NVIDIA Iray

Executive overview

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Contents

Rendering with NVIDIA Iray — accurate, flexible, scalable

NVIDIA Iray® 2014 **rendering technology** represents a comprehensive approach to state-of-the-art rendering for **design visualization**.

A single, interactive rendering system for physical plausibility and predictability

Iray is designed for a dynamic world where designers can explore, evaluate, and most importantly, edit physically-based imagery in real time. Physical plausibility goes hand-in-hand with predictability enabling designers to work more intuitively and confidently. Iray provides multiple, interactive render modes to address a range of user requirements:

- *Iray Photoreal*—Production-final rendering with full global-illumination support
- *Iray Interactive*–Interactive path tracing and editing
- *Iray Realtime*—Large display capability and real-time editing

The same high-level scene description and materials are shared by all rendering modes, enabling seamless image blending when switching between modes.

Scalable, distributed, high-performance rendering

To support dispersed teams and an interactive user experience, Iray features distributed, high-performance rendering that scales for multiple GPU/CPU usage on one or more machines. Rendering performance scales for massive scenes, multiple users, and remote, interactive collaboration. Advanced parallelization and optimization techniques, fault-tolerant clustering, and cloud-ready design, offers a completely new user experience.

Simplified material creation and re-use

Iray is shipped with catalogs of physically-based materials that can be used across all render modes. These materials were created using NVIDIA Material Definition Language (MDL™), which represents a new paradigm in material definition and re-use. Material parameter values can be edited and materials can be re-used to create new materials of varying complexity.

Seamless integration of Iray into your applications

Iray provides a C++ API for seamless integration of the renderer in applications running on Mac OS X, Windows, and Linux. Detailed documentation, code examples, and an example application in which Iray is integrated, are provided.

1 Physically-based rendering: accuracy

"Lights! Camera! Action!" These famous words immediately evoke the physicality and glamour of a Hollywood film set interwoven with emotion-laden images triggered by our movie memory banks. One of the reasons these images are so vivid and memorable for us is because they intimately reflect the physical world in which we live out our lives. The types of lights and materials chosen for a scene may be intended to create a special effect or reflect a particular mood but their interaction is rooted in the natural world.

How does this experience compare with imagery rendered for product and architectural design and marketing? If you take a close look at the algorithms and techniques underlying general-purpose rendering software, you will find that they tend to support photorealistic imagery at the expense of physical plausibility. This can be a logical choice when the primary goal is to create beautiful, photorealistic imagery for a marketing campaign. However, such imagery is of limited value to designers and architects who need to understand how the materials they choose for a product or a building will interact with light in the physical world.

A physically-based image of an explorer's desk. Rendered with Iray Photoreal.

Researchers at NVIDIA and its Advanced Rendering Center have thought long and hard about this disconnect between photorealism and physical plausibility and about how to address it. They have invested considerable time and money to mathematically and computationally model the physical world and create an easy-to-use, high-performance renderer called NVIDIA Iray, which generates photorealistic, physically-plausible imagery based on the interaction of light and materials in the physical world.

Physically-plausible imagery provides real, direct, tangible benefits not only for designers but for the extended design, manufacturing, and marketing processes that are the life blood of design start-ups and more established design-centric enterprises. Designers can work more intuitively and confidently. Physical plausibility goes hand in hand with predictability; it makes sense for enterprises to invest more time and money in the digital design process and to allocate fewer resources to building costly physical models. Physically-based imagery

also offers a valuable multiplier effect: It can be reused in other business processes such as marketing and manufacturing where physically-plausible imagery can intelligently inform decision making.

A physically-based image of an architect's desk rendered with Iray Photoreal. Iray generates photorealistic, physically-plausible imagery based on the interaction of light and materials in the physical world.

The following sections of this executive overview explore how Iray supports physically-based rendering and the key features and benefits of this comprehensive, and unique solution to design visualization.

2 Multiple render modes: multiple workflows

Iray is designed for a dynamic world where designers can explore, evaluate and, most importantly, edit physically-based imagery in real time. Iray provides multiple, interactive render modes to address a range of user requirements.

The same high-level scene description and materials are shared by all rendering modes, enabling seamless image blending when switching between modes

Iray supports seamless blending between different configurations of the same render mode, or two render modes to enable fast previews during navigation, and high-quality final images.

