DE
Desktop Engineering®

MAKING THE CASE

FOR PREDICTIVE RENDERING

Unambiguous and fast iteration transforms design workflows.

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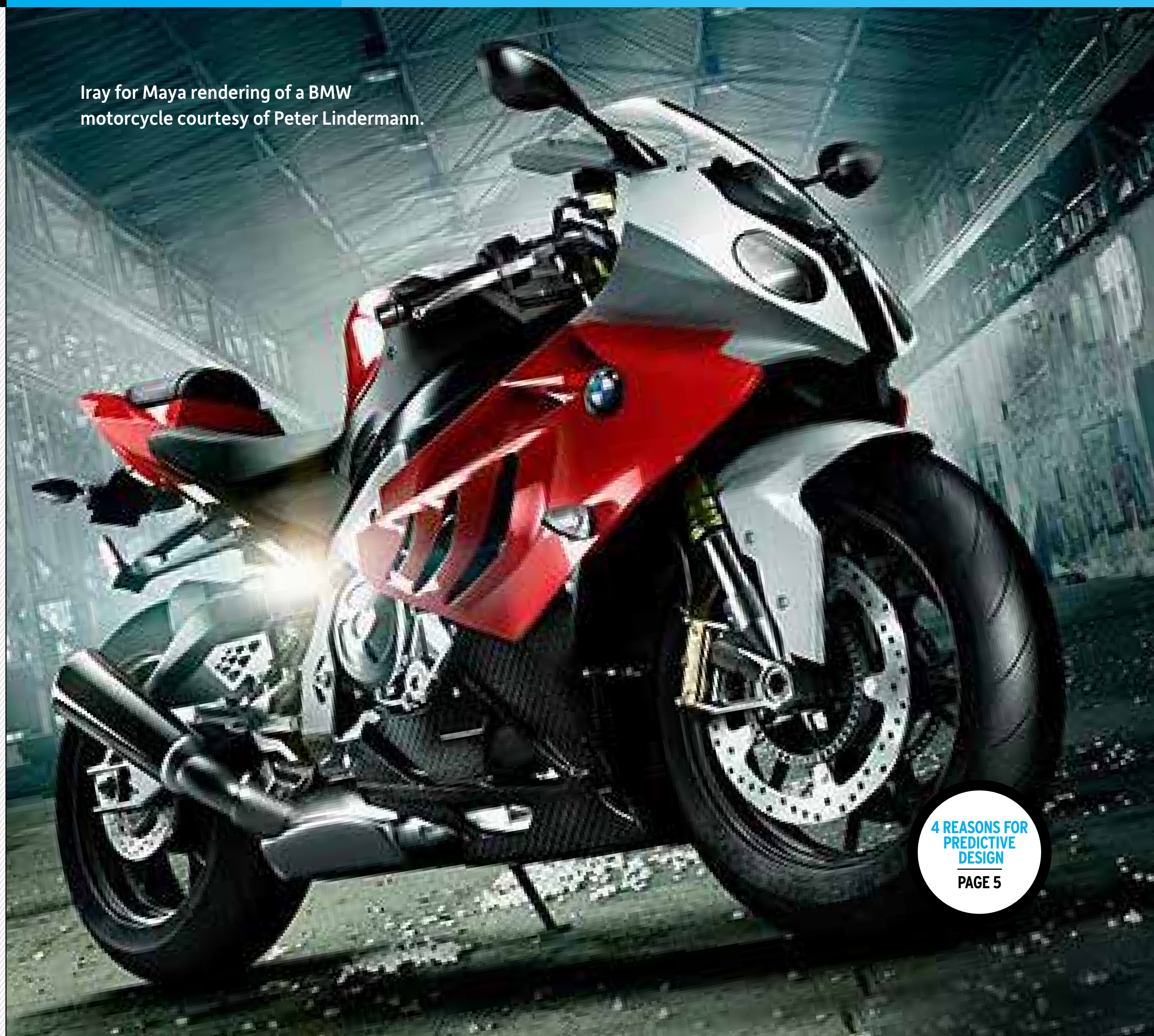
NVIDIA.

SPEED YOUR WORKFLOW

Differentiate your designs with more effective iterations driven by physically based rendering.



