DirectX 11 Rendering & NVIDIA GameWorks in Batman: Arkham Origins

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WB GAMES MONTRÉAL

GPU TECHNOLOGY CONFERENCE

AGENDA

PREFACE

→ Motivations

PART 1–DEFORMABLE SNOW

Excerpts from GDC 2014

→ Novel technique for surfaces covered with fallen deformable snow

→ Enhanced for PC using DX11

PART 2–CHROMA SUBSAMPLING

→ Various pipeline enhancements

PART 3–NVIDIA GAMEWORKS

→ Enhanced game features using NVIDIA GameWorks






NVIDIA THE WAY IT'S MEANT TO BE PLAYED

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[Barré-Brisebois 2014]

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PART 1
DEFORMABLE SNOW RENDERING

Deformable Snow Surfaces

ENHANCE THE WORLD WITH DYNAMICS OF DEFORMABLE SNOW

- THREE REQUIREMENTS:
  1. **Iconic visuals** of deformable snow
  2. **Organic deformation** from walking, falling, sliding, fighting and more
  3. **Low memory usage and low performance cost** for an open world game

[Barré-Brisebois 2014]

Iconic & Organic Deformable Snow

From Google Images - http://bit.ly/M7T9kV (footsteps in snow, left) and http://bit.ly/M7TbJB (snow angel, right)

[Barré-Brisebois 2014]

Previous Work?

[ST-AMOUR 2013] (ASSASSIN'S CREED 3)
[EDWARDS 2012] (JOURNEY)

- RAYCAST ON A TERRAIN / MODIFY TERRAIN MESH.
  - We don't have terrain. We have rooftops and streets.
  - Besides, we don't want to add raycasts.

- REQUIRES VARIABLE TRIANGLE DENSITY FOR VISUALLY CONVINCING VERTEX DISPLACEMENT IN ALL CASES
  - PC DX11 with tessellation is great… but what about consoles?

[Barré-Brisebois 2014]

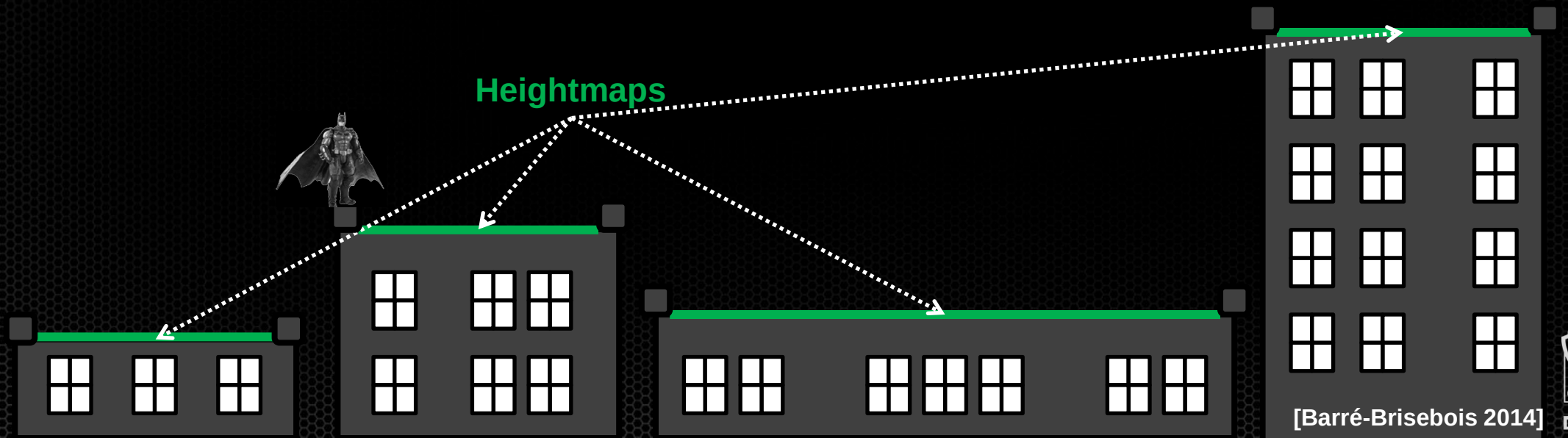
Our Approach (1/)

- GENERATE DISPLACEMENT HEIGHTMAPS AT RUNTIME
  - Snow deformation is a semi-low frequency detail effect
  - Cheap approximation works with **footsteps & more**
  - Great performance, and low memory usage
- CONSOLES: VIRTUAL DISPLACEMENT VIA RELIEF MAPPING
  - Minimal taps. No “swimming”
  - Independent of triangle density
- PC: DIRECTX 11 VERSION WITH TESSELLATION

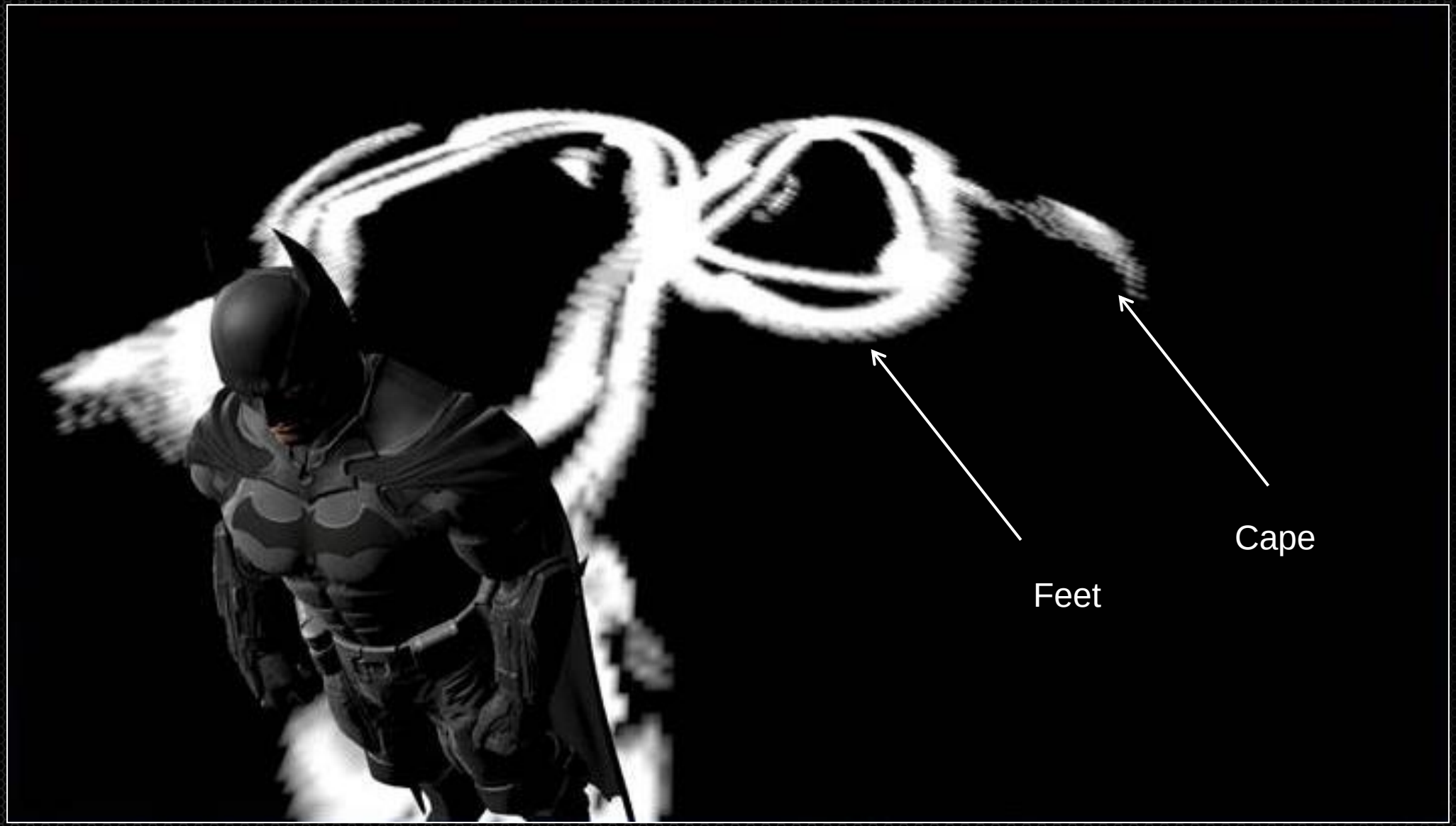
[Barré-Brisebois 2014]