2.1 Iray Photoreal

A path tracer with a focus on generating "push-button", photorealistic imagery. It is an ideal choice when complex global illumination effects are desired.

Rendered with Iray Photoreal. Courtesy Delta Tracing srl.

2.2 Iray VCA

Iray offers an Ethernet and InfiniBand network solution that enables noiseless, high-definition imagery rendered with Iray IQ. This solution offers a completely new user experience that satisfies the most demanding customer needs for an interactive workflow.

2.3 Iray Interactive

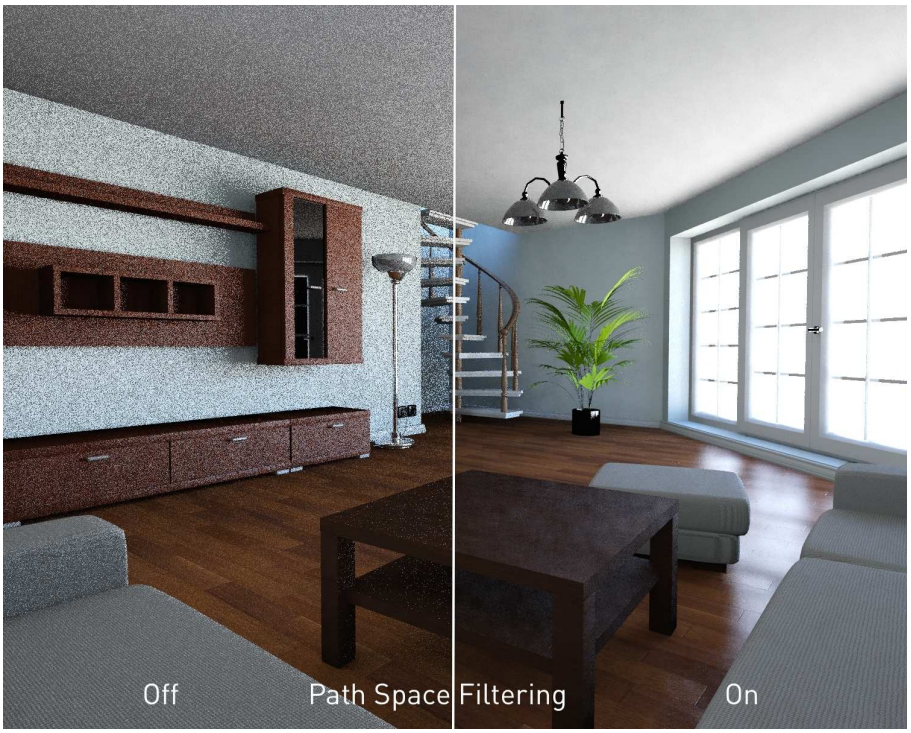
A ray tracer with a focus on interactivity and editing. It is an ideal choice when ray-tracing effects, such as reflections and refraction, are desired.

Rendered with Iray Interactive

Iray Interactive uses progressive rendering to enable fast feedback. The initial render call generates a somewhat low quality frame. Subsequent render calls refine the image incrementally. Each frame generated by a progressive rendering operation is exported to a file. Displaying all files in sequence shows the incremental refinement of the image.

Iray Interactive now incorporates a new and unique approach to image sampling that speeds up the incremental refinement of an image by a factor of 10. This patent-pending approach uses the Quasi Monte Carlo (QMC) method to ensure high-quality imagery and efficient, fast rendering and Path Space Filtering (PSF) to reduce image noise.

Traditional noise reduction solutions filter pixel data. PSF, on the other hand, collects and filters data along the complete ray-traced path and selectively averages the shading results obtained in neighboring pixels. Over time, averaging is reduced so that any artifacts introduced during the filtering process do not show up in the final frame.



The image on the right demonstrates the dramatic speed up in the refinement of an image when using the new patent-pending Path Space Filtering feature in Iray Interactive

2.4 Iray Realtime

An OpenGL rasterizer that uses conventional GPU raster algorithms to achieve real-time rendering speed. It is an ideal choice when rendering speed or large display support is a priority.

Rendered with Iray Realtime

2.5 Key benefits

The targeted use of multiple render modes in Iray allows support for physically-based realism and fast display updates in a single rendering system. Interactive exploration, evaluation, and editing are intuitive and fast and allow insights that would otherwise be impossible.

