Far Cry 4, Assassin's Creed Unity and War Thunder: Spicing Up PC Graphics with GameWorks

Alexandr Polischuk, Rendering Engineer, Ubisoft Kiev
Andrei Tatarinov, Senior Developer Technology Engineer, NVIDIA
Tim Tcheblokov, Senior Developer Technology Engineer, NVIDIA
Anton Yudintsev, CEO, Gaijin Entertainment

NVIDIA

Far Cry 4 and Assassin's Creed Unity: Spicing Up PC Graphics with GameWorks

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Outline

- What games are we dealing with?

- How to make these games look even better on PC?

- The Mighty Three: HBAO+, PCSS, TXAA

- Far Cry 4: Making the beasts look cute

- Far Cry 4: Illuminating Kyrat with divine light

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Far Cry 4

Far Cry 4

- Open-world action-adventure first-person shooter

- Set in Kyrat, a breathtaking, perilous and wild region of the Himalayas

- Terrain spans from lush forests to the snowcapped mountains

- Kyrat is home to abundant wildlife

- Uses Dunia Engine 2

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Set in astounding Himalayas

Player finds himself in the midst of a civil war

Absolute freedom of movement

Dangerous and deadly wildlife

Assassin's Creed Unity

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Set in Paris during French Revolution

Set in Paris during French Revolution

Open world

Variety of moves

Focus on stealth action

Cooperative mode

Making PC Versions Look Better

- PC offers extra performance to add extra features

- NVIDIA has technology that is ready to be integrated

- Experience gained while working on Assassin's Creed IV Black Flag

- Both Ubisoft and NVIDIA dedicate engineers for collaboration

NVIDIA.

What GameWorks can offer?

- We played both games and thought of what can NVIDIA GameWorks offer to make them look even better

- NVIDIA ShadowWorks and NVIDIA PostWorks are a great fit for both Far Cry 4 and Assassin's Creed Unity

- NVIDIA HairWorks and NVIDIA Godrays are a great fit for Far Cry 4

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The Mighty Three: HBAO+, PCSS, TXAA

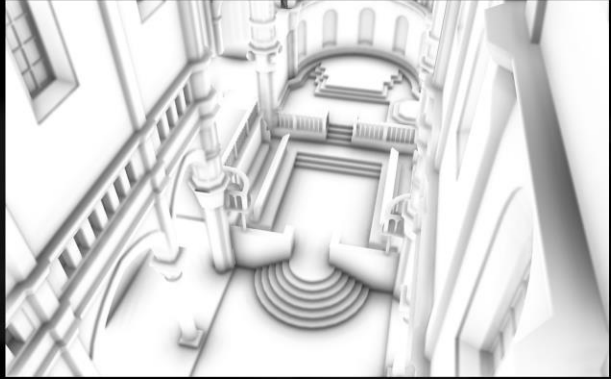NVIDIA.

NVIDIA ShadowWorks

- Consists of different technologies to provide cinematic shadows

- HBAO+

  - State of the art SSAO approach

  - Optimal performance

  - Scalable

- Advanced Soft Shadows

  - State of the art soft shadows

  - Support for cascaded shadow maps

  - Simple, but powerful interface

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Horizon-Based Ambient Occlusion+

- State of the art SSAO approach

- Optimal performance

- Scalable

No AO

Default

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HBAO+

SSBC

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HBAO+

Tuning HBAO+

Radius
- Size of HBAO kernel

Bias
- Hides low-tessellation artifacts

Exponent
- Occlusion fall-off

Detail occlusion
- Weight of high-frequency occlusion component

Coarse occlusion
- Weight of low-frequency occlusion component

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Advanced Soft Shadows

- State of the art soft shadows

- Based on Percentage Closer Soft Shadows (PCSS)

- Support for cascaded shadow maps

- Simple, but powerful interface

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Advanced Soft Shadows

Tuning Advanced Soft Shadows

- Light size
- Maximum threshold
- Minimal percentage
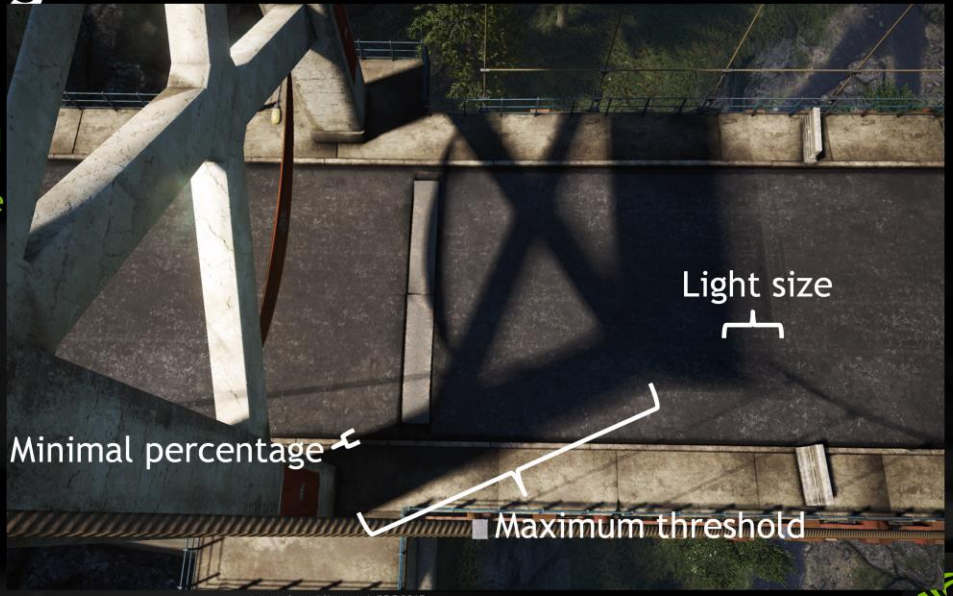- Blend percent
- Border percent

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Tuning Advanced Soft Shadows

- Light size
- Maximum threshold
- Minimal percentage
- Blend percent
- Border percent

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Tuning Advanced Soft Shadows

- Light size
- Maximum threshold
- Minimal percentage
- Blend percent
- Border percent