Our Approach (2/)

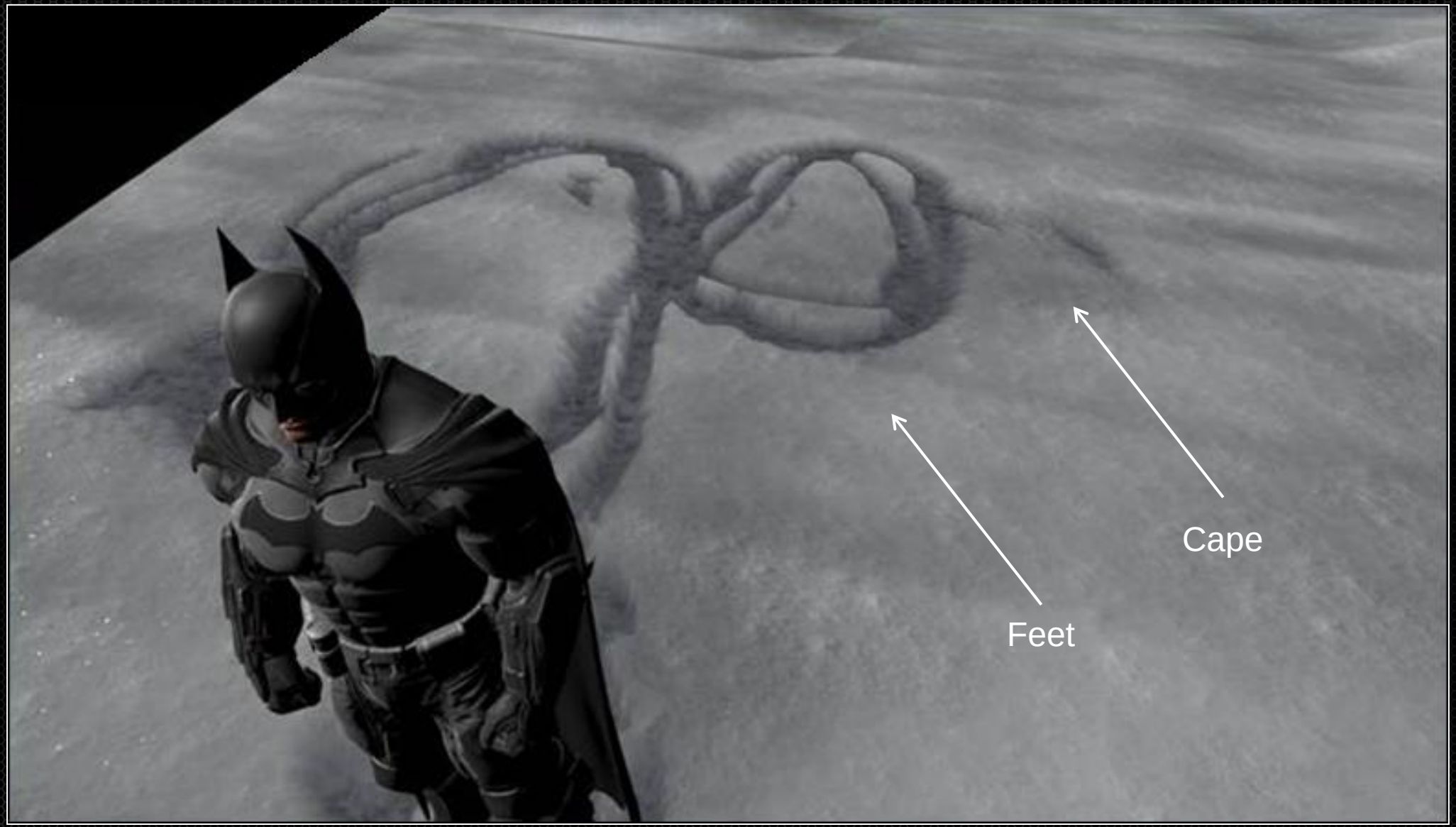
- GOTHAM HAS MANY ROOFTOPS AND STREETS
  - Dynamically alloc/dealloc heightmaps based on size, player/AIs and visibility



[Barré-Brisebois 2014]



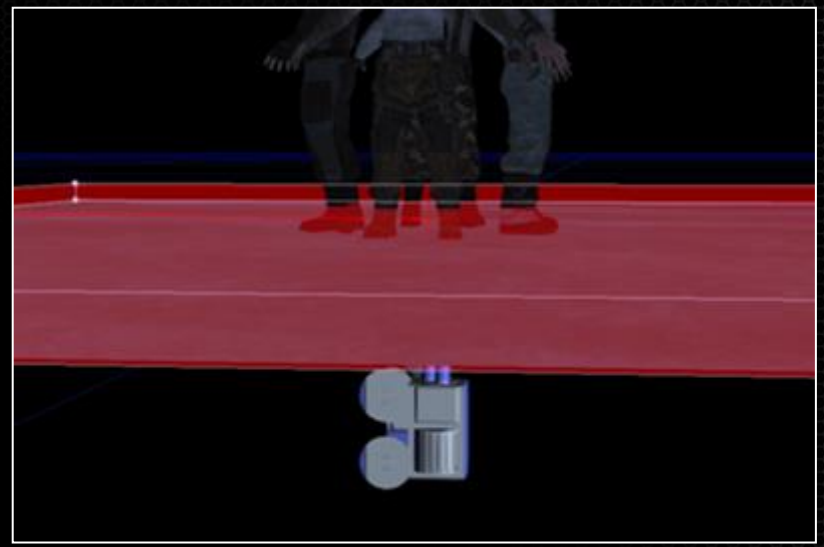
[Barré-Brisebois 2014]



[Barré-Brisebois 2014]

Generating the Heightmap ?

- RENDER SNOW-AFFECTING OBJECTS LOOKING FROM UNDER THE SURFACE USING AN ANKLE-HIGH ORTHOGONAL FRUSTUM
  1. Clear to black
  2. Render actors in white
  3. Filter and accumulate (ping/pong) in a texture



- ANYTHING IN THAT ZONE WILL AFFECT THE HEIGHTMAP
  1. Feet, hands
  2. Sliding, throwing a thug to the ground…

[Barré-Brisebois 2014]

Ankle-high Orthogonal Frustum

[Barré-Brisebois 2014]

[Barré-Brisebois 2014]

[Barré-Brisebois 2014]

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[Barré-Brisebois 2014]

Video!