3 Distributed, high-performance rendering: scaling up

The design process is increasingly dependent on designers, evaluators, and marketers that are dispersed across continents. At the same time, there is accelerating demand for physically accurate digital designs that can be evaluated interactively. These business requirements drive the demand for efficient and scalable network-based rendering solutions.

Rendered with Iray Photoreal. Courtesy Renault Design.

Iray is an ideal solution for high-performance rendering and globally-based teams. Its distributed networking features and parallelization techniques support efficient and scalable rendering on a single host or a cluster. Its network capabilities scale for local and remote collaboration and for high-performance rendering of massive scenes.

3.1 Unique features

3.1.1 High-performance distributed computing on a single host or cluster

NVIDIA Distributed Computing Environment (DiCE) technology is used by Iray to enable high-performance, efficient rendering on a single host or a cluster. Special features include:

- Advanced parallelization and network optimization techniques
- Distributed in-memory data store
- Built-in support for data redundancy and dynamic cluster size

3.1.2 Efficient and scalable multi-user support

DiCE is specifically designed for multi-user support on a single host or a cluster. Users working on the same scene can share the same scene data. DiCE can store variants of data objects,

which allows users to use different versions of one scene. All parts of the scene which are the same for multiple users are shared between them, which can dramatically reduce memory requirements.

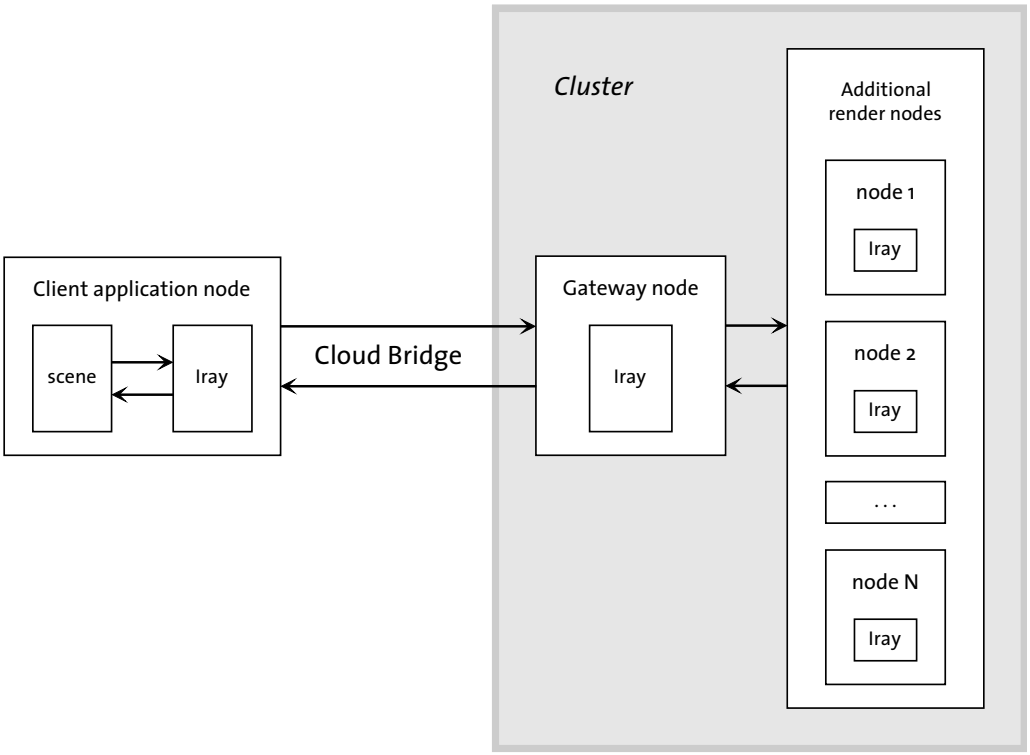
3.1.3 Short start-up times for cluster rendering of large scenes

DiCE includes a distributed, in-memory data store, which is used to store the complete representation of the scene and to efficiently distribute the scene data to all hosts in a cluster. This eliminates the long startup times typically needed to distribute data for massive scenes to a cluster.