Iray for Maya rendering of a BMW motorcycle courtesy of Peter Lindermann.

4 REASONS FOR PREDICTIVE DESIGN
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Design is the key differentiator among products in today's economy, but predictability and iterative speed are key differentiators in the economics of design. At its heart, design engineering is the process of iteration: An idea is visualized, critiqued and refined, until it is ultimately delivered. More iterations mean more chances to try new ideas, to catch mistakes, to polish concepts into ever better designs. It's not enough, however, to have a beautiful design. Speed to market and cost of production are both essential in the creation of a competitive, profitable product. While it's important to do enough design iterations, the changes need to happen quickly and with the confidence that the final product will emerge as the designer intended.

Rendering has long been an important tool for visualizing 3D designs. Real-time display renderers, such as OpenGL, lend themselves well to rapid iteration. However, such rendering can only approximate the appearance of materials and objects. It is often useful for working with the mechanical components of a shape, but it cannot accurately predict the appearance of a finished product, meaning the designer can only make educated guesses. Various forms of ray tracing and other CPU-based rendering methods that simulate light more realistically than OpenGL have been available to designers for years, but these have been difficult to use and too slow to fit well into rapid iterative design. As a result, many designers have simply learned to do without realistic rendering, or they have saved it for special occasions.

Interactive, predictive, physically based rendering (PBR) is poised to change the way such designers work. It combines easy-to-use physically based lighting, verifiable realistic materials and reliably accurate photorealistic results, with the computational performance of graphics processing units (GPUs). Not only can a designer see how the product will really look, he can see it in his application's interactive viewport, while he designs it. Just as hardware-accelerated OpenGL became the standard mode for working interactively in 3D, GPU acceleration turns physically based rendering into an interactive design mode that will become an essential part of iterative design workflows.

> **"IT USED TO TAKE FOUR PEOPLE ON OUR TEAM A FEW MONTHS TO DEVELOP A NEW BIKE DESIGN. NOW, TWO PEOPLE CAN DESIGN A FULL MOTORCYCLE IN TWO WEEKS."**
>
> — MATHEW GUELLER, SENIOR SURFACE DESIGNER FOR HARLEY-DAVIDSON

Physically based rendering allows the internal and external parts of a product to be accurately visualized, which can help avoid expensive manufacturing and serviceability issues.

Image courtesy of Nik Nastev.

KEYS TO PREDICTIVE RENDERING

PREDICTIVE DESIGN. In predictive design, materials and lights are verified to look and work like their real-world counterparts. It's what you see is what you get (WYSIWYG) for 3D design and manufacturing. Material Description Language (MDL) materials can be verified by a material manufacturer, or within a design team, with the confidence that the material will look and behave consistently throughout the design process, even from one application to another. Lighting is verifiable, as well. 3D environments can be captured from the real world as an image-based lighting solution, and the scene can be calibrated to match the real-world conditions. Similarly, light fixtures can be calibrated to match manufacturer's specifications, or measured behavior of their real-world counterparts.

MDL (MATERIAL DESCRIPTION LANGUAGE)
NVIDIA's MDL is a language that describes how materials are implemented. These materials are based on the physics of real-world materials. MDL acts as a currency between design applications, and provides verifiable material descriptions that can be shared from one application to the next. This means materials and lights can move from end-to-end in the design process. Engineering, industrial design and marketing can all exchange 3D designs without losing valuable design work and starting over at each stage of the process. For example, a material assigned to a component in CATIA v6 and verified to look correct by the designer could be passed to the marketing department for rendering and animation of that design in Autodesk Maya. If they're both using Iray, they'll look the same in the renders.

Predictive design is especially important in consumer goods, where the look and feel of a product is as critical as its function.

Image courtesy of Lightwork Design.

NVIDIA's vMaterials (the "v" is for verified) are materials that have been calibrated by eye and measurement to match their real-world counterparts. Manufacturers can create their own libraries of vMaterials. In addition, MDL supports the use of measured materials, using scanners from X-Rite, for example.