Update Loop

FOR EVERY ACTIVE* SNOW SURFACE

1. Figure out if surface-affecting object is on the surface
   - We use a quad tree look-up rather than keeping an actor list for each surface
2. Override materials on all parts
   - Simple white material
3. Render actors
4. Process/Accumulate with custom post-process chain

[Barré-Brisebois 2014]

Heightmap Accumulation & Render

- STAGE 1 – GET RESULTS & SMALL BLUR
  - 4-tap bilinear Poisson
- STAGE 2 – ADD TO EXISTING HEIGHTMAP
  - During this stage, you can also subtract a small value to the heightmap to make snow gradually replenish (since it's snowing) ☺
- STAGE 3 – SHADING

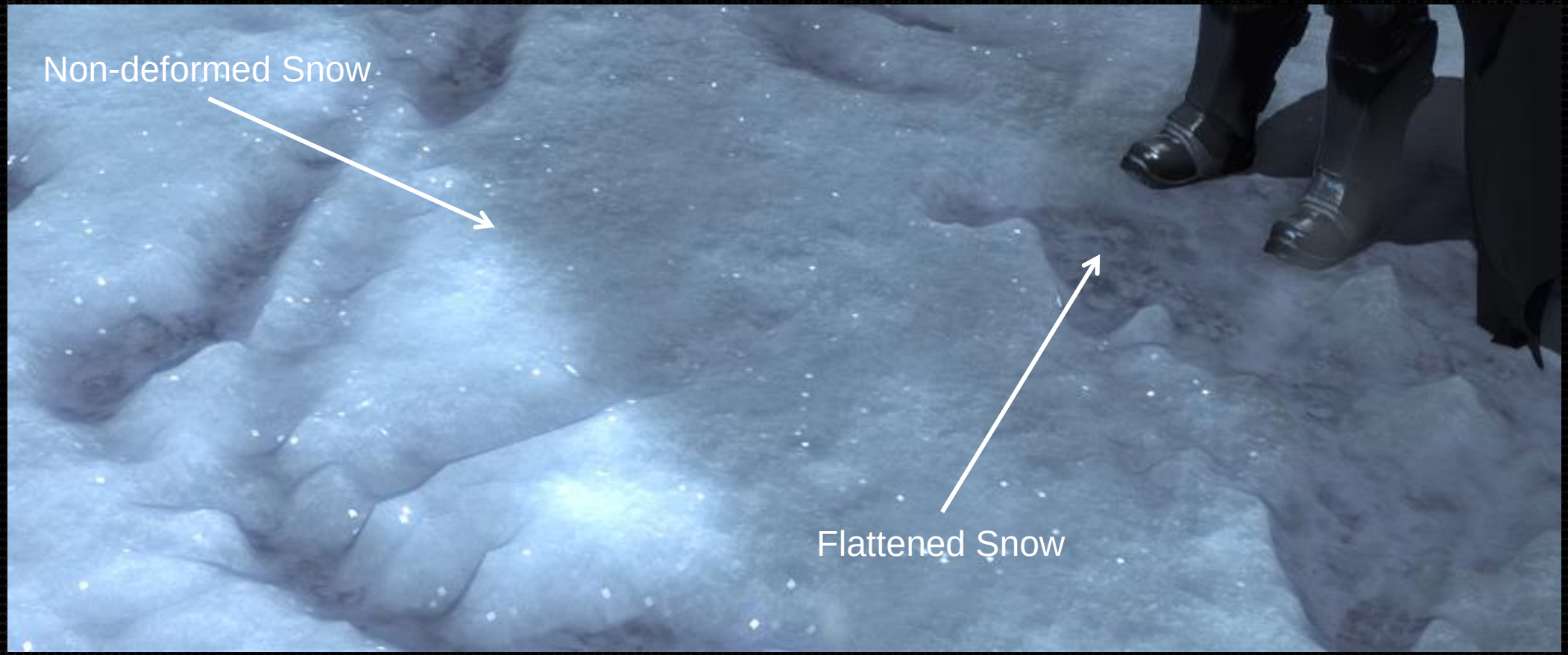
[Barré-Brisebois 2014]

Stage 3 - Shading (1/)

- SNOW SURFACES HAVE 2 MATERIAL OPTIONS:
  1. ***Basic Snow Material***
     - Active when surface is not being deformed
     - Shows new / clean / untouched snow, cheaper
  2. ***Deformable Snow Material***
     - Two stages: non-deformed or fully flattened snow
     - Non-deformed part the same as Basic Snow Material
     - Fully flattened shows rooftop tiles / concrete.
     - Blends both stages using heightmap & Relief Mapping

[Barré-Brisebois 2014]

Stage 3 - Shading (2/)



[Barré-Brisebois 2014]

Stage 3 - Shading (3/)

- BLENDING MATERIAL STAGES
  - For diffuse & spec, simple lerp
    - Also, tint diffuse with sky color in transition area to fake SSS
  - For normals, blend using ***Reoriented Normal Mapping***
    [Barré-Brisebois & Hill 2012]
    - Normals are not colors.
    - You can't lerp/overlay between directions!
    - Used in game to:
      - Blend the snow detail normal and the macro "wave" snow normal
      - Add detail normal maps everywhere

[Barré-Brisebois 2014]

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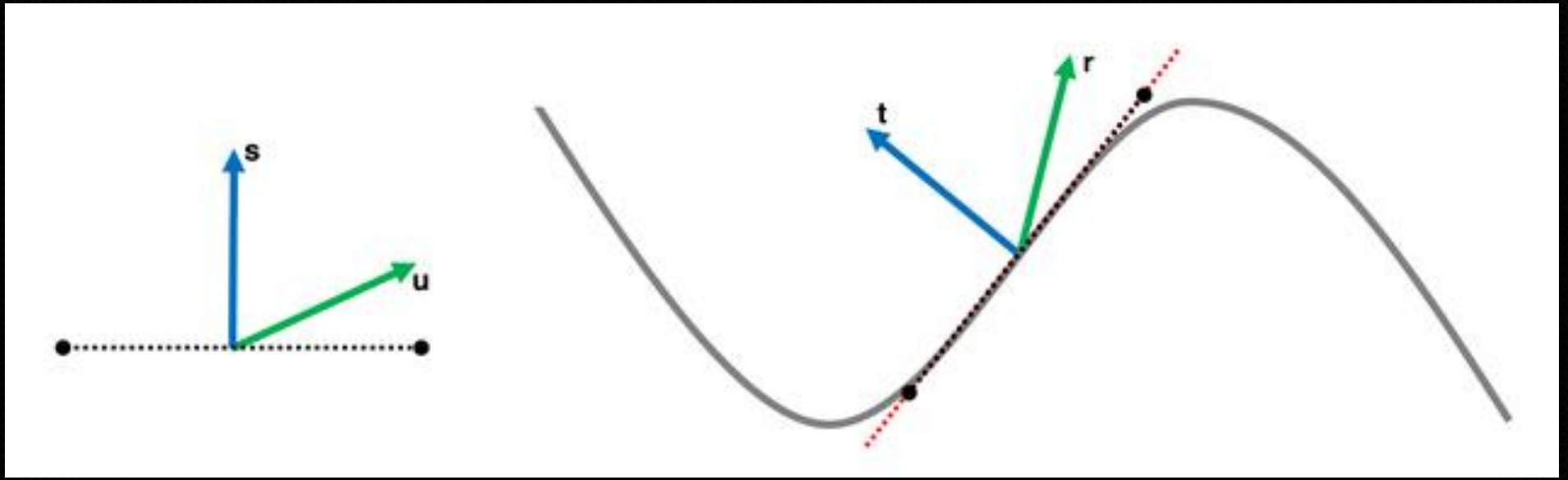
Stage 4 - Shading (4/)