3.1.4 Minimal application configuration for remote rendering over the Internet

Iray Cloud Bridge is intended for low-bandwidth and high-latency connections such as the Internet. Cloud Bridge is an ideal network technology to support multiple users of the same scene data. It is also ideal for off-loading interactive and batch rendering tasks, thereby freeing up a user's local machine for less compute-intensive operations. Application configuration is minimal because the Cloud Bridge render plugin uses the same interface as Iray Photoreal, Iray Interactive, and Iray Realtime.

The following figure illustrates a possible configuration for rendering on a remote cluster. Iray is installed on the client node and every node in the remote cluster that is used for rendering. The application node is a client of the rendering service that is installed on the remote cluster. Cloud Bridge is used to enable communication between the client and the remote cluster.



Creating an Iray-based configuration for remote, cluster-based rendering in the cloud

At runtime, a copy of the scene is created or loaded into the client application. This scene is then stored in the Iray scene database on the client and on each rendering node in the remote cluster. Incremental changes made to the scene database on the client are sent to the remote

cluster where they are automatically shared with all rendering nodes. The Iray API provides C++ classes to enable the original scene on the client to be updated.

3.1.5 Network appliance to accelerate rendering

NVIDIA announced the revolutionary NVIDIA Iray Visual Computing Appliance at GTC 2014. The VCA is intended for any application that wants to accelerate Iray and support interactive, noise-free imagery. Photorealistic inspection enables designers and evaluators to examine virtual models as real objects and make adjustments and design decisions accordingly. Using Ethernet or InfiniBand connections, you can build a VCA cluster that satisfies the most demanding customer requirements. NVIDIA is currently working with all Iray licensees to support Iray VCA. For more information, contact NVIDIA ARC at `IrayIntegration@nvidia.com`.

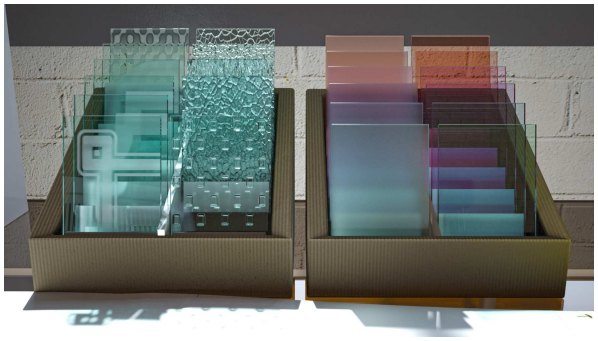
3.2 Key benefits

The underlying network technologies and supported network configuration in Iray enable you to offer high-performance rendering solutions to your end users. Iray supports:

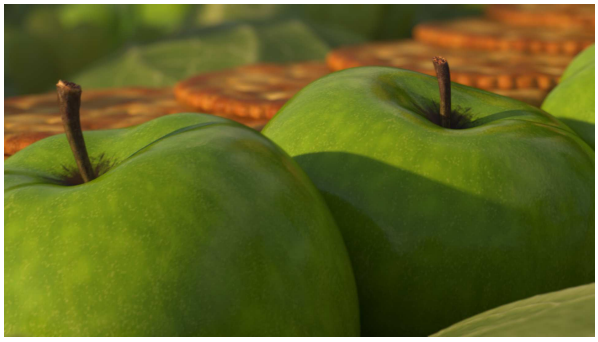
- The demand for more computing power, efficiency, and true scalability
- Common networking modes such as UPD multicast and TCP unicast and provides a built-in HTTP server
- Efficient tradeoffs in network latency, throughput, and reliability to suit particular user needs
- Multiple users, locally and remotely
- A range of configurations for single-host rendering, server-side rendering, batch rendering and cluster rendering
- New business models such as cloud-based applications for Software as a Service (SaaS)

4 Physically-based materials: one definition, multiple uses

Iray is shipped with physically-based materials created using Material Definition Language (MDL). MDL represents a new paradigm in material definition and re-use. MDL materials apply to geometry, lights, and cameras.



An MDL glass material used to simulate glass plate samples. Rendered with Iray Photoreal.



An MDL material used for the apples that models real-world sub-surface scattering behavior.

Material definitions incorporate distribution functions for reflection and refraction, for volume scattering effects, and for light emission properties.