PCSS Light Leaks

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Fixing Light Leaks

- Light leaks occur when light size is too big

  - PCSS kernel gets too wide and samples outside cascades

- Adjust border percent to limit the kernel

- If light leaks are still there, decrease light size and maximum threshold

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Advanced Soft Shadows

- PCSS shadows are softer at mornings and evenings and sharper at noon

9:00AM

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Advanced Soft Shadows

- PCSS shadows are softer at mornings and evenings and sharper at noon

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10:00AM

Advanced Soft Shadows

- PCSS shadows are softer at mornings and evenings and sharper at noon

11:00AM

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Advanced Soft Shadows

- PCSS shadows are softer at mornings and evenings and sharper at noon

12:00AM

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NVIDIA

Advanced Soft Shadows

- PCSS shadows are softer at mornings and evenings and sharper at noon

Advanced Soft Shadows

- PCSS shadows are softer at mornings and evenings and sharper at noon

2:00PM

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Advanced Soft Shadows

- PCSS shadows are softer at mornings and evenings and sharper at noon

4:00PM

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Advanced Soft Shadows

- PCSS shadows are softer at mornings and evenings and sharper at noon

5:00PM
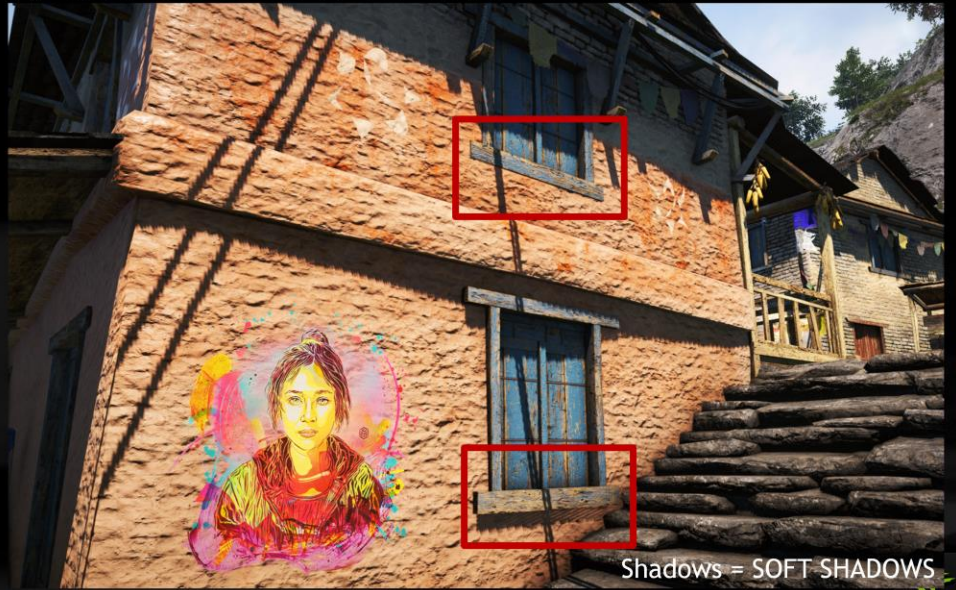
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Advanced Soft Shadows

- PCSS missed small-scale details

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Advanced Soft Shadows

- PCSS missed small-scale details

Small features are completely gone

Small features start disappearing

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Advanced Soft Shadows

- Make light size depend on daytime
  - Shadows became softer at noon

- Re-configure cascades
  - Make cascade 0 cover bigger area
  - Increase cascade resolution to 4096x4096

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Temporal Anti-Aliasing (TXAA)

- Film-style anti-aliasing technique designed specifically to reduce temporal aliasing

- Part of NVIDIA PostWorks family

No AA   8x MSAA   TXAA
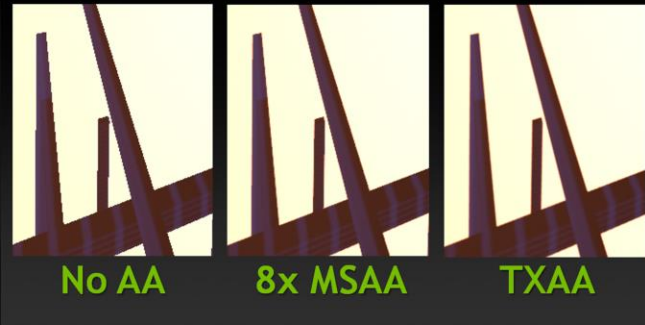
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No AA

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FXAA

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4xMSAA

TXAA

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Temporal Anti-Aliasing (TXAA)

- TXAA requires properly generated MSAA image as input

- MSAA path in the engine should work correctly

  - Use g-buffer with MSAA

  - Make shading pass support MSAA

  - Add MSAA support for post-processing techniques

Summary

- Five engineers were involved in integrating these features into both Assassin's Creed Unity and Far Cry 4
  - One man-month per effect per title on average
- Experience and knowledge from past collaborations saved us a lot of time

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Wildlife in Far Cry 4

- This is how the animals of Kyrat look in real life:

Wildlife in Far Cry 4

- This is how they look in Far Cry 4:

Wildlife in Far Cry 4

- The cutest creature in the whole game:

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Wildlife in Far Cry 4

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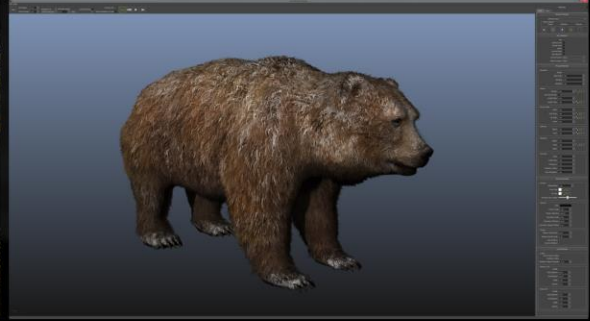

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NVIDIA HairWorks

- Enables users to simulate and render fur to provide a truly interactive game experience

- A combination of run-time library and a content creation tool

Actual game

HairWorks Viewer

HairWorks Workflow

- Get a proof-of-concept for HairWorks to be a good fit for Far Cry 4's content

- Integrate the run-time library into the engine and the level editor

- Author the HairWorks assets

- Add them to the game's content
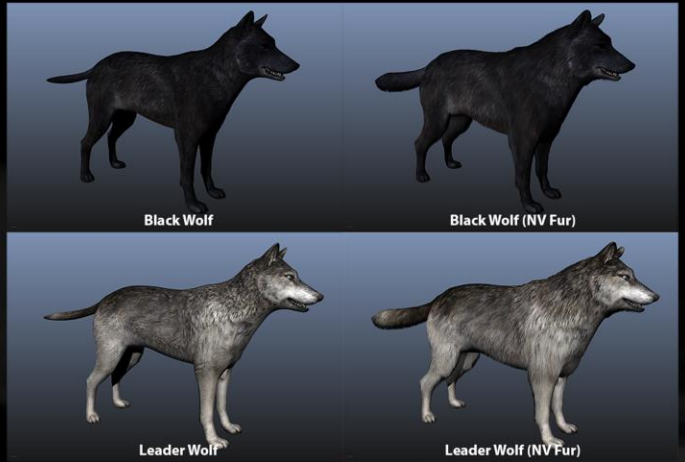
- Perform the QA pass

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Proof Of Concept

- Perform initial experiments on assets from Far Cry 4 to see if HairWorks is a good fit for the game
- Experiments were performed in the HairWorks Viewer

Black Wolf

Black Wolf (NV Fur)

Leader Wolf

Leader Wolf (NV Fur)

Proof Of Concept

- Perform initial experiments on assets from Far Cry 4 to see if HairWorks is a good fit for the game

- Experiments were performed in the HairWorks Viewer

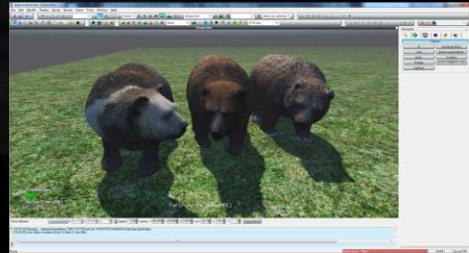Yak

Yak (NV Fur)

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Integration Into The Engine

- HairWorks run-time has a customizable rendering functionality

- HairWorks fur properties are stored in additional textures

- Far Cry 4 level editor has been modified to add new properties to support HairWorks
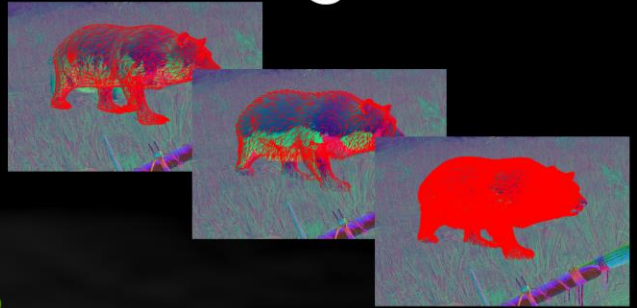
Authoring The Assets

- HairWorks Viewer was used to create the assets that were later exported to the game

