



Technical Brief

NVIDIA nfiniteFX Engine:
Programmable Pixel Shaders

*N*VIDIA

The NVIDIA nfiniteFX Engine:

The NVIDIA® nfiniteFX™ engine gives developers the ability to program a virtually infinite number of special effects and custom looks. Instead of every developer choosing from the same hard-coded palette of effects and ending up with the same generic look and feel, developers can specify personalized combinations of graphics operations and create their own custom effects. Games and other graphics-intensive applications are differentiated and offer more exciting and stylized visual effects. Two patented architectural advancements enable the nfiniteFX engine's programmability and its multitude of effects: Vertex Shaders and Pixel Shaders. This paper covers the engine's programmable Pixel Shaders.

Realism for Lighting and Materials: Programmable Pixel Shaders

The final output of any 3D graphics hardware consists of pixels. Depending on resolution, in excess of 2 million pixels may need to be rendered, lit, shaded, and colored. Pixel Shaders create lighting and other custom shading effects at the pixel level. This is an unprecedented level of hardware control for consumers.

Pixel Shader Basics

Today's 3D graphics hardware lets developers create virtual worlds. Ideally, users can freely interact with and navigate through these worlds at high frame rates.



When first introduced, the image quality in Tomb Raider II was considered excellent, but wouldn't pass muster today.



Last year's NVIDIA GeForce2 series performed fixed function, per-pixel lighting. (Image shown is from Giants by Planet Moon.)

As 3D graphics hardware has evolved over the years, new features have been continuously added resulting in steady improvements to image quality.

In the early days of 3D accelerators, the best technologies consisted of bilinear filtering of relatively low-resolution texture maps. These low-resolution texture maps were mapped onto relatively large polygons, resulting in blurry textures and relatively poor image quality.

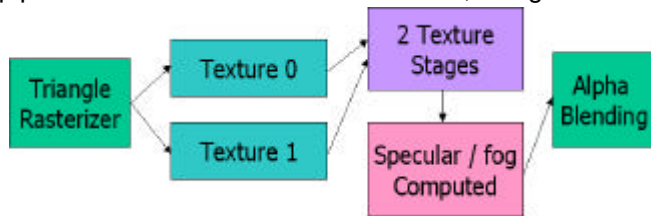
In 1999, the NVIDIA GeForce2™ series introduced a new technology: the NVIDIA Shading Rasterizer™ (NSR). The NSR gave developers the ability to add per-pixel lighting effects including sophisticated

techniques such as dot3 bump mapping. Today, the latest NVIDIA technology gives developers full control of the pixel

shading process through the use of *programmable Pixel Shaders*. Part of the NVIDIA nfiniteFX engine, programmable Pixel Shaders provide unprecedented control for determining light, shade, and color of each individual pixel.

Architectural Details

The NVIDIA GeForce2 GTS™ performed dot3 and other per-pixel effects through its fixed-function pixel pipelines. Textures could be combined, using either single pass or multi-pass techniques, to create



The GeForce2 texture stage pipeline. Note that the GeForce2 GTS supported only two texture-blend operations per pass.

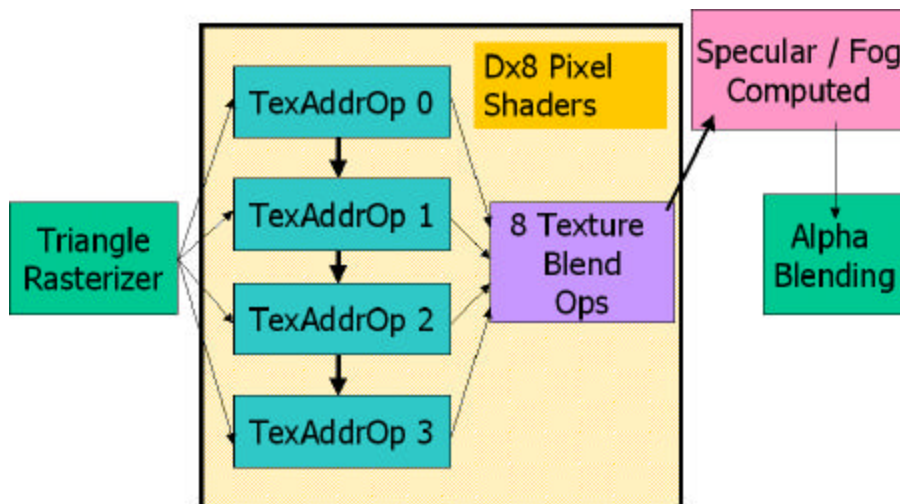
effects. There was no loopback, so effects that needed dependent texture reads, such as true, reflective bump mapping were simply not possible.