While MDL does not depend on a specific renderer (it works with Iray and it has been licensed by Chaos Group for use in V-Ray) it's important to note that different renderers, even if they are physically based, may render the same scene with some differences, just as two cameras will photograph the same scene with subtle variations. However, if both renderers are physically based and support MDL, it is still possible to have confidence that each renderer, within its own limitations, will correctly represent that material.

GPU-ACCELERATED PHYSICALLY BASED RENDERING (PBR). Physically based rendering relies on ray tracing and global illumination, and the physics of light and materials. It is computationally very expensive. Ray tracing means firing light rays into the scene and allowing them to bounce on and through materials as they would in the real world. As the light rays bounce around, they fill the volume of the scene with secondary bounces, so objects act as light sources themselves. This bounced light, which can illuminate all of the nooks and crannies of the scene, even objects that aren't directly in the path of the sun or a light bulb, is called global illumination, often referred to as GI.

Iray and V-Ray RT, are built on CUDA, NVIDIA's massively-parallel supercomputing programming language, but designers don't need a supercomputer or top-of-the-line CPUs to use these renderers. They run on the same NVIDIA Quadro graphics cards designers already use to power their professional CAD applications. Users can leverage the cost of computing hardware by optimizing their systems to use lower-end CPUs coupled with more powerful GPUs, which provide more benefit in terms of real-time display performance and rendering compute performance.

PROGRESSIVE RENDERING. Global illumination requires billions of calculations to generate an image. Fortunately, it can be calculated progressively. This means an image is generated like a pointillist painting – with successive shotgun blasts of rendered pixels that gradually fill the frame until the image is perfectly resolved. If this progressive rendering happens fast enough — which, in practice, requires GPU acceleration — it allows for real-time use, allowing the designer to render while he works, and to almost instantly see the effects of his changes. Because the designer can so quickly visualize the impact of design decisions, he can make many design iterations based on this photorealistic feedback — small adjustments of color or texture, or modifications to geometric details — in the time it might take to do a single bucket render on a CPU.

4 REASONS FOR PREDICTIVE DESIGN

A PREDICTIVE DESIGN APPROACH THAT LEVERAGES REALISTIC, ITERATIVE RENDERING can accelerate the design workflow, help designers identify flaws earlier in the process, increase creativity, save costs and provide a platform for better decision making and collaboration with non-engineers during the product development process. GPU-accelerated, physically based rendering ultimately improves the end product.

To convince your team to incorporate predictive design into your overall product development workflow, focus on these four points:

1. Easier, faster rendering on workstations you already use for daily design engineering tasks allows you to make better use of your time, completing your work faster. With Iray-enabled PBR, designers can explore more concepts in less time, and have confidence that what they see in the photorealistic rendering accurately reflects what the design will look like when it is built.

2. Potentially catastrophic design flaws can be identified earlier in the process through visualization. This saves expensive re-work down the road and improves client satisfaction. Having access to a lifelike representation earlier in the design process ultimately results in better products, because engineers can make design decisions faster and more effectively.

3. Managers and clients can clearly see the impact of a design change, or better understand the intent of a design idea in real-time. This improves collaboration, saves time and further speeds the development cycle.

4. By enabling the design engineering team to create realistic digital prototypes on demand, you can save the cost of creating physical models and prototypes. Reducing or eliminating the number of physical models/ prototypes required can result in significant savings.

MORE INFORMATION

NVIDIA Iray
nvidia.com/object/nvidia-iray.html

NVIDIA Advanced Rendering
nvidia.com/object/advanced-rendering.html

NVIDIA MDL
nvidia.com/object/material-definition-language.html

RAMPED-UP RENDERING

GPUs transform the rendering workflow

The unfortunate paradox of physically based rendering has been that although it's much easier to use than other types of renderers, it is much more expensive computationally. Simulating billions of light rays, bouncing around in a scene many times before they expire, requires a lot of computer power, and CPUs simply aren't the best processor for the job. GPUs have always been good at the real-time, OpenGL rendering that provides real-time interaction with shaded and wireframe views of your work. But thanks to the evolution of NVIDIA GPUs as general-purpose computing devices, they are now stellar performers when it comes to the general-purpose computation required for photorealistic rendering. GPU-accelerated PBR, provided by Chaos Group's V-Ray RT, or NVIDIA's Iray, for example, combine the benefits of physically based realism with the speed that allows them to be useful as interactive renderers in the viewport of the design application.

