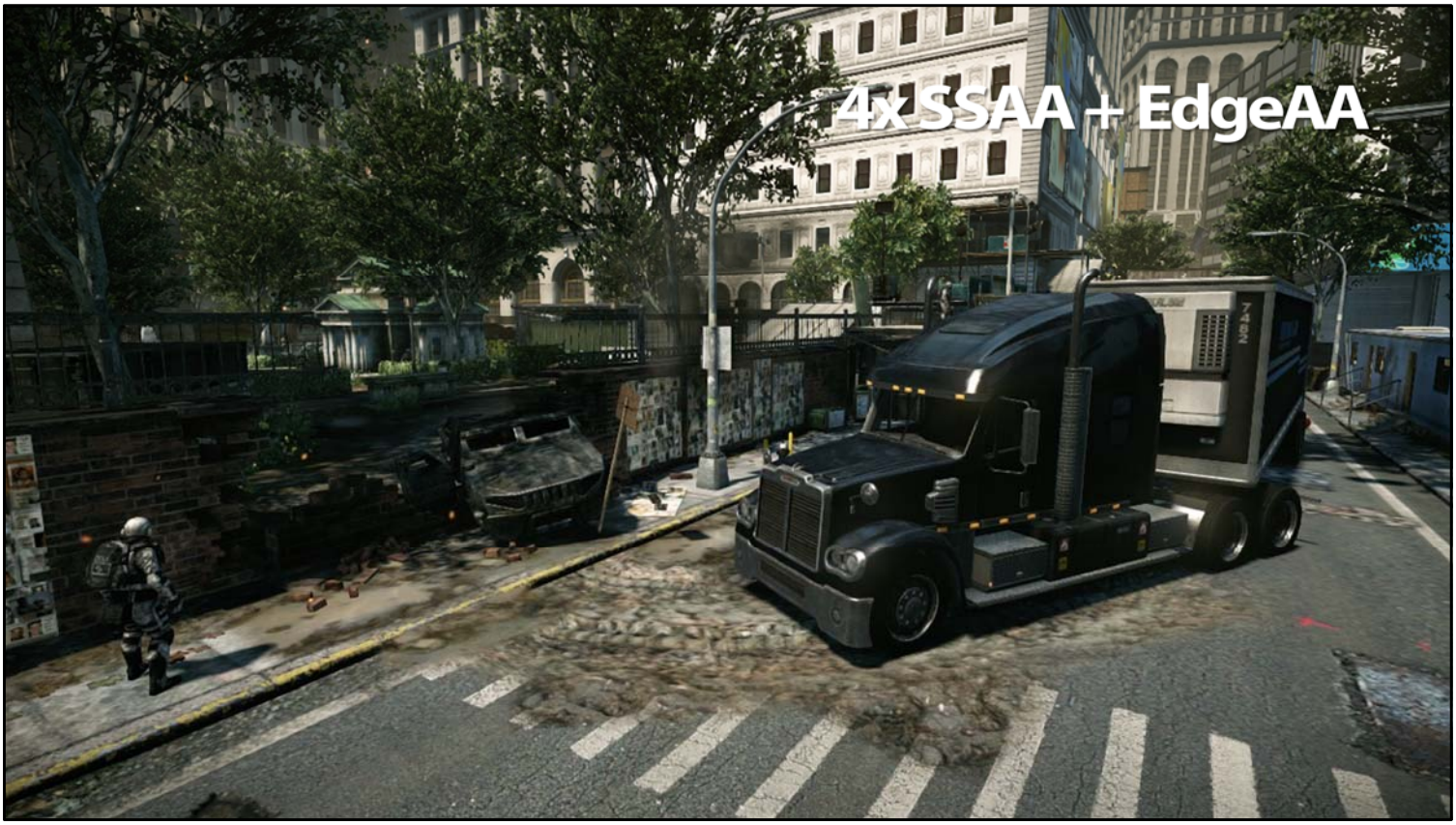
- SSAA combo with post processed AA
  - Maybe similarly to DLAA: horizontal/vertical edges, blend taps
    - This means at least 4 additional taps
  - AA on disocluded regions