4.1 Unique features

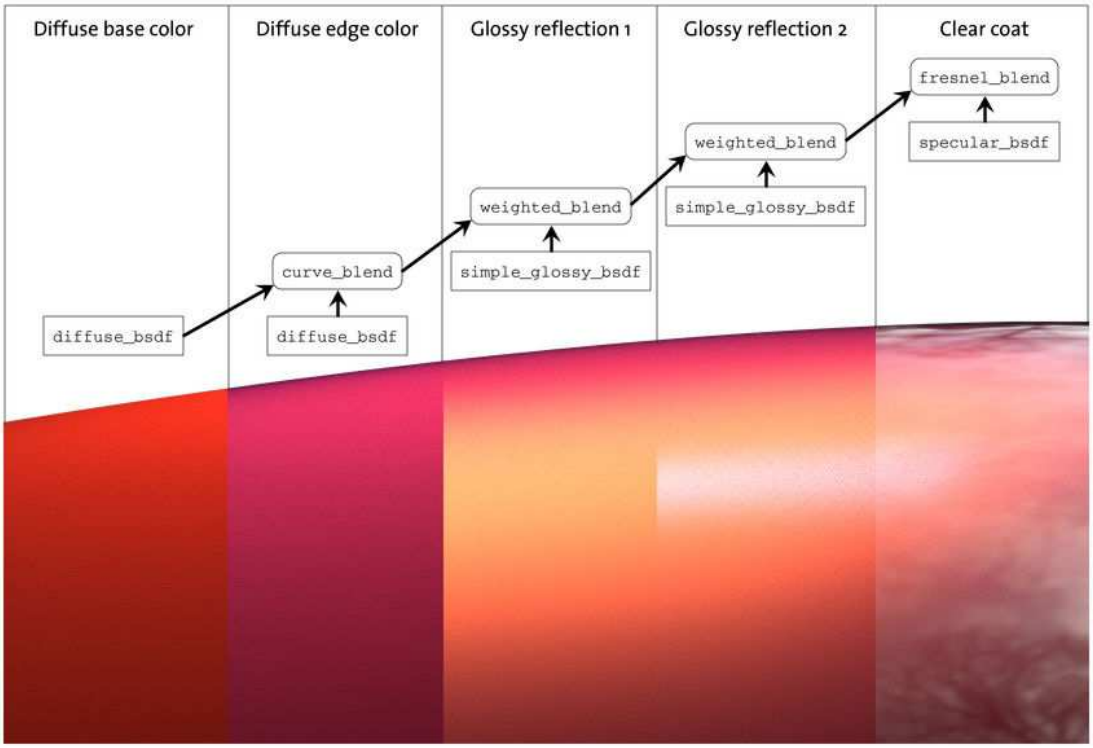
4.1.1 Eliminating dependencies between material and render operations

Traditionally, shading languages have been used to define operations on materials as well as renderer-specific operations. This approach has closely bound materials to a specific renderer and limited their reuse. MDL is not a shading language. It simply defines a material: the "what to compute". The renderer decides "how to compute" the material definition. This split of responsibilities enables all Iray rendering modes to use the same materials. Any differences in the rendered appearance of materials are due to the capabilities of the rendering mode.

The same materials shared by all rendering modes

4.1.2 Simplifying material creation and use

MDL offers a new approach to simplify material creation and use. Rather than creating a monolithic material with many editable parameters, MDL uses a material model that is based on a layered, modular concept. Material authors can program a wide variety of distribution functions to initialize material parameters and artists can edit material parameter values to create a particular look. Existing materials can be re-used to create new materials.



An example of a complex, layered material. It consists of five layers: A diffuse base color, a diffuse edge color, two glossy reflections, and a clear coat

The following image shows the same material rendered with Iray Photoreal. The band on the left represents a rendering of the diffuse base color layer only. The second band represents a rendering of the diffuse base color layer and the diffuse edge color layer. The last band (far right) represents a rendering of all five layers.

Layering of materials simplifies their creation and use. Typically, this material would be used for car paint.

4.1.3 Measuring materials—a look into the future

MDL also supports the use of measured materials as building blocks in the creation of new materials.

Light interaction with objects is measured over a series of different incident light and viewing angles. The resulting dataset is used as input for a measured distribution function.

Measured materials represent the measurement of real-world surfaces and are increasingly viewed as critical input to product design and manufacturing decisions.

4.2 Key benefits

MDL provides a thoroughly modern and simplified approach to material creation and use.