The power of parallel processing

A physically based renderer, working at a respectable resolution on a workstation with a single CPU, may need many hours to create a single high-quality rendered image, as its handful of cores works like a bucket brigade to render bucket after bucket of pixels. In contrast, a digital camera could capture the equivalent of a single image in the real world in one thousandth of a second, owing to the fact that its sensor chip contains a grid of tiny sensors, one for each pixel, and these all capture part of the image simultaneously. A GPU, meanwhile, works conceptually like a digital camera's sensor – thousands of small cores working in parallel. The latest NVIDIA GPUs contain more than 3,000 cores, and each renders a stream of pixels in tandem with all the other cores. And unlike CPUs, GPUs are easily ganged together. If 3,000 cores aren't fast enough, a second graphics card will make the render almost twice as fast. The regular grid of data inherent to 3D images plays perfectly into the parallel processing strength of GPUs. What used to take a farm of computers running overnight can now be done interactively on a desktop.

Because CPU-based rendering has traditionally been slow, it has been perceived as a tool to be used only at the *end* of the design process. Some designers invest the significant effort and time of rendering a product after the design is essentially complete, but this means it is mostly used as a tool to win approval for a finished design, or to aid in marketing after a design is done. Often, designers simply hand their 3D data to an art department or marketing team, which employs one or more highly skilled 3D rendering technicians. These professional artists navigate the complexities of these tools, creating materials and setting up lights and the complicated blend of settings required to generate good looking renders. It requires a lot of skill and a lot of trial and error. There is plenty of iteration, but it's all in the service of the render, not necessarily iteration that pushes the design itself to improve. While the results are useful, relatively few designers — and even fewer engineers — will disrupt their workflows to such a degree to render while they design.

[GPU-ACCELERATION MAKES PBR SO FAST THAT IT CAN BE USED INTERACTIVELY, IN THE DESIGNER'S NORMAL DESIGN VIEWPORT.]

PBR is much simpler to use than other types of rendering that rely on approximations and lighting tricks. It doesn't require rendering expert technicians. In its simplest form, image-based lighting uses a single high-dynamic-range image file as environment and materials can be dragged and dropped onto objects. This reduces the setup time for a realistic render from hours to a few button clicks. However, even with this level of simplicity, PBR is too disruptive when the render times are too long. GPU-acceleration makes PBR so fast that it can be used interactively, in the designer's normal design viewport. This means design engineers can work normally, but evaluate the appearance of materials and lights, as well as changes to the geometry of the designs, with almost no disruption to the design workflow.

Different materials can be quickly changed in a predictive design workflow to speed the review process, saving time and money.

Image courtesy of Bluemotion IT srl.

RENDERING AS PROTOTYPING

Designers have long relied on physical prototypes to overcome some of the uncertainties in design. But prototyping is a slow, expensive process where time and money are two commodities always in short supply. Design engineers have turned to simulation and analysis to predict the physical behavior of a design. 3D printing, similarly, is exploding in popularity as a way to avoid the waste and expense of tooling up for hold-in-your-hand prototypes, and can be thought of as a way to simulate the shape of a design. However, it cannot faithfully replicate the appearance and finish of many materials.

Just as finite element analysis simulates the physics of a machine's components, physically based rendering simulates the physics of light and materials. Many renderers perform rough approximations of real-world lighting in order to generate an attractive illustration of a 3D scene. While these renderers may seem realistic at first glance, only PBR can accurately simulate the real-world appearance of shapes, materials and light, which are essential elements of a finished design. Take a ubiquitous consumer electronics device – the TV remote control. Does the plastic have a particular color or texture that's important to the design? Is it too glossy or too matte? Are the illuminated buttons too bright, or not bright enough? Does light leak through seams? How does a second shot of clear coat affect the appearance of textured surfaces? Unlike "illustrative" renderers, PBR can reliably answer such questions, as long as the CAD design accurately represents the engineered forms, and the renderer faithfully reproduces the behavior of light.