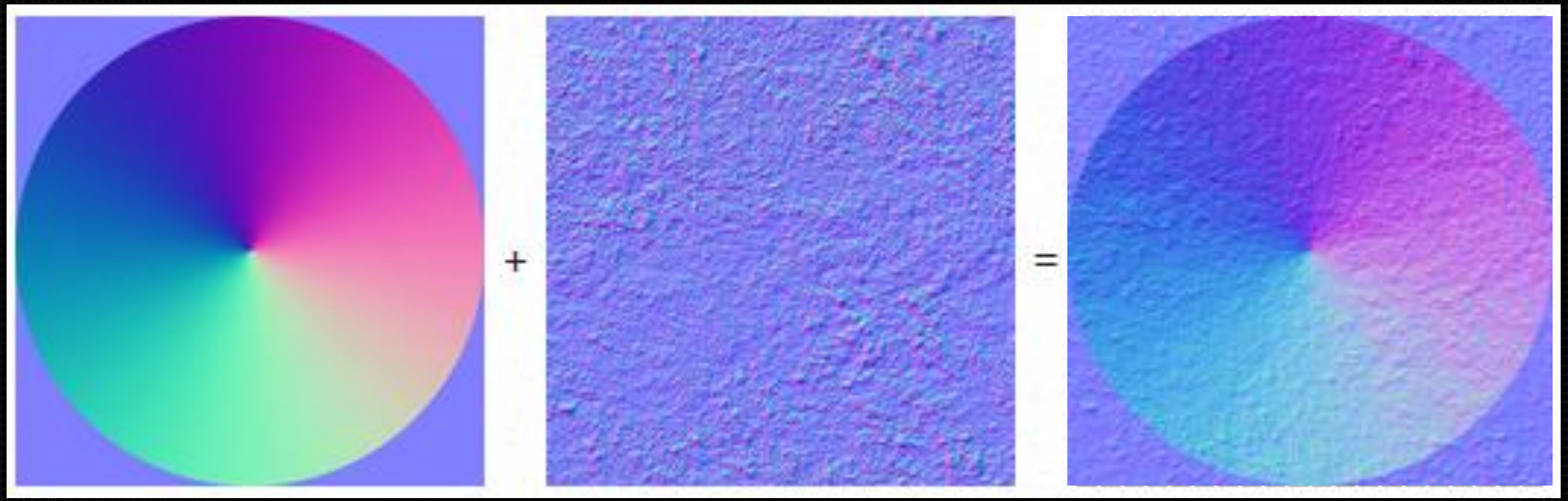
REORIENTED NORMAL MAPPING




```
float3 t  = tex2D(BaseNormal, uv) * float3(2, 2, 2) + float3(-1, -1, 0);
float3 u = tex2D(DetailNormal, uv) * float3(-2, -2, 2) + float3(1, 1, -1);
float3 r  = t * dot(t, u) / t.z – u;
```

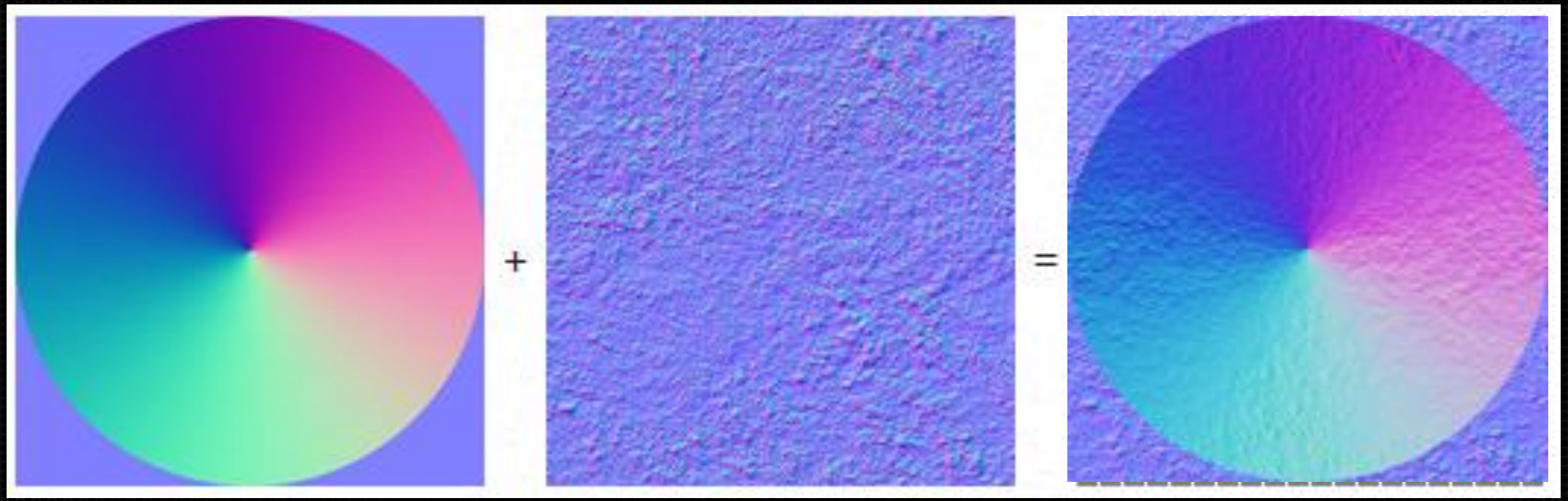
[Barré-Brisebois & Hill 2012]

LINEAR INTERPOLATION



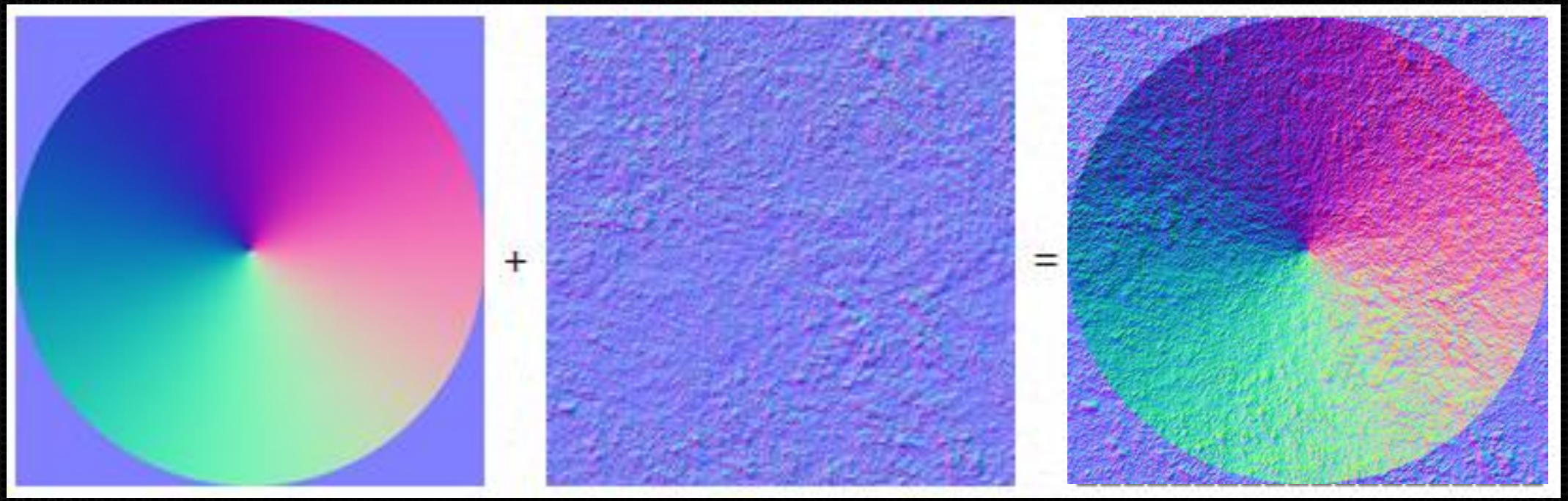
[Barré-Brisebois 2014]