- Provides a programmatic, symbolic representation of a material that is independent of rendering algorithms
- Provides plugin support for easy integration into any MDL-aware renderer
- Designed to leverage the performance benefits of GPU-based rendering
- Tuned for modern rendering algorithms such as those used by path tracers

5 Compositing: marketing and sales campaigns

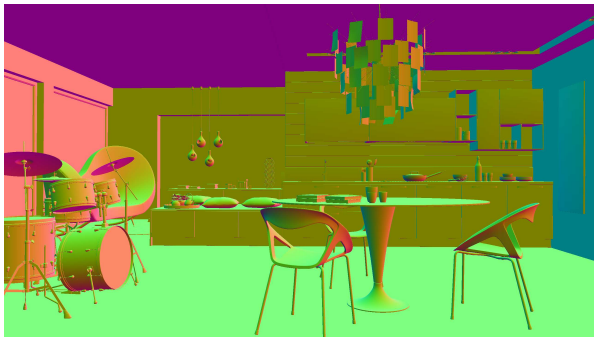
Accurate imagery is critical for design evaluation and the time invested in creating the design imagery represents a significant investment. Today's product cycles are getting progressively shorter. Any efficiencies that can be gained from re-using and re-purposing existing imagery are invaluable.

Iray gives artists creative control by enabling specific image components to be output with the final output image. Components are rendered out simultaneously with the final output image at no additional expense. Components can be enhanced in compositing software and re-integrated into the final output image without time-consuming and possibly expensive re-rendering.

5.1 Unique features

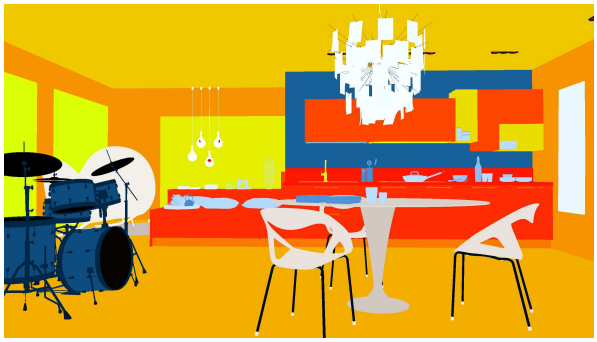
5.1.1 Outputting image data components

Iray supports the rendering out of a wide range of image data components such as normals, texture co-ordinates and material IDs.

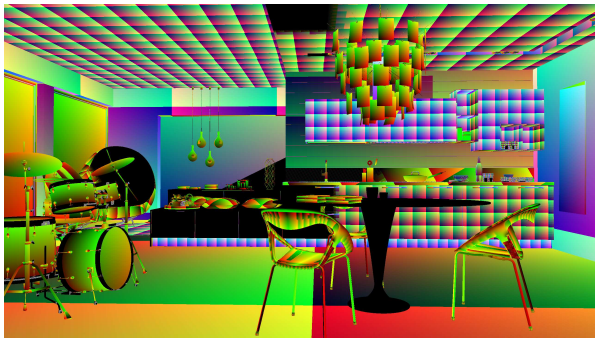


Normals

Depth



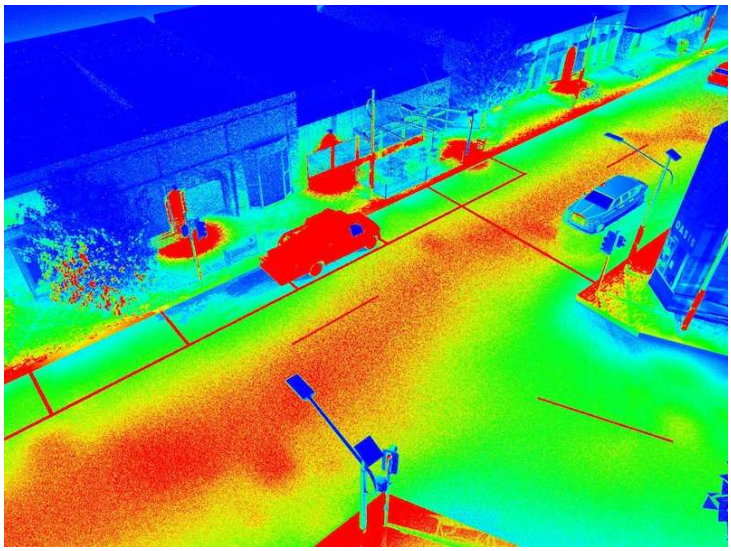
Material ID



Texture coordinates

5.1.2 Outputting irradiance components and probes

Iray supports the rendering out of irradiance components and irradiance (light) probes to measure illumination.