An experienced designer can make educated guesses about such questions, especially when dealing with relatively simple objects and familiar materials. But it's much more difficult to guess about some difficult design questions: Will the illuminated instrument panel of a rescue boat create distracting reflections on the windshield at night? Will the electronic circuit board of a motorcycle's turn signal show through its amber plastic lenses? How will light transmit through the translucent light pipes of an electronic game controller? These are real design problems, faced by real designers, all of who can use PBR to improve their designs early in the design cycle. Integrating predictive design and visualization into the design workflow will lead to more rapid innovation, better decision making, lower development costs and faster time to market.

Simulation helps a designer understand, with confidence, how a finished product will behave. Predictive rendering gives the designer confidence that his design will behave as intended in the light of day. It's the 3D version of what-you-see-is-what-you-get (WYSIWYG).

PREDICTABLE RESULTS

CASE STUDIES

Companies that integrated predictive design into their product development processes are reaping the benefits in more efficient designs and reduced costs.

GPU-accelerated rendering has allowed Harley-Davidson to cut its new bike development time from months to weeks.

Harley-Davidson: Digital Prototyping

At Harley-Davidson, traditional design methods that included sketches and producing clay prototypes resulted in slow design iterations. As the design process moved along, changes and iterations became even more challenging. By adopting 3D modeling tools (along with 3D printing) the motorcycle manufacturer accelerated the creation of prototypes from months to just a few hours.

GPU-accelerated physically based rendering has allowed the company to do real-time design reviews with peers on the design team and clients. The images can be manipulated and edited live on a high-definition screen.

The company uses Autodesk 3ds Max, Maya, Mudbox and Alias, along with McNeel Rhinoceros 3D and Z-brush, running on Lenovo D30 workstations powered by NVIDIA's Quadro 6000 and Tesla C2075 GPUs, along with the Cubix GPU Xpander (an external PCIe slot expansion system). Instead of spending several days creating a component model, designers can now accomplish this work in just minutes.

Engineers and stylists can make fast changes to designs, which facilitates accelerated feedback. The drawings can then be sent to a 3D printer to create full-size part models. Designers can easily show potential designs to management in a way that is easy for them to see and understand. The engineering team can also render more concepts for evaluation, while simultaneously creating assets that can be used for marketing.

"It used to take four people on our team a few months to develop a new bike design. Now, two people can design a full motorcycle in two weeks," says Matthew Gueller, senior surface designer for Harley-Davidson.

With NVIDIA Iray for Maya, Renault can render design changes in real-time, without pre-processing.

> "SWITCHING TO IRAY RAY TRACING WAS LIKE A DREAM – WE CAN GO SO QUICKLY FROM 'IDEA' TO 'RENDER.' THERE'S NO PRE-PROCESSING REQUIREMENT. MATERIAL AND GEOMETRY CHANGES ARE MADE EXTREMELY EASY TO HANDLE INTERACTIVELY AND IN NEAR REAL-TIME."
>
> — RENAULT DESIGN DIGITAL VISUALIZATION'S GUILLAUME SHAN

Renault: Fast Path from Idea to Render

Automaker Renault has leveraged NVIDIA's Iray for Maya physically based rendering capabilities to accelerate design analysis of its vehicles. The company's Design Digital Visualization team works with a bespoke rendering solution called 3VISU based on Maya, and is responsible for creating images and video of closed-door concepts. The team produces thousands of images and animations every year.

The team wanted to be able to render changes to images quickly without having to pre-compute light maps and other pre-processing tasks. Using a CPU-based solution, this would take hours to accomplish. Renault wanted this functionality in real time.

Renault updated its 40 render nodes with NVIDIA GPUs to boost Iray's rendering speed, and deployed NVIDIA Quadro K6000 GPUs in its workstations. Design changes can be rendered in real time now, without the pre-processing work and long wait times. They can even quickly and realistically model how light enters and leaves a headlamp lens, as well as create complex animated scenarios.

"Switching to Iray ray tracing was like a dream — we can go so quickly from 'idea' to 'render,'" says Renault Design Digital Visualization's Guillaume Shan. "There's no pre-processing requirement. Material and geometry changes are made extremely easy to handle interactively and in near real-time."