OVERLAY BLEND



[Barré-Brisebois 2014]

REORIENTED NORMAL MAPPING



ADOBE, PLEASE ADD TO PHOTOSHOP!

[Barré-Brisebois & Hill 2012]

Add. Implementation Details

- SURFACE UV ALIGN WITH ORTHO FRUSTUM
  - 0-1 range, simplifies heightmap-to-displacement
- SCALED WORLD-SPACE HEIGHTMAP RES.
  - Min(512, ¼ * (SurfaceX, SurfaceY))
  - Tries to keep texels “square”
  - Doesn’t need to be high-res, looks better in lower resolutions
  - Must scale *Relief Mapping* parameters
- SPLIT RENDER & TICK OF ACTIVE SURFACES
  - Snow surface where Batman stands has priority
  - We only render 2 surfaces/frame (tweakable, distance-based)

[Barré-Brisebois 2014]

DirectX 11 With Tessellation (1/)

- DEVELOPED WITH OUR FRIENDS@NVIDIA (EVGENY MAKAROV)
- ACCURATE DISPLACEMENT BASED ON DEPTH
  - Capture the height field like a z-buffer
  - Two channels:
    - Minimum height field
    - Projected displacement
  - Allows for additive capture, smoother results and deformable snow banks! ☺
- TESSELLATED VERSION ADDS DETAILED DISPLACEMENT CALCULATED FROM THE NORMAL MAP
  - Macro deformation breaks surface uniformity

[Barré-Brisebois 2014]

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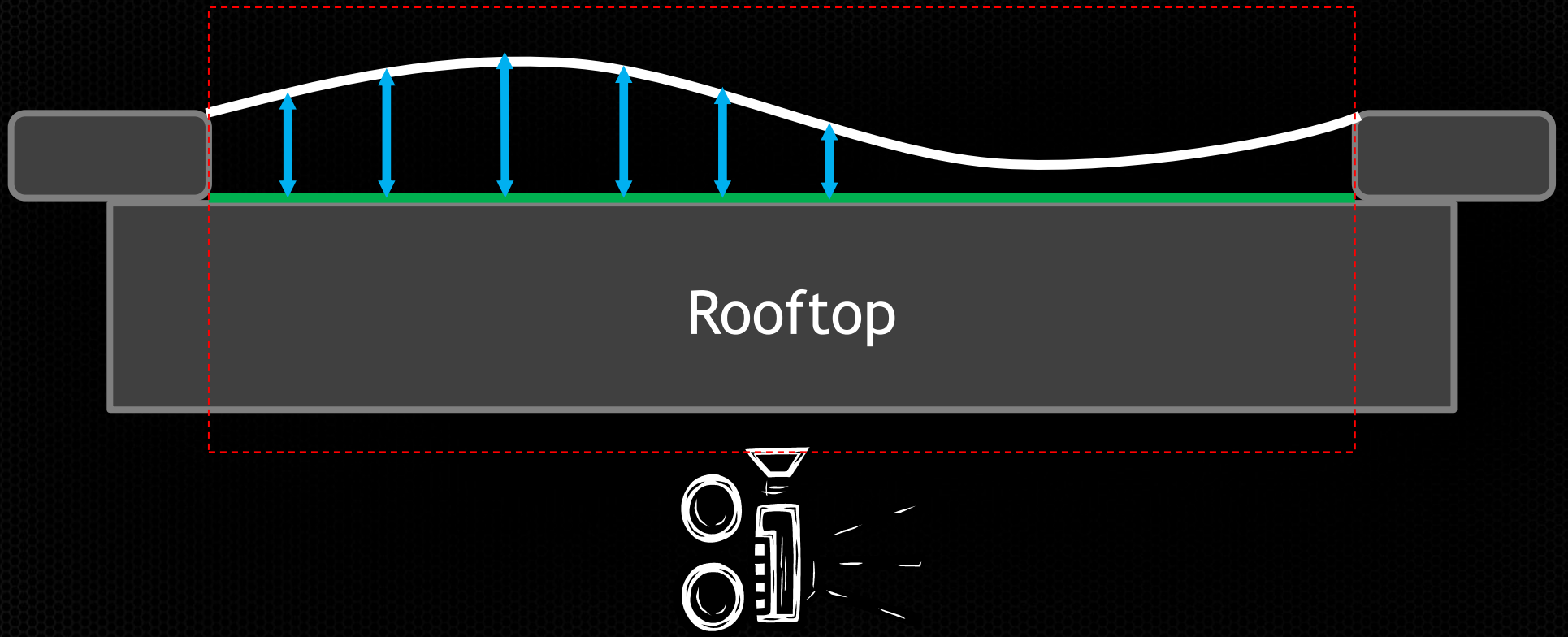
DirectX 11 With Tessellation (2/)