While programmers were somewhat limited by the NSR's fixed-function pipeline, it was possible to create superb per-pixel effects, including dot3 bump mapping so realistic looking that it seemed to have a huge amount additional geometric detail.

NVIDIA nfiniteFX Programmable Pixel Shaders

The NVIDIA nfiniteFX engine adds a high degree of flexibility for several reasons:

- It's programmable, allowing developers to create their own custom pixel-shading effects.
- There are more texture operations and texture address registers available.
- Dependent texture reads are now possible, giving programmers even greater flexibility.



The NVIDIA nfiniteFX texture pipeline supports up to eight texture-blend operations, dependent texture reads, and programmable Pixel Shaders.

Note that the NVIDIA nfiniteFX architecture doesn't preclude the use of Microsoft® DirectX® 7 texture operations. However, if the developer uses the more sophisticated Pixel Shader application programming interface (API) in Microsoft DirectX 8, more complex operations are possible.

Unlike Vertex Shaders, however, there is no feasible way of emulating this using software. Using Pixel Shaders on graphics hardware that doesn't support them forces the entire graphics pipeline to run in software and causing performance to fall by 100x! The NVIDIA nfiniteFX Pixel Shader architecture has unbelievably fast floating-point performance, and is capable of generating the per-pixel effects with superb performance.



A shiny, bumpy surface "breathing" in real time

The figure on the left shows one of the more sophisticated techniques possible. The object is an animated, bumpy, reflective surface—something impossible to achieve in real time with previous 3D hardware.

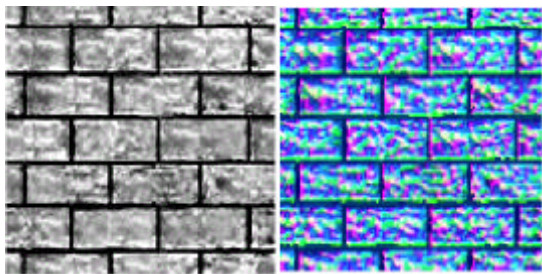
The Joy of Four Textures

Because of its abilities to handle four textures in a single pass, the NVIDIA nfiniteFX engine achieves excellent performance and enables previously impossible pixel-level effects on consumer-level platforms. Applying multiple textures in one pass almost always yields better performance than performing multiple passes. Multiple passes translate into multiple geometry transformations and multiple z-buffer calculations, slowing the overall rendering process.

Making Bump Mapping Work

Bump mapping creates the illusion of additional geometry, such as the crinkles in the warping NVIDIA logo or the deep wrinkles in the earlier *Giants* shot.

Dot3 bump mapping requires the application of multiple layers of textures. The key textures are derived



The height map is on the left; the normal map is on the right.

from the *height map* and the *normal map*. These help define the visible surface geometry. The height map is a simple gray scale, where the shades of gray represent the relative height or indentation. The normal map is an RGB color map that defines the effect from light shining on the surface. Note that "normal" in this instance refers to a mathematical



The final, bump-mapped surface.

normal, which defines a vector direction. The Pixel Shader architecture of the NVIDIA nfiniteFX engine is capable of applying the required textures in a single pass.

Pixel Shader Programmability

When people think of programs, they almost always think of high-level languages such as C++ or BASIC. However, Pixel Shader programs are much lower-level programs—assembly language programs. The native assembly language for the NVIDIA nfiniteFX programmable Pixel Shaders is the one defined in the

Microsoft DirectX 8 API.



A simple cartoon effect created with programmable shaders.

Developers can program Pixel Shaders to create personalized effects or shading algorithms. For example, Pixel Shaders could be programmed to provide a low-tech cartoon look or myriad of other stylized looks.

The possible range of effects is limited only by each developer's imagination. The nfiniteFX engine, coupled with DirectX 8 or the OpenGL™ drivers, give the programmer an unprecedented level of control with unbelievable performance.

Conclusion

The NVIDIA nfiniteFX Pixel Shader architecture represents incredible breakthrough in 3D graphics hardware. Incorporating blazing-fast floating-point performance, total control at the pixel level, and programmable shaders, NVIDIA's nfiniteFX engine brings advanced image quality to the PC desktop.