Open Image Denoise
Open Source Denoising for Ray Tracing

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Overview
Algorithm
Quality & Performance
API
Roadmap & Conclusion
Noise is inevitable with Monte Carlo ray/path tracing

Rendering fully converged, noise-free images is often too expensive

Denoising partially converged images is getting more and more popular

The movie industry is already using denoising to reduce rendering times
  - About 2-10x overall speed improvement
  - Negligible image quality loss

Denoising is crucial for real-time ray tracing (e.g. games)
  - Typically ~1 sample per pixels → extremely noisy
  - Enables fully dynamic ray traced shadows, reflections, AO, and global illumination
Open Image Denoise

- Denoising library for images rendered with ray tracing
- Provides a high-quality deep learning based denoising filter
- Suitable for both interactive preview and final-frame rendering
- Runs on any modern Intel® Architecture CPU (SSE4.1 → AVX-512)
- Windows (64-bit), macOS, Linux
- Clean, minimalist C/C++ API and library design
  - Straightforward application integration (in hours)
  - Depends only on the Intel® TBB library
- Free and Open Source under Apache 2.0 license
  - http://openimagedenoise.github.com
Intel® Rendering Framework

- Open Image Denoise is a stand-alone library...
- ... but is a component of the Intel® Rendering Framework
  - A collection of open source libraries developed by Intel for advanced rendering and visualization
Open Image Denoise Features

- Multiple input buffers
  - Color buffer
  - Optional auxiliary/feature buffers
    - Albedo
    - Normal
- LDR and HDR images
  - Robust HDR support
  - Handles fireflies without pre-filtering
- Hardware-agnostic API (CPUs and more)
- Supports querying denoising progress and cancellation
Example: Input and Output Buffers

- **Color**
- **Albedo (optional)**
- **Normal (optional)**

Denoised Color

Scene by Evermotion.
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Denoising Algorithm

- Open Image Denoise currently uses a single denoising algorithm
- Convolutional neural network (CNN) based
  - Direct-predicting autoencoder [Chaitanya et al. 2017]
    - Variant of the U-Net architecture [Ronneberger et al. 2015]
- Good balance between quality and performance
  - Quality suitable for final-frame rendering
  - Interactive performance on many-core CPUs
- The library ships with a set of pre-trained models
- Inference implemented using the open source Intel® MKL-DNN library
Denoising Pipeline

1. LDR input
2. Transfer function
3. CNN
4. Inverse transfer function
5. LDR output
Denoising Pipeline

- **LDR input**
  - Transfer function
  - CNN
  - Inverse transfer function
  - LDR output

- **HDR input**
  - Autoexposure
  - Transfer function
  - CNN
  - Inverse transfer function
  - HDR output
Denoising CNN

3x3 convolution + ReLU*
2x2 max pooling
2x2 upsampling (nearest neighbor)
concatenation

* except final convolution
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Example: Crytek Sponza (16 spp) – Original

Scene courtesy of Frank Meinl, downloaded from Morgan McGuire's Computer Graphics Archive.
Example: Crytek Sponza (16 spp) – Denoised

Scene courtesy of Frank Meinl, downloaded from Morgan McGuire's Computer Graphics Archive.
Example: Amazon Lumberyard Bistro (16 spp) – Original

Scene created by Amazon Lumberyard, released publicly in the NVIDIA Open Research Content Archive collection.
Example: Amazon Lumberyard Bistro (16 spp) – Denoised

Scene created by Amazon Lumberyard, released publicly in the NVIDIA Open Research Content Archive collection.
Example: Corona Academy Interior (4 spp) – Original

Rendered with Corona Renderer. Scene provided by Chaos Czech a.s. www.corona-renderer.com
Example: Corona Academy Interior (4 spp) – Denoised
Example: Corona Academy Exterior (4 spp) – Original

Rendered with Corona Renderer. Scene provided by Chaos Czech a.s. www.corona-renderer.com
Example: Moana Island Scene (8 spp) – Original

Rendered with Intel® OSPRay. Publicly available dataset courtesy of Walt Disney Animation Studios.
Example: Moana Island Scene (8 spp) – Original

Rendered with Intel® OSPRay. Publicly available dataset courtesy of Walt Disney Animation Studios.
Example: Moana Island Scene (8 spp) – Denoised

Rendered with Intel® OSPRay. Publicly available dataset courtesy of Walt Disney Animation Studios.
Denoising Performance

- CPU: 2 × Intel® Xeon® Platinum 8180
  - 2 × 28 cores, 2.50 GHz, AVX-512
Open Image Denoise API Overview

- Very similar to the Embree API
- C and C++ (wrapper) version
- Object oriented
- Reference counted
- Device concept
- Compact and easy to use
- For details visit: https://openimagedenoise.github.io/documentation.html
Example: Filter Creation

- Images can be denoised using a filter object
- Changes must be committed (oidnCommitFilter), which typically triggers JIT code generation

```c
// Include Open Image Denoise headers
#include <OpenImageDenoise/oidn.h>

int main()
{
    // Create an Open Image Denoise device
    OIDNDevice device = oidnNewDevice(OIDN_DEVICE_TYPE_DEFAULT);
    oidnCommitDevice(device);

    // Create a denoising filter
    OIDNFilter filter = oidnNewFilter(device, "RT");

    // Set filter parameters
    ... later slide ...

    // Commit changes
    oidnCommitFilter(filter);

    // Filter the image
    oidnExecuteFilter(filter);

    // Cleanup
    oidnReleaseFilter(filter);
    oidnReleaseDevice(device);
}
```
Example: Filter Parameters

- Buffers have to be attached to the filter
- Shared buffers of flexible layout (offset + strides) supported

```c
// Set input color buffer
oidnSetSharedFilterImage(filter, "color",  colorPtr,
    OIDN_FORMAT_FLOAT3, width, height, 0, 0, 0);

// Set input albedo buffer (optional)
oidnSetSharedFilterImage(filter, "albedo", albedoPtr,
    OIDN_FORMAT_FLOAT3, width, height, 0, 0, 0);

// Set input normal buffer (optional)
oidnSetSharedFilterImage(filter, "normal", normalPtr,
    OIDN_FORMAT_FLOAT3, width, height, 0, 0, 0);

// Set output color buffer
oidnSetSharedFilterImage(filter, "output", outputPtr,
    OIDN_FORMAT_FLOAT3, width, height, 0, 0, 0);

// Set other filter parameters
oidnSetFilter1b(filter, "hdr", true); // image is HDR
```
Roadmap & Conclusion
Roadmap

- Next version *(coming very soon!)*:
  - Higher denoising quality with no performance impact (as shown in this talk)
  - Significantly lower memory consumption (especially for high resolutions)

- Later versions:
  - Support for more auxiliary/feature buffers (e.g. depth)
  - Temporal coherence
  - Possibly other, more specialized denoising filters/algorithms
  - *... what else do you need?*
Conclusion

- Open Image Denoise is an open source denoising library for ray tracing
- Suitable for both interactive and final-frame rendering
- Runs on almost any CPU (only SSE4.1 support is required)
- Takes advantage of AVX2 and AVX-512 instruction sets
- Simple, clean API
- Easy integration into renderers
- Under active development
Questions?

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