Orthogonal Capture Frustum

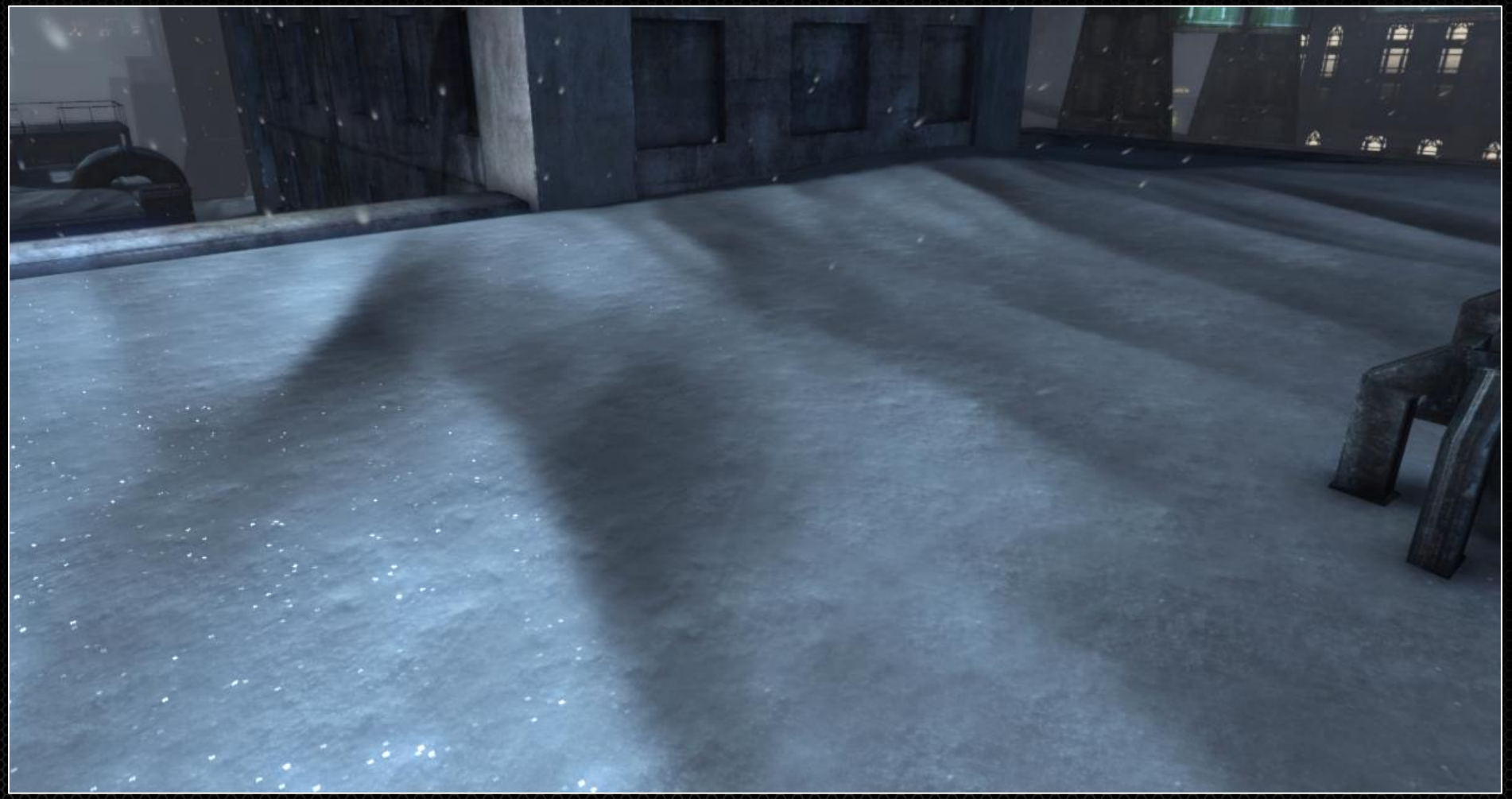
Minimum Height field

Projected Displacement

Final Surface (displaced)

[Barré-Brisebois 2014]

Without Tessellation (No Macro Deformation)



[Barré-Brisebois 2014]

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With Tessellation (Macro Deformation)

[Barré-Brisebois 2014]

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DirectX 11 With Tessellation (4/)

- RUNTIME DICING OF SNOW MESHES
- REAL GEOMETRY MEANS:
  - ***Works with Dynamic Shadows***
    - Character shadows now follows the surface and shift with the deformation
    - Self shadowing & self-shading
  - ***Works with dynamic ambient occlusion***
    - AO fills-in the trails

[Barré-Brisebois 2014]

[Barré-Brisebois 2014]

Performance & Memory

- PERFORMANCE
  - Heightmaps update < 1.0ms GPU on PS3/360
- MEMORY
  - 2 MB (360 / PS3 / WiiU)
    - Since we're using low resolution heightmaps
    - This is flexible, but sufficient for our needs since we allocate/deallocate as the player flies in the world
  - 2-4 MB (FP16 vs FP32 on PC)

[Barré-Brisebois 2014]

Caveats / Issues ?

- RELIEF-MAPPED APPROACH
  - Deformation looks great, but will never be as thick as tessellation. Replace with Parallax Occlusion Mapping?
  - Derive parametric AO from the heightmap?
- TESSELLATED APPROACH
  - When artists were working on content creation, displacement wasn't taken into account (pre-pass actors, open edges being visible, etc...)
  - Some meshes couldn't use tessellation as there were parts of geometry right under the snow, not supposed to be visible

[Barré-Brisebois 2014]

Future Endeavors…

- Save the heightmaps and reload them?
- Use this technique for other cases, such as sand, mud, etc…
- Improvements to slopes with the depth-based approach

[Barré-Brisebois 2014]

PART 2
CHROMA SUBSAMPLING IMPROVEMENTS

Chroma Subsampling? (1/)

- ARKHAM ORIGINS' WORLD IS DOUBLE THE SIZE OF ARKHAM CITY
  - More data, but same amount of storage…
- USE CHROMA SUBSAMPLING

  Chroma subsampling *is the practice of encoding images by implementing less resolution for chroma information than for luma information, taking advantage of the human visual system's lower acuity for color differences than for luminance.* [1]

- THIS IS NOT NEW…
  - Broadcasting
  - Oh, and in games too! [White and Penty 2009]

[1] http://en.wikipedia.org/wiki/Chroma_subsampling

Chroma Subsampling? (2/)

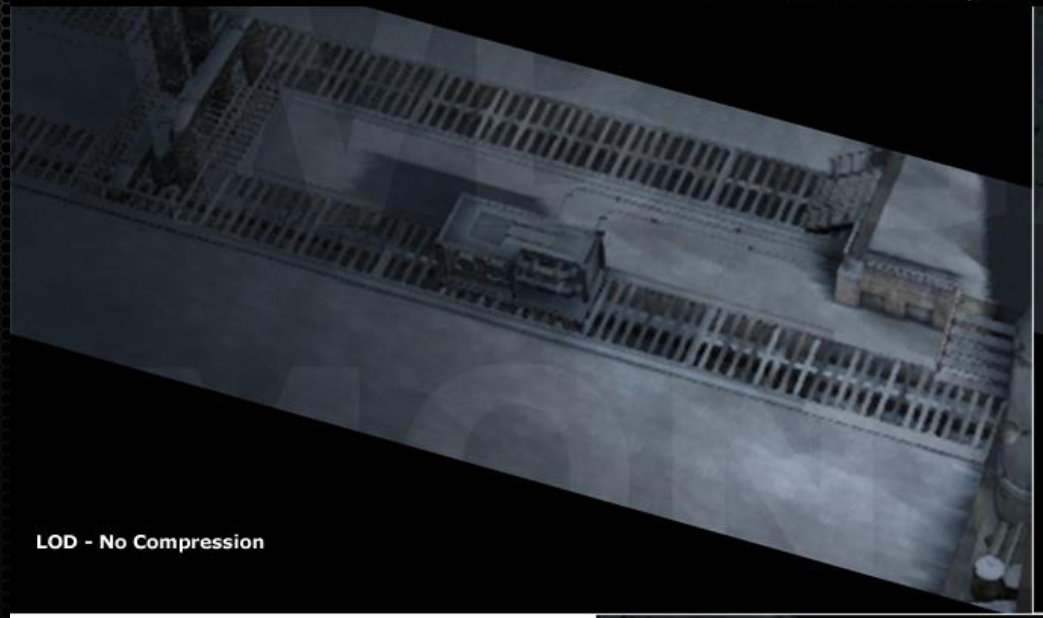
N → Your art director's tolerance to compression (2, 4…) ☺

Chroma Subsampling? (3/)