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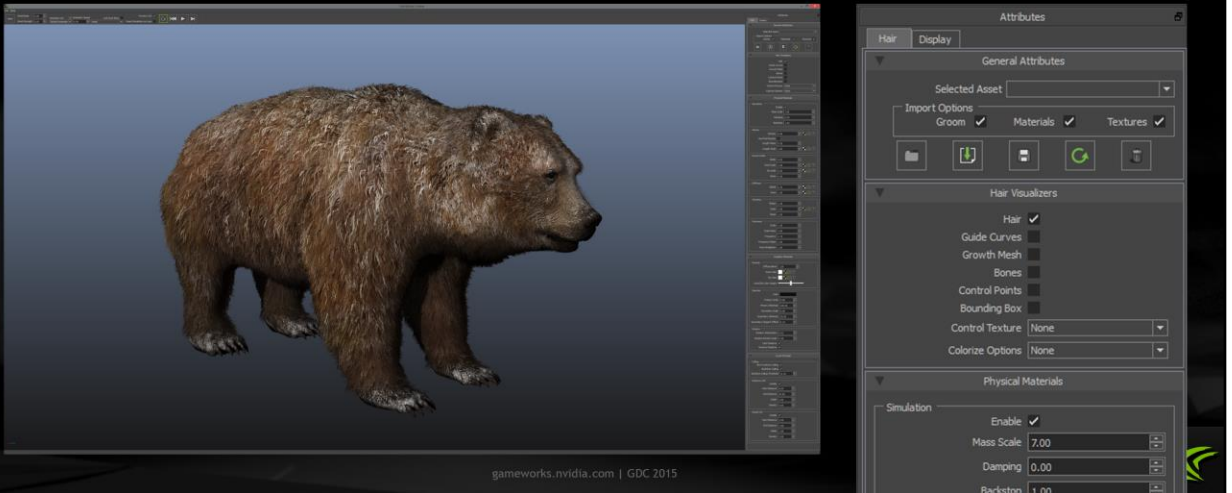
Authoring The Assets

- Two days were required to do the initial authoring of each asset
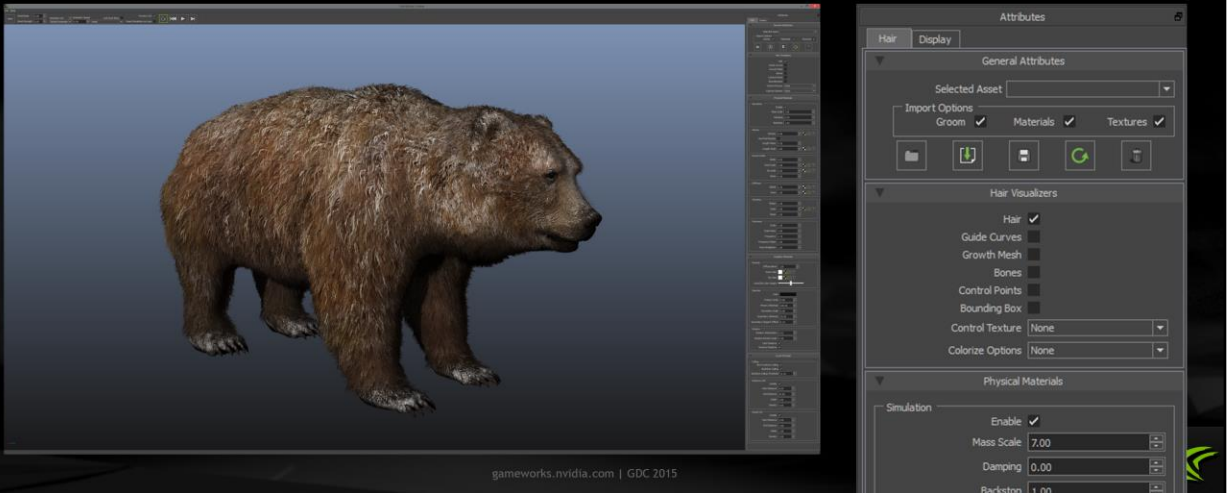
- 30 assets total were created

Preserving The Silhouettes

- Original mesh has fur "baked" into it

Preserving The Silhouettes

- Original mesh has fur "baked" into it

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Preserving The Silhouettes

- Artifacts will appear if you try to both preserve the silhouette and leave the original mesh beneath the fur

Preserving The Silhouettes

- A modified mesh should be rendered when HairWorks is active

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Preserving The Silhouettes

- A modified mesh should be rendered when HairWorks is active

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Preserving The Silhouettes

- A modified mesh should be rendered when HairWorks is active

Shading

- In Far Cry 4, we rely on Dunia rendering mechanics to perform shading
- Custom material is used
- HairWorks parameters are stored in g-buffer

Diffuse color, compressed

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Shading

Normals

- In Far Cry 4, we rely on Dunia rendering mechanics to perform shading
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Shading

- In Far Cry 4, we rely on Dunia rendering mechanics to perform shading
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Specular power and scale

NVIDIA.

Shading

- In Far Cry 4, we rely on Dunia rendering mechanics to perform shading
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- HairWorks parameters are stored in g-buffer

HairWorks Fur tangents

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Shading

- In Far Cry 4, we rely on Dunia rendering mechanics to perform shading
- Custom material is used
- HairWorks parameters are stored in g-buffer

Result of deferred shading

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Anti-aliasing

- HairWorks generates a lot of tiny fur springs

- Shimmering can be visible on fur

No AA applied

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Anti-aliasing

- Best solution is to render HairWorks fur in a separate, anti-aliasing enabled pass

- In Far Cry 4 fur is rendered in the main pass and relies on global anti-aliasing

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Anti-aliasing

- Far Cry 4 relies on global anti-aliasing settings to fight shimmering

No AA applied

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Anti-aliasing

- Far Cry 4 relies on global anti-aliasing settings to fight shimmering

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NVIDIA.

Anti-aliasing

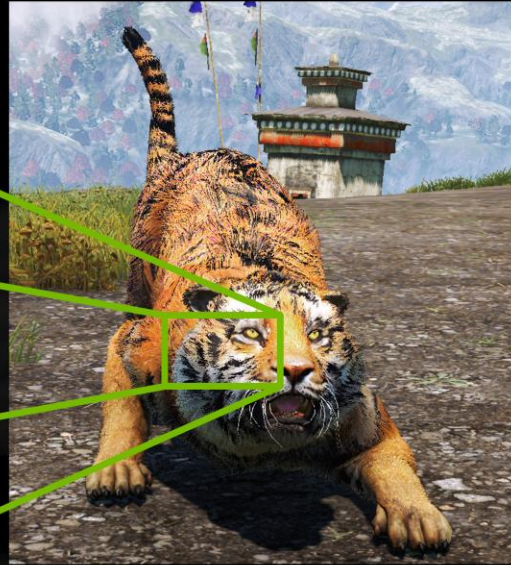- Far Cry 4 relies on global anti-aliasing
  settings to fight shimmering
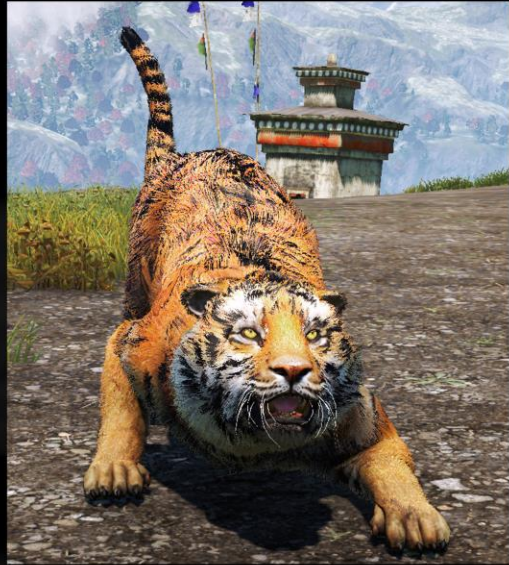
No AA applied