Example of irradiance output used to create a luminance distribution study. Courtesy miGenius.

5.1.3 Integrating synthetic objects in real-world photographs

Iray can be used to integrate synthetic objects in a real-world photograph. Artists can use the photograph as a backplate; match the setup of the virtual camera and lights in Iray to the setup used to capture the photograph; and arrange the objects.

Backplate information, environment lighting, interactions of both matte and synthetic objects (global illumination) and the artificial shadows cast onto the matte objects are combined in a single rendering step. Rendered with Iray Photoreal. Courtesy Bunkspeed.

5.1.4 Using Light Path Expressions (LPEs) for fine grained control

Light path expressions (LPEs) can be used to define components to be rendered out. An LPE is a symbolic representation of the path that light takes between one or more light sources and the eye. Because the LPE syntax is simple but expressive and precise, specific light components required for post-processing tasks can be extracted more easily.

The following set of images shows the final output image as well as components rendered out by using LPEs.

All components

Left light

Top light

Right light

Diffuse

Specular

Glossy

Direct light

Diffuse, specular and glossy

5.2 Key benefits

Requirements for marketing and sales imagery must satisfy important aesthetic goals, support a campaign story, and connect on an emotional level. Iray support for compositing tasks can make the artist's job easier, more efficient, and ultimately, more fun.

6 Integrating Iray: the render solution for your design application

The Iray C++ API enables seamless integration of Iray into applications running on Mac OS X, Windows, and Linux. Detailed documentation and code examples are provided as well as an example application in which Iray is integrated. The following sections describe the tools, resources, and instructions shipped with Iray.

6.1 Tools

The C++ libraries provide the following APIs for integration and customization tasks:

- The C++ programmer's API provides a single access point to the library classes and methods used for integration and customization tasks. This API supports the import and customization of materials written in NVIDIA Material Definition Language (MDL).
- The Plugin API allows programmers to extend the capabilities of Iray to suit application needs. Example plugins are shipped with Iray as instructional aids.

6.2 Resources

The C++ libraries provide the following resources to support high-performance, interactive rendering over a network of hosts:

- The Iray renderer with multiple rendering modes. If you have special requirements, NVIDIA can work with you to develop additional rendering modes. (Contact NVIDIA ARC at `IrayIntegration@nvidia.com`.)
- NVIDIA Distributed Computing Environment, which provides:
  - Scene database creation and editing
  - Multi-threading of rendering processes
  - Scalable clustering using multiple GPUs for rendering on a local area network (LAN) or in the cloud
  - Node failure detection and data recovery based on redundancy

An example material catalog written in MDL is shipped with Iray. The materials are supported by all Iray rendering mode s and can serve as examples for creating your own materials.

6.3 Instructions

Comprehensive documentation explains:

- The concepts underlying Iray, its capabilities, and how to integrate it into design visualization applications.
- The concepts underlying MDL and its capabilities

A demo viewing application integrates a core feature set of Iray.

7 A new perspective on rendering: contact us

Iray offers a new perspective on rendering. It is a comprehensive, physically-plausible, unified rendering solution.

Rendered with Iray Photoreal. Courtesy Bunkspeed.

Multiple rendering modes use a common scene representation and a common material catalog. This means that Iray can seamlessly blend imagery when switching between modes and designers can remain confident that the appearance of objects remains consistent.

Because Iray incorporates the latest advances in GPU and network technologies, it can support high-performance computing and facilitate collaboration with colleagues and customers in remote locations. Most importantly, the Iray C++ API is designed to enable you incorporate the Iray features best suited to your application needs.

To learn more about Iray and its unique capabilities, contact `IrayIntegration@nvidia.com`.

NVIDIA is the world leader in visual computing and its Advanced Rendering Center (ARC) has decades of experience in providing software rendering solutions that define new industry standards. NVIDIA ARC has invested many years of research and development in visualization solutions that take advantage of the latest developments in GPU and network technology. Iray is an expression of this commitment to technical excellence and a desire to create software applications that delight its customers.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