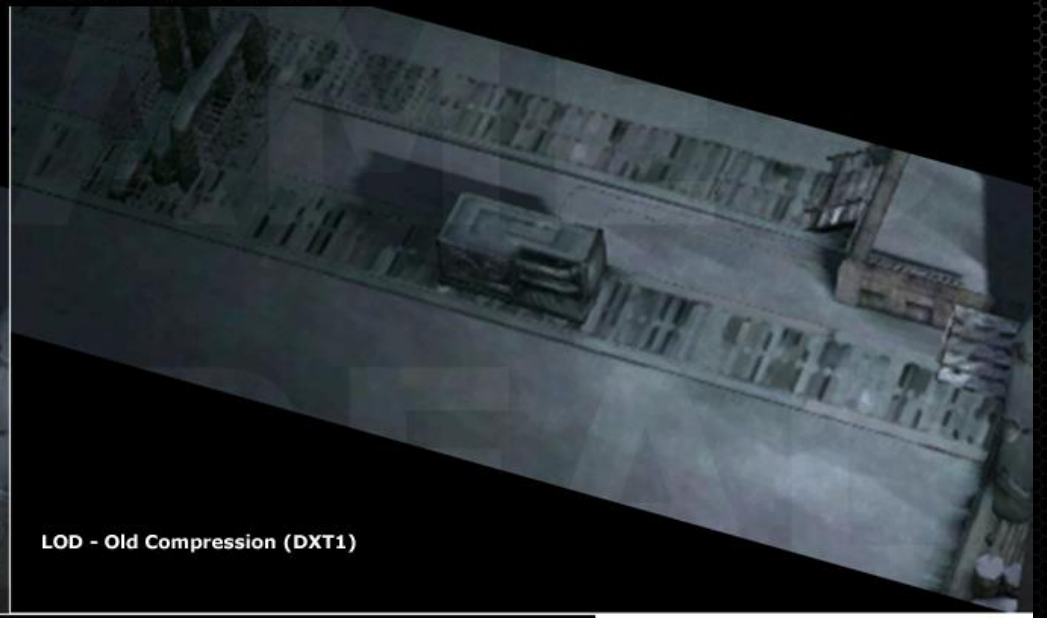
- USED EXTENSIVELY ON LIGHTMAPS
  - Unlike [White and Penty 2009], we used YCoCg
  - Pack two luma textures together instead of 3
    - Blue channel pollution from DXT1 compression is too significant in our case when packing 3
    - Improve quality by setting B channel to 0 and/or set the DXT weights
      - (R=0.5, G=0.5, B=0)

$$\begin{bmatrix} Y \\ C_o \\ C_g \end{bmatrix} = \begin{bmatrix} 1/4 & 1/2 & 1/4 \\ 1/2 & 0 & -1/2 \\ -1/4 & 1/2 & -1/4 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

- USED EXTENSIVELY ON LODS
  - We have 2 (NEAR & FAR) levels of LODs, let's compress more!
- OVERALL BETTER COMPRESSION RESULTS OVER VANILLA DXT1 LIGHTMAPS & LODS

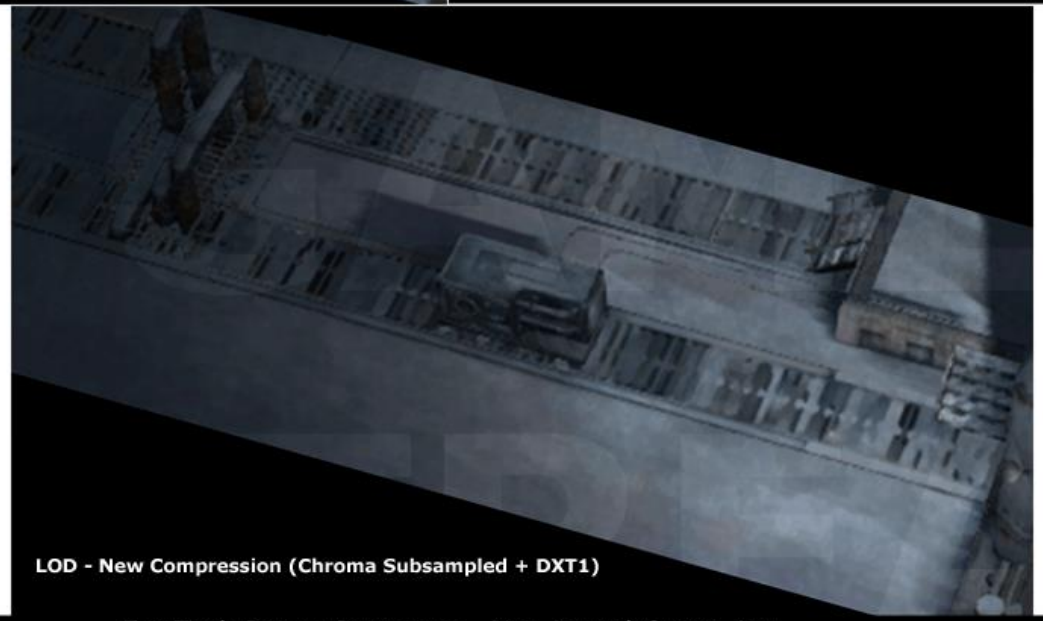


LOD - No Compression



LOD - Old Compression (DXT1)

Image	DXT1	Chroma + DXT1
Mean absolute error	5.05	4.11
Max absolute error	164.00	134.00
Root mean squared error	11.19	8.92
Peak signal to noise ratio (dB)	27.15	29.11



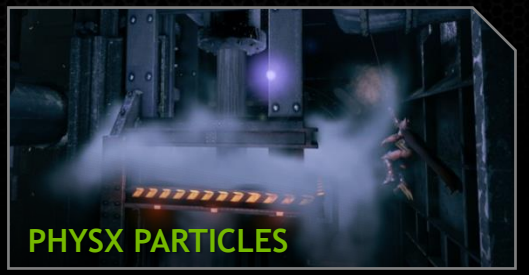
LOD - New Compression (Chroma Subsampled + DXT1)

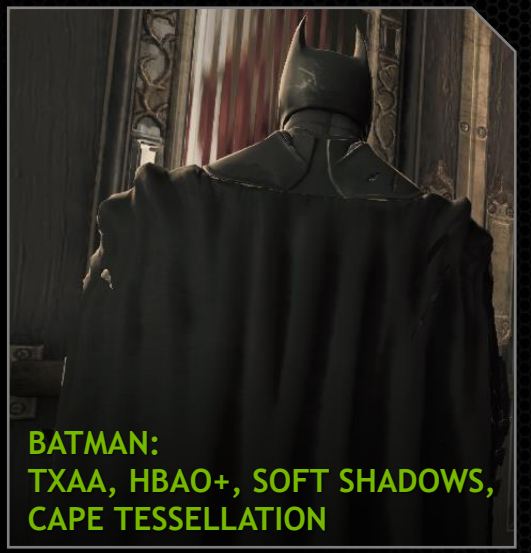
Chroma Subsampling? (4/)

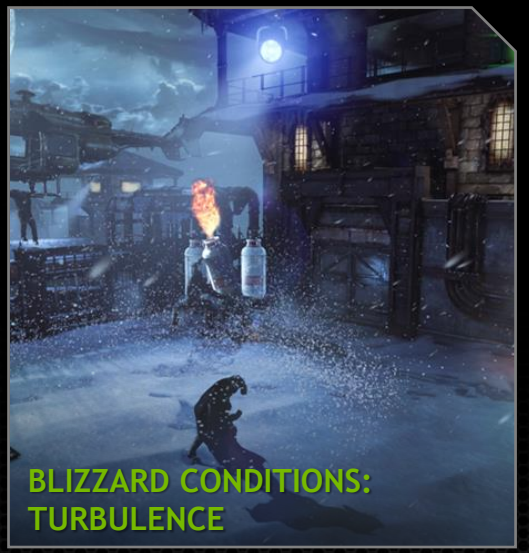
- CHROMA SUBSAMPLING CAN BE USED EXTENSIVELY…
  - We started implementing chroma frame buffer compression
  - Similar to [Mavridis & Papaioannou 2012]'s *The Compact YCoCg Frame Buffer*
  - Didn't make it into the final game ☹
  - Nonetheless…
- WE SHOULD ALWAYS FIND MORE OPPORTUNITIES TO COMPRESS MORE, ESPECIALLY WHEN IT MAKES "VISUALLY SENSE"!
  - Next time! ☺