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Anti-aliasing
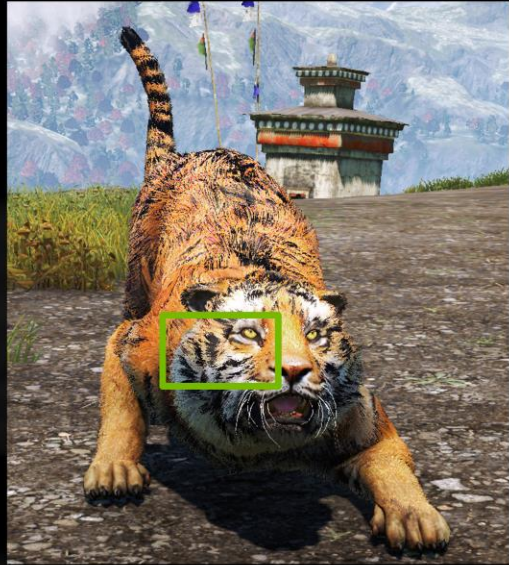
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4xMSAA
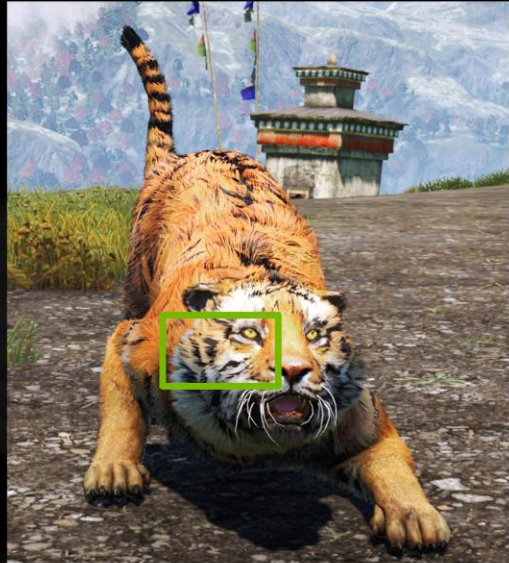
NVIDIA.

Summary

- The animals of Kyrat now look even more realistic

- One man-year and three engineers were needed to add this feature

  - One software engineer from Ubisoft

  - Two technical artists from NVIDIA

- 30 assets were created total

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Summary

- The animals of Kyrat now look even more realistic
- One man-year and three engineers were needed to add this feature
    - One software engineer from Ubisoft
    - Two technical artists from NVIDIA
- 30 assets were created total

- Most of these cuties are just too deadly!

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Far Cry 4:
Illuminating Kyrat With Divine Light

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OFF ENHANCED GODRAYS

Add Some Color!

- First integration of Godrays used the in-game color of smoke

Add Some Color!

- Using the sun color showed the best results

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Finding The Balance

- The scene looks completely fogged
- In fact, it is just godrays adding too much density
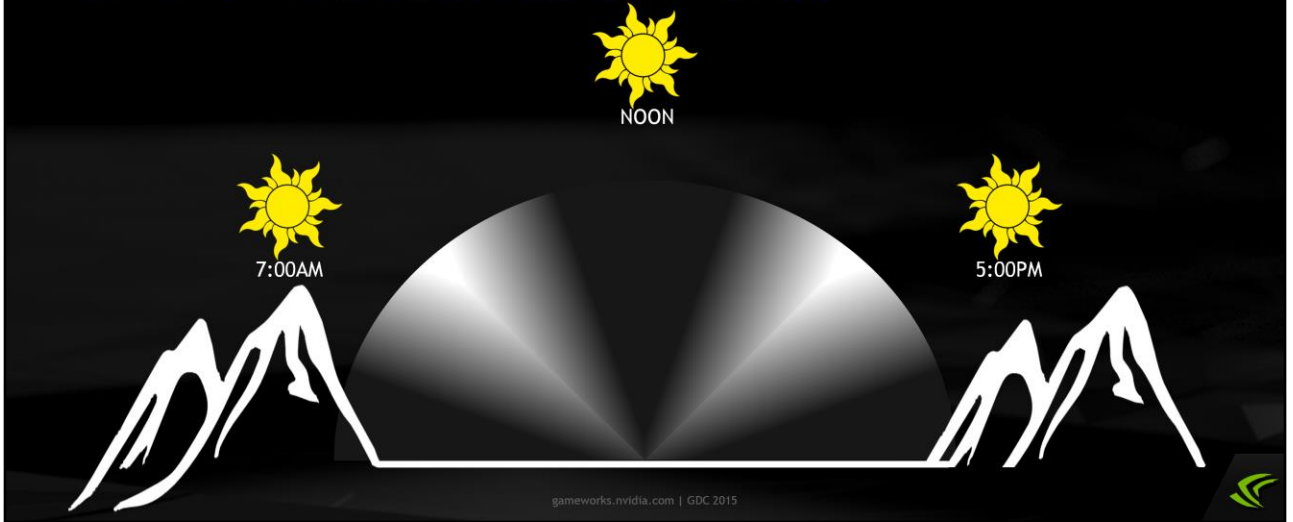
Summary

"This is a very exciting feature. Above all, this one makes a big difference in image quality that is noticeable throughout the game. The drastic changes between turning it on and off can totally transform scenes in Far Cry 4."

HardOCP

- One man-month and one engineer were needed to add this feature
  - One software engineer from NVIDIA
  - One week to perform a basic integration
  - Three weeks to tune the effect and fix artifacts

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Overall Summary

- Five effects integrated into Far Cry 4

- Three effects integrated into Assassin's Creed Unity

- Active phase of engagement took six months

- Seven engineers from Ubisoft Kiev and six engineers from NVIDIA involved

Special Thanks To:

NVIDIA:

- Dane Johnston
- Johnny Costello
- Tim Tcheblokov
- Oleg Arutyunyan
- Alexey Barkovoy
- Tae-Yong Kim
- Chad Vivoli

Ubisoft Kiev:

- Sam Kovalev
- Roman Bobel
- Mikhail Kravets
- Artem Kandinsky
- Dmitry Rozovik
- Artem Kotsiuba
- Anton Remezenko

NVIDIA.

Thanks!

NVIDIA.

War Thunder: Spicing Up PC Graphics with GameWorks

Tim Tcheblokov, Senior Developer Technology Engineer, NVIDIA
Anton Yudintsev, CEO, Gaijin Entertainment

War Thunder

- Ground and Air forces combat simulator

  - Tank mode: Shooter-like level of details

  - Features/detail size of 2-3cm

War Thunder

- Destroyed by tank, revenge with bomber!

  - Air combat simulator level of details

  - Realistic LOS, up to 160 km

  - Features/detail size of several kilometers

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Anton introducing War Thunder and its nature

Anton talking

30% of War Thunder users have single core CPUs!

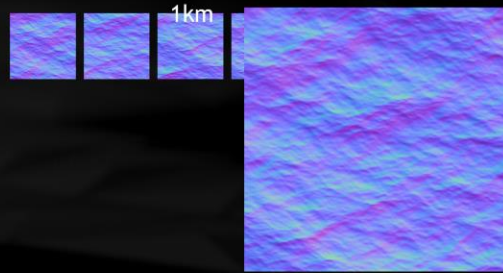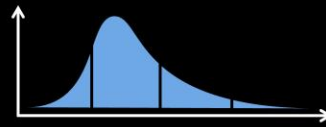The picture from War Thunder with WaveWorks integrated

Anton talking

30% of War Thunder users have single core CPUs!

The picture from War Thunder with WaveWorks integrated

What WaveWorks can offer?