No AA


2x SSAA


2x Quincunx SSAA


4x SSAA

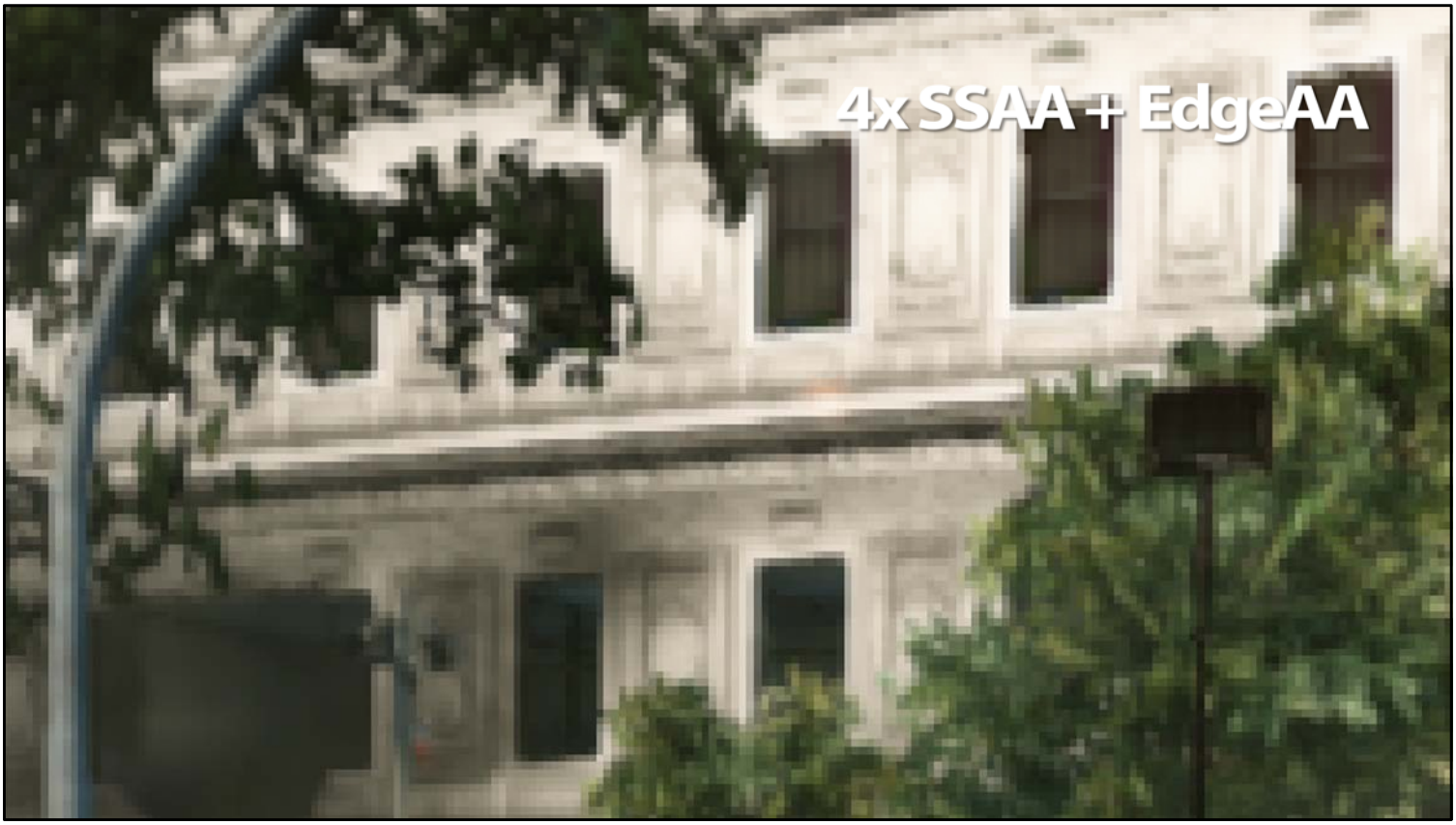

4x SSAA + EdgeAA

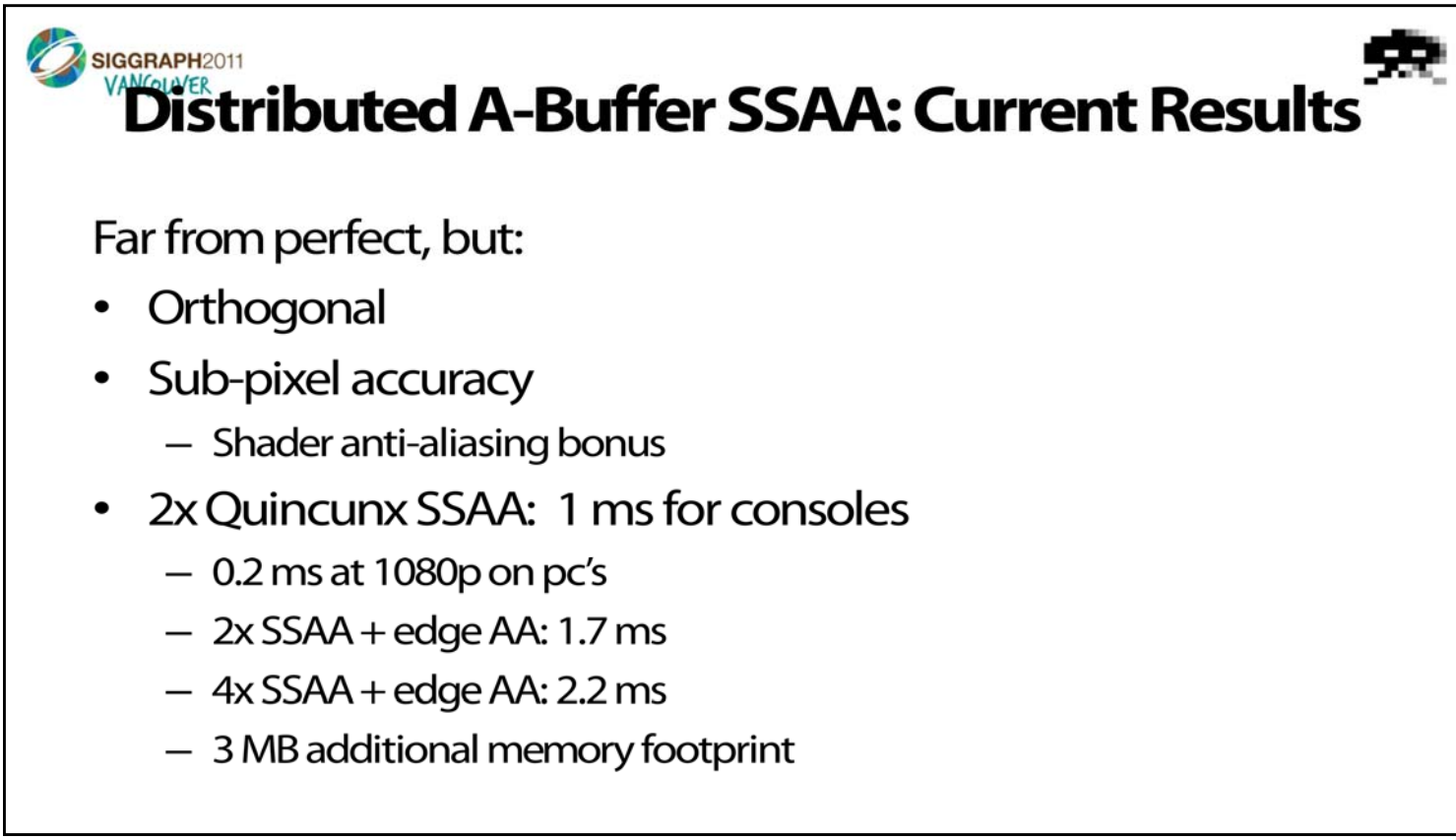

No AA


2x SSAA


2x Quincunx SSAA


4x SSAA


4x SSAA + EdgeAA



Missing pretty pictures

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- Jorge Jimenez, Diego Guitierrez, Naty Hoffman

- And to the entire Crytek team

Further Readings

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Questions ?

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Bonus: Marketing Screenshots

If time allows

Bonus: Marketing Screenshots

- Always some trickery
  - On CryENGINE 2 rendered multiple tiles at big resolutions and downsampled to get SSAA
- On CryENGINE 3 distributed SSAA with many samples
  - Random sub-pixel jitter
  - Almost perfect SSAA
  - All Crysis 2 marketing shots used this variation