PART 3
NVIDIA GAMEWORKS ENHANCEMENTS

BATMAN: ARKHAM ORIGINS
FEATURED NVIDIA TECHNOLOGY







NVIDIA THE WAY IT'S MEANT TO BE PLAYED

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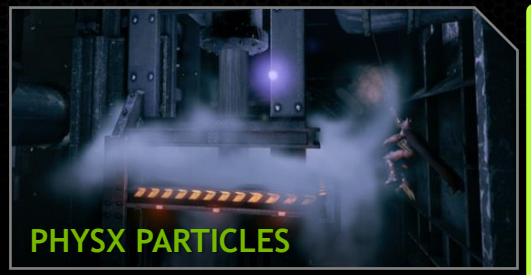
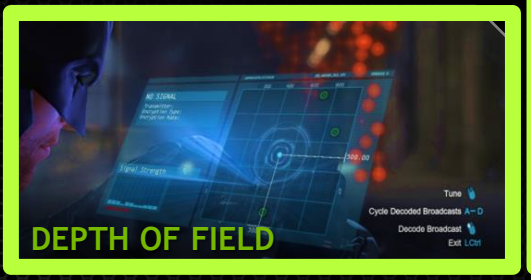
VIDEO

BATMAN: ARKHAM ORIGINS
FEATURED NVIDIA TECHNOLOGY





NVIDIA THE WAY IT'S MEANT TO BE PLAYED

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HBAO+

HBAO+

HBAO+

DEPTH OF FIELD

TURBULENCE PARTICLES

PARTICLES

PARTICLES

PARTICLES

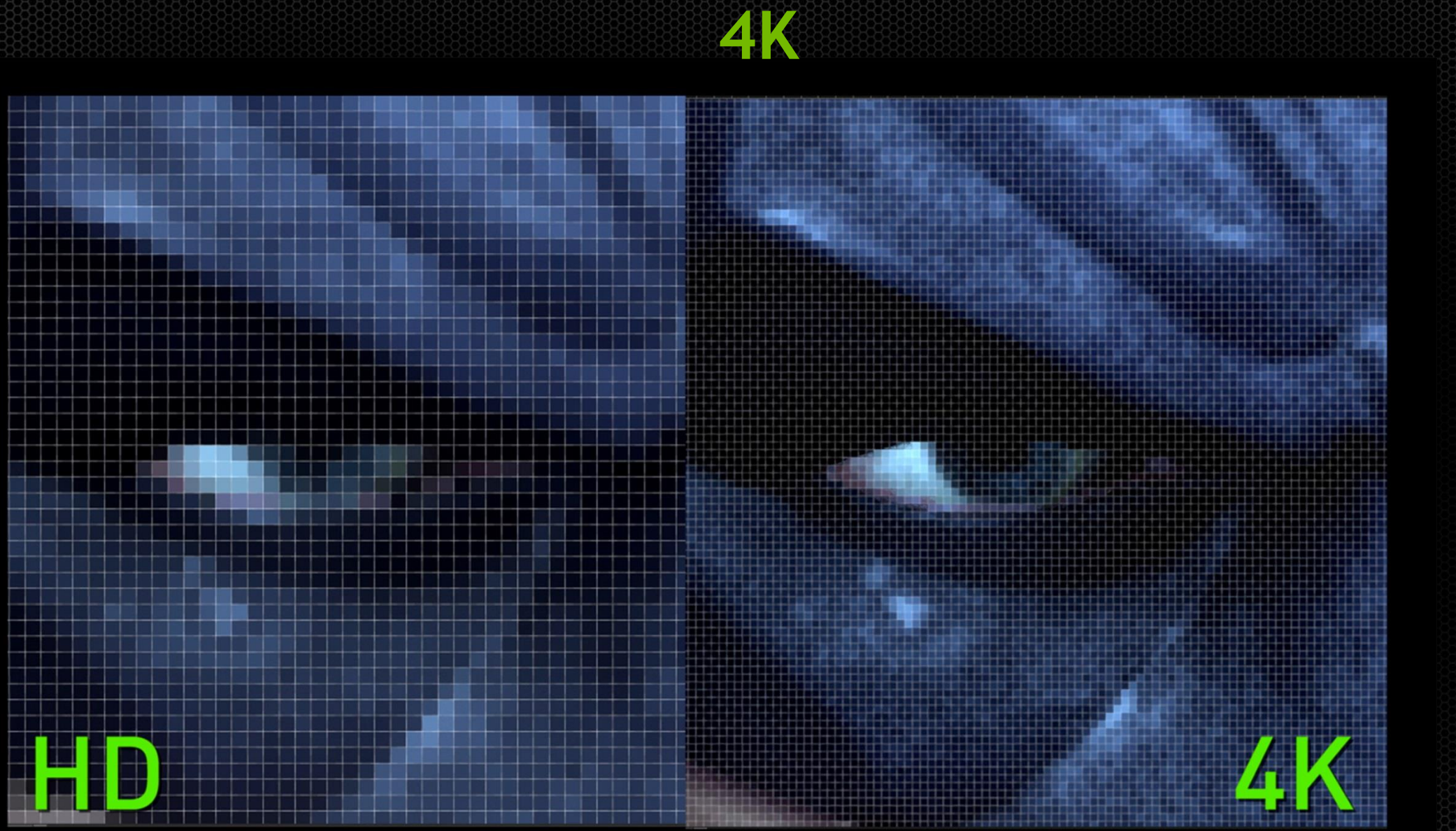
PARTICLES

PARTICLES

PARTICLE SHADOW MAPPING

CAPE TESSELLATION (1/)

CAPE TESSELLATION (2/)


4K
HD
4K

Summary

- A FAST AND LOW-MEMORY FOOTPRINT TECHNIQUE TO RENDER DEFORMABLE SNOW SURFACES
  - Adds a really nice level of interaction between players and the world
  - Depics iconic & organic visuals of deformable snow
  - A good tessellation case for your DX11 game using minimal editing and art tweaks
- CHROMA SUBSAMPLING FOR YOUR ART PIPELINE IS DEFINITELY A VENUE TO CONSIDER
- HOW WE USED NVIDIA'S GAMEWORKS TO ENHANCE THE VISUALS OF SNOW BEHIND BATMAN: ARKHAM ORIGINS

Thank You!

Érick Bilodeau
David Massicotte
Sébastien Turcotte
Jimmy Béliveau
Olivier Pomarez
Philippe Bernard
Ryan Lewis
Marc Bouchard
Jean-Noé Morissette
Pierric Gimmig
Patrick Dubuc
Reid Schneider
Maggy Larouche
Miguel Sainz
Evgeny Makarov
Jon Jansen
Louis Bavoil
Holger Gruen
Andrei Tatarinov
Andrew Burnes
Jon Greenberg
NVIDIA

Questions?

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We’re Hiring! http://www.wbgamesmontreal.com

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