Simulation in frequency domain,
iFFT to spatial domain

- No repeats!

- 3D displacements & normals

- Energy based foam

- Readbacks for physics

- Textures as results

iFFT

1km

5m
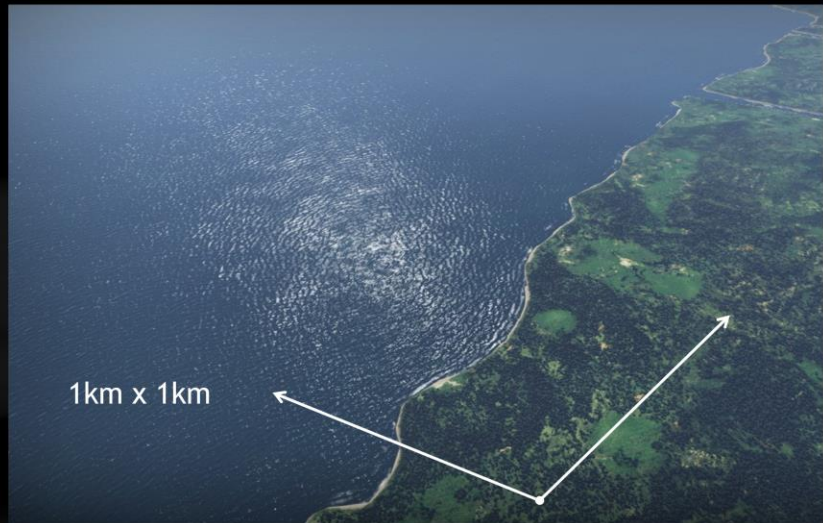
WaveWorks in War Thunder

- Rendering
  - WaveWorks brings new look to the water
  - Able to reuse some existing features
- One man-week for basic integration

Reflection
Refraction
Shadows
Atmospherics
+
Displacements
Surface foam
Bubbles
Scattering

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What we got in War thunder in terms of rendering water surfaces is mostly natural outcome of using WaveWorks.

We only needed to add extremely low resolution texture affecting the Fresnel factor to hide repeats at extreme altitudes:

WaveWorks offers large, but not infinite dynamic range of wavelengths. It is 16000 to 64000 depending on simulation quality preset, and as WaveWorks allows to pick the FFT texels/worldspace units ratio, we decided to provide more details in closeups by choosing 2km per largest FFT cascade.

But implementing the interactive features, like the water surface affecting the gameplay and the players affecting water surface, was not trivial. Let's talk about this in more details.

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Challenges: Simulation
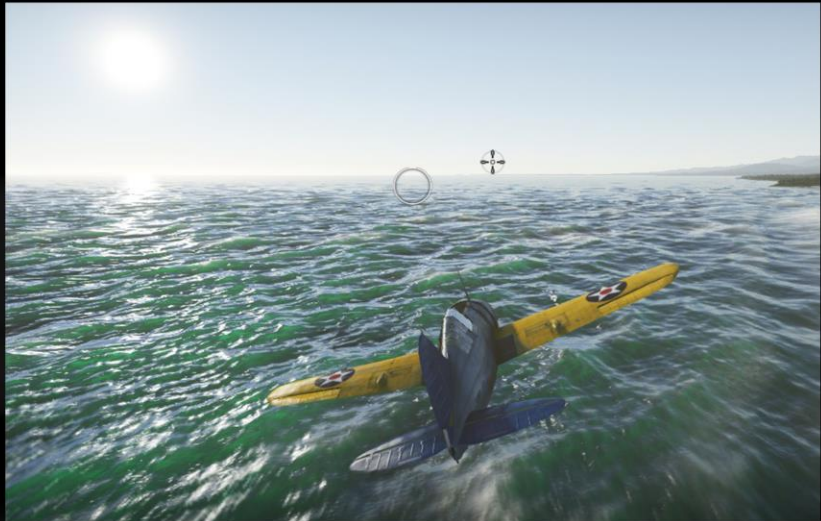
- As fast as possible, High-End PCs down to toasters:
  - WaveWorks: CUDA, DC and CPU simulation
  - Gaijin: added simulation support for some other platforms
- Same physics for every player
  - Physics displacements vs Graphics displacements
- Interaction with the world:
  - Displacement readbacks for vessels and hydroplanes
  - Raycasts for planes and projectiles
  - Shores, Rivers, Lakes

WaveWorks naturally supports CUDA, DirectCompute, CPU simulation. Gaijin has source license, added GPGPU simulation.

While FFT resolution can be different on various clients, displacements for rendering must be as similar as possible: this is done by generating ocean spectrum for highest FFT resolution and resampling down for lower FFT resolutions iside the WaveWorks library. The actual difference is below 5cm for Beaufort 6 ocean waves, see next slide for example.

Physics simulation runs in parallel with simulation for rendering and it is always done on CPU in low resolution to avoid taxing the CPU much. It is guaranteed to be exactly similar on server and all the clients: time is synced and FFT spectrum is the same.

The water surfaces are affected by players and are affecting gameplay: the vessels move according to water surface displacements, and projectiles hit the water surface generating splash effects.

Challenges: Simulation

- Simulation for physics runs on CPU
  - Ensure **same** physics for everybody
  - Server + each client
  - Fixed timestep, 48 ticks/second

- Simulation for graphics runs on CPU or GPU
  - Prefer GPU if possible
  - Client only
  - Variable timestep, each frame

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The water surfaces are affected by players and are affecting gameplay: the vessels move according to water surface displacements, and projectiles hit the water surface generating splash effects.

Simulation: FFT size

- Large sized FFT is expensive for CPU!

- Physics: 128x128

- Graphics: up to 512*512

- Close enough!
  - < 5 cm discrepancy @ 3m amplitude

512x512   256x256   128x128
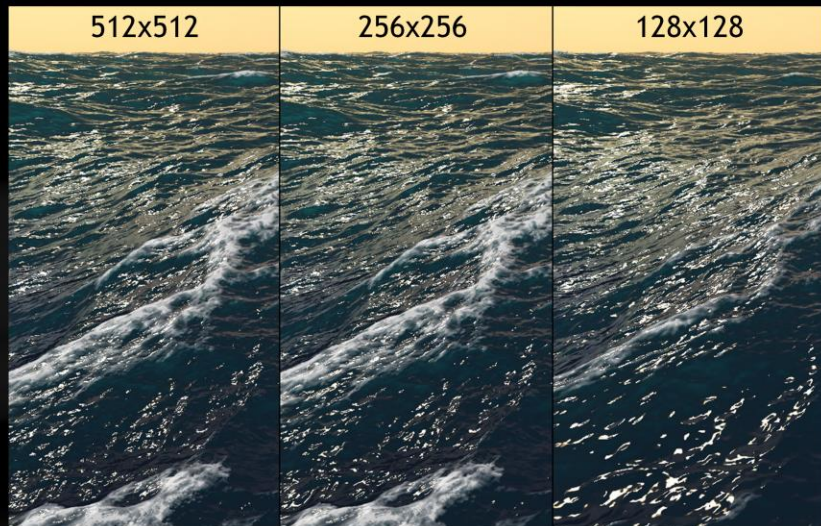
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There is no way to have exactly similar displacements using different FFT dimensions mathematically, but the actual difference is very small thanks to spectrum downsampling implemented in WaveWorks.
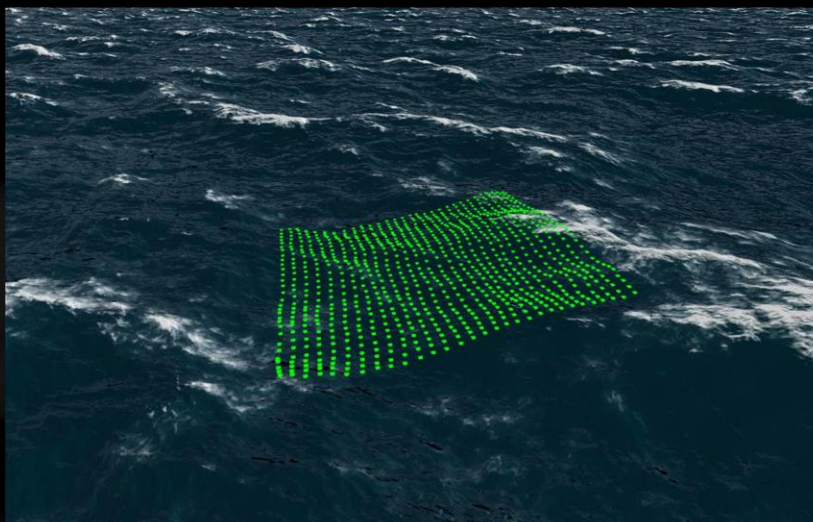
The picture shows how water surface looks at Beaufort 6 with Extreme (512*512), High (256*256) and Normal (128*128) quality presets.

The CPU simulation for physics in War Thunder uses 128*128 FFT dimension (which shown on right picture) while GPU simulation for graphics uses 512*512 FFT dimension (which is shown on left picture), so you can visually estimate the difference between the two.

Our measurements show that the average difference does not get above 6 cm with Beaufort 6 waves.

WaveWorks provides full 3D displacement data via textures, so it is not a heightfield.

The math behind readbacks is SSE/NEON optimized, so thousands of readbacks can be done without noticeable performance degradation. The picture shows 900 readback markers placed on top of the water surface.

In-plane movements and vertical displacements allow the vesslels in War Thunder to behave naturally using few readback positions spread along hulls of the floating objects.
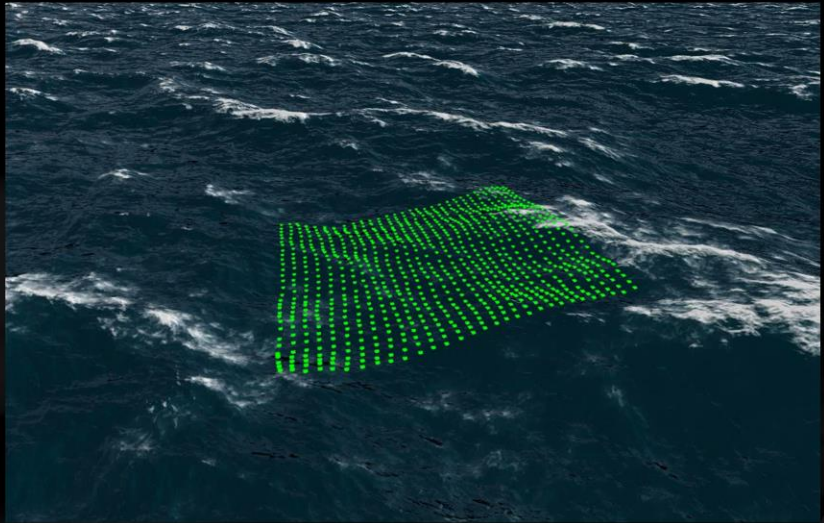
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Simulation: Ray Casts

- Can't do triangle/ray tests!

- Successive approximation using a number of readbacks

- Up to ~2000 projectiles in flight
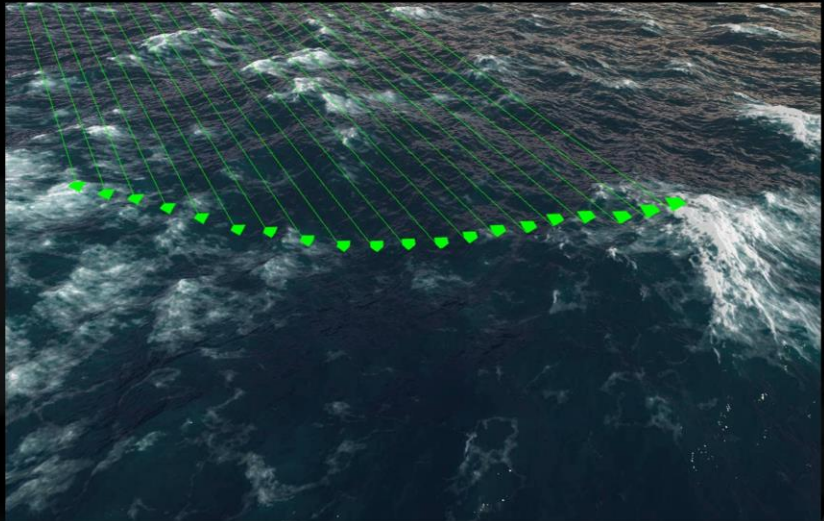
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War Thunder needs ray casts to determine positions of projectiles and planes penetrating the water surface.

WaveWorks does not have built-in ray casts, but these can be easily implemented based on readbacks.

We can find intersection points exploiting local linearity of water surface and doing few successive approximation steps (Newton method).

You can see on the picture that the ray cast position markers are just a tiny bit above the actual ray/water intersection positions: we exit refinement loop as early as possible

Raycasts in War Thunder are SSE/NEON optimized, and this allows to handle ~2000 projectiles being in flight without significant impact on CPU.

WaveWorks distro has sample with basic raycasts implemented.

Challenges: GPU readbacks

- We need readbacks for in-game physics!

- DirectX11: no stalls

- OpenGL: PBO is expected to give access to GPU data without stall.
  Some drivers do introduce stall

- DirectX9: GPU readbacks always introduce stall

- Avoid readbacks by performing simulation on CPU

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Anton talking

Challenges: API limitations

DX11 implementation is great and straightforward:

- DX11 is well supported by all major vendors

- Not fully supporting some new GPUs features

- The best of all APIs so far

Anton talking

Challenges: API limitations

DX11 implementation is great and straightforward:

- DX11 is well supported by all major vendors

- Not fully supporting some new GPUs features

- The best of all APIs so far

- But we have other APIs to consider

Anton talking

Challenges: API limitations

- A lot of textures are fetched in both Vertex and Pixel Shaders:
  - Reflection
  - Refraction,
  - Shoreline,
  - Foam,
  - Depth,
  - Shadows,
  - Atmospherics,
  - etc...

- At least 15 samplers in PS plus 6 in VS

DX11 is not available on Windows XP

> Still 35% of total computers, and 32% of Gaming computers in China
> -> we still   DX9

All DX9 drivers issues will apparently stay forever

OpenGL drivers updating somewhere good only on PC. MacOS, for example, do that really rare

Challenges: API limitations

- OpenGL: many implementations do not follow specification
- For instance, you can't use more than 16 samplers per program on many drivers

- Use Texture Arrays instead
  - Texture Arrays support added to WaveWorks

DX11 is not available on Windows XP

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- OpenGL: You can't use more than 16 samplers on many drivers

- Use Texture Arrays instead
  - Texture Arrays support added to WaveWorks

- DirectX9: No support for Texture Arrays

  - Degrade quality of displacements on DX9

DX11 is not available on Windows XP

> Still 35% of total computers, and 32% of Gaming computers in China
> -> we still   DX9

All DX9 drivers issues will apparently stay forever

OpenGL drivers updating somewhere good only on PC. MacOS, for example, do that really rare

NVIDIA.

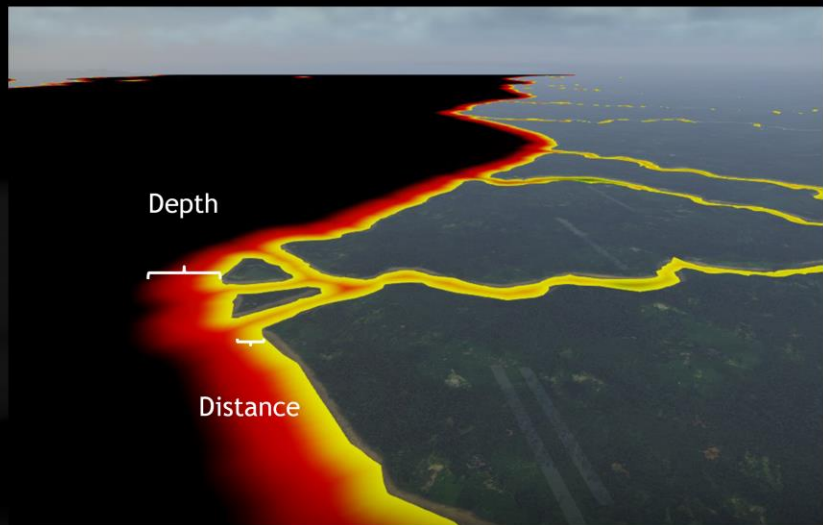Red is depth on the picture

Distance is Green on the picture, giving yellow color

Red is depth on the picture

Distance is Green on the picture, giving yellow color

Interaction: Shores, Rivers, Lakes

Nature:

Rivers and lakes

- No shore waves
- No ocean waves

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We wanted to minimize the amount of work required from artists and to try to minimize the amount of "magic numbers" and "tweaks", so we generate as much data as possible procedurally.

The damping factor is encoded in blue color on this picture where the island is located in open ocean.

We need not a single line of samples facing the wind, but a fan of lines as the waves travel in all the directions and the wind direction given to WaveWorks only defines the direction at which the waves will travel with maximal probability.

Interaction: Shores, Rivers, Lakes

Nature:

Terrain is obstacle for wind & ocean waves

- Smaller shore waves
- Smaller ocean waves

Wind

Downwind area

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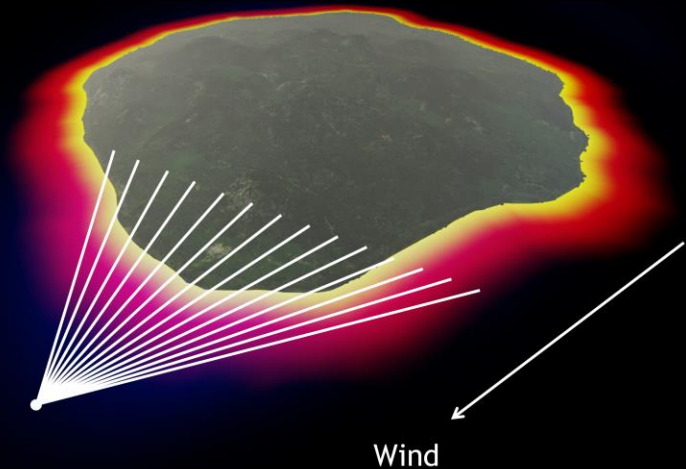
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Interaction: Shores, Rivers, Lakes

How much the terrain is obstacle for waves?

- Sample range of directions
- 1 (terrain) / 0 (water)
- Sum -> [0..1]
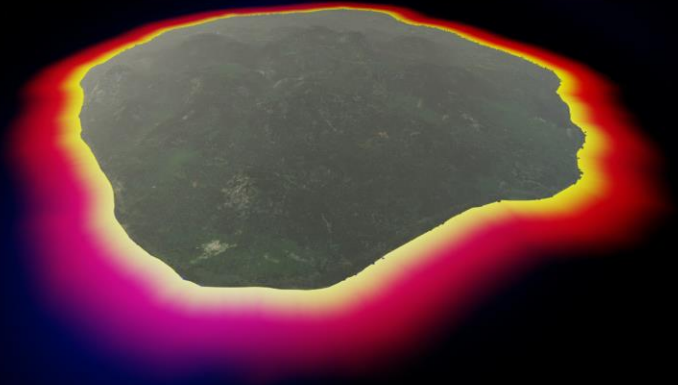- Large texels -> blurred

Wind

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Tuning down the amplitudes for large wavelengts is done on per-cascade basis: we know that the larger is the cascade, the larger are the wavelengths it represents, so we selectively scale down the displacements in cascades according to "openness" factor.
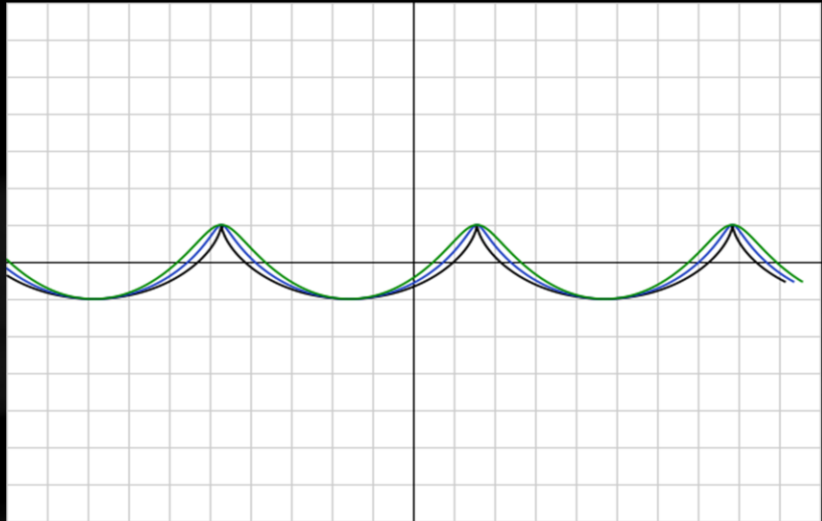
This is natural for downwind areas and lakes: there are no large ocean waves, but ripples and some small to medium waves can easily build up.

Sure our spectrum equalizer has just 4 wide bands (4 cascades), but the results it provides are surprisingly good.

Shore waves

Gerstner waves

- Shore waves amplitude depends
  on ocean waves amplitude

- Normals calculated analytically

- Sawtooth for foam

Shore waves

Gerstner waves

- Shore waves amplitude depends
  on ocean waves amplitude

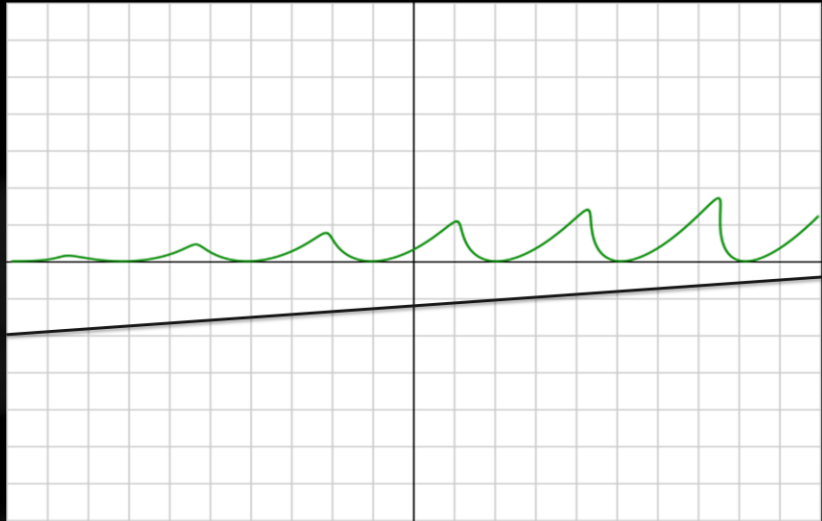- Normals calculated analytically

- Sawtooth for foam

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According to oceanographers' empirical data,

Shore waves start to form when depth is less than half the wave length

Shore wave will start to break when it approximately reaches a water depth of 1.28 times the wave height, empirically:
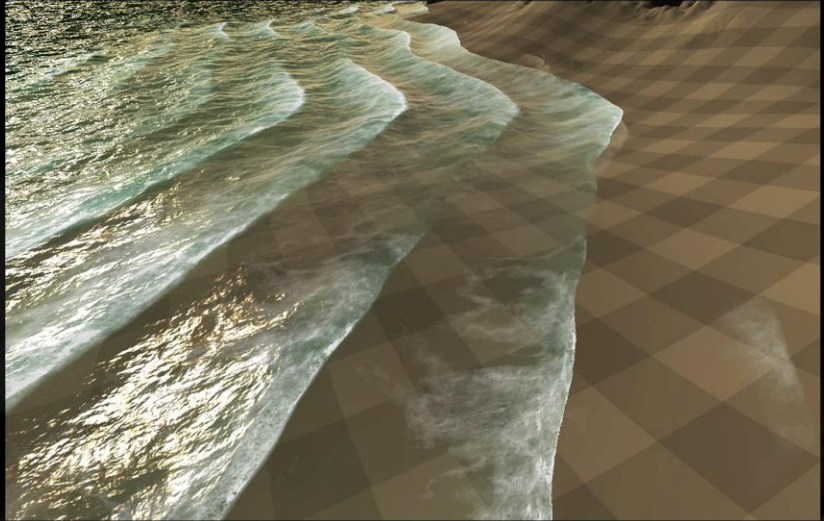http://passyworldofmathematics.com/mathematics-of-ocean-waves-and-surfing/

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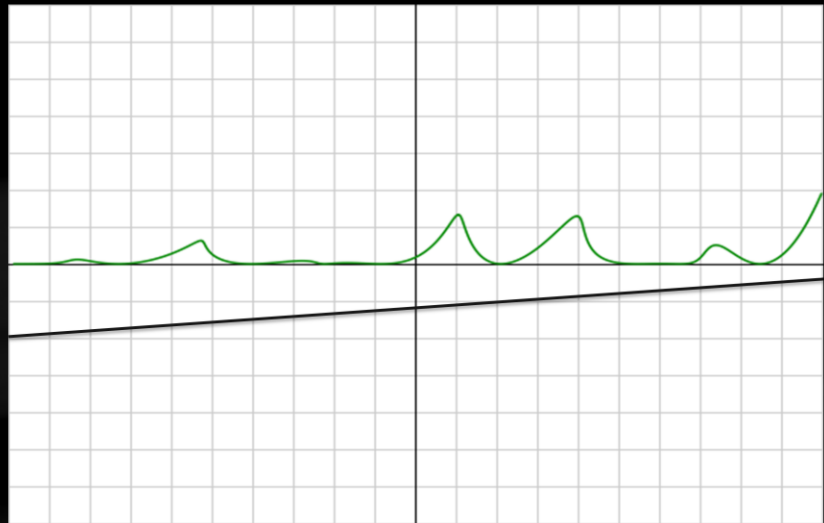
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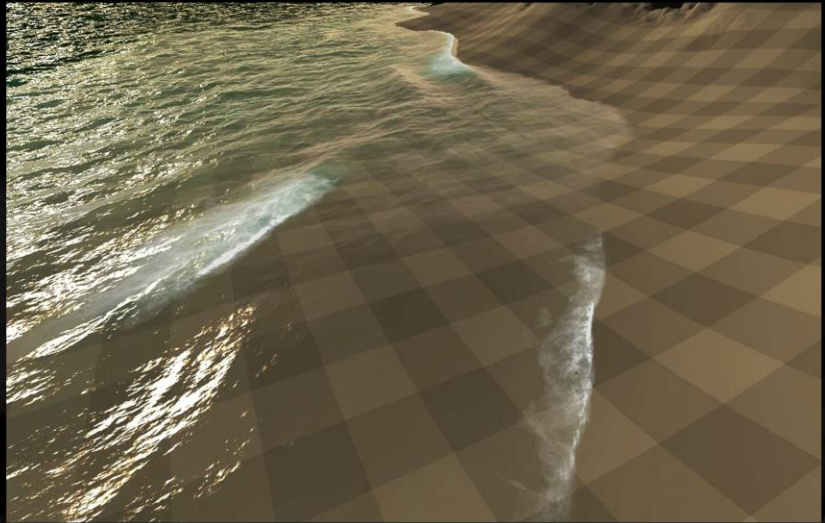
Group speed for water waves is half of the phase speed, this is true for deep water, but works fine for our shore waves

Shore waves

Break regularity

- Add noise

- Apply energy loss

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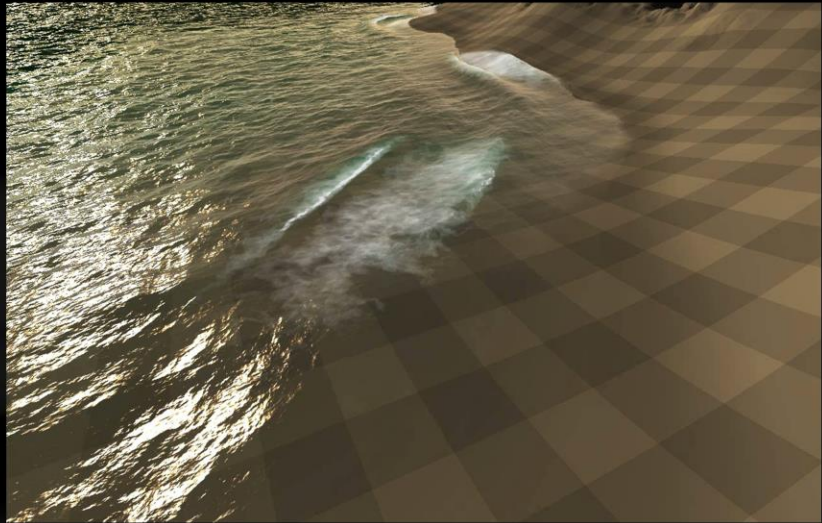
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Group speed for water waves is half of the phase speed, this is true for deep water, but works fine for our shore waves

Shore waves

Distant view

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Group speed for water waves is half of the phase speed, this is true for deep water, but works fine for our shore waves

Rendering Performance

Aggressive LODs for everything:

	Close up	Mid range	At distance
Displacements and normals	All cascades	Some cascades	Largest cascade
Water geometry	Dense grid	Coarse grid	Flat quad
Refractions	Distorted	Simple	None
Reflections	Distorted	Blurred	Blurred
Shore interaction	Full	Full	Normals + Foam
Wakes & splashes	Full	Normals only	Normals only
Light scattering	Yes	Yes	No

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Summary

- Basic WaveWorks integration: extremely easy!

- War Thunder specific:

  - MMO: physics runs in parallel on CPU

  - Shores, rivers and lakes

  - Texture arrays

  - Raycasts

Group speed for water waves is half of the phase speed, this is true for deep water, but works fine for our shore waves

PCSS Tweaking Workflow

1. Tweak maximum threshold and light size to achieve desired look
2. Tweak per-cascade biases
3. Look for light leaks due to the kernel getting wide and sampling outside cascades
4. Increase border percent to eliminate light leaks
5. Tweak blend percent
6. Look for light leaks due to disappearing objects (if objects in finer cascades don't get rendered into coarser cascades)
7. Go to Step 5 or Step 1 if light leaks are still there

GAMEWORKS

- Get the latest information for developers from NVIDIA and continue the discussion
- gameworks.nvidia.com

◎ NVIDIA.