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A New Framework For Non-Photorealistic Rendering

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Abstract

Non-photorealistic rendering, or NPR, has emerged as an important field of computer graphics. Most NPR methods attempt to create imagery mimicking a particular style produced by an artist. Several such styles have been investigated, including painting, watercolor, engraving, pen and ink, color pencil, charcoal, cartoon coloring, stippling, and loose sketching. Thus far, most published NPR algorithms focus on a specific artistic style, or a closely related class of styles. Underlying these diverse artistic effects, however, are several recurring themes common to most NPR techniques. In this report, we present a novel framework for NPR based on adaptively sampled distance fields (ADFs). By representing a model as an ADF, we can interactively and accurately generate view-dependent particles (for stroking and coloring) and view-dependent triangles (for stroking, coloring, and visibility determination). From these view-dependent elements, many diverse styles can be realized by employing existing techniques. The multi-resolution nature of ADFs provide regulation of stroke (particle and triangle) density, guaranteed frame rates, and optimal use of processing resources in a system that scales both to new hardware and to models of increasing complexity. This approach thus unifies several operations common in artistic rendering. Furthermore, because ADFs can represent both hard surfaces and soft organic volumetric forms, opportunities exist to develop new volumetric NPR techniques in this single framework. We propose such a volumetric style.

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A New Framework For Non-Photorealistic Rendering

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Non-photorealistic rendering, or NPR, has emerged as an important field of computer graphics [1]. Most NPR methods attempt to create imagery mimicking a particular style produced by an artist. Several such styles have been investigated, including painting, watercolor, engraving, pen and ink, color pencil, charcoal, cartoon coloring, stippling, and loose sketching. Thus far, most published NPR algorithms focus on a specific artistic style, or a closely related class of styles. Underlying these diverse artistic effects, however, are several recurring themes common to most NPR techniques:

Strokes and Particles: Artwork typically consists of multiple separate strokes, ranging from dabs with a paintbrush to lines drawn with a pencil. Consequently, most NPR algorithms cast rendering as a process of generating and positioning strokes. These strokes are usually positioned and rendered with some degree of randomness to model the unpredictability of the artist, but this randomness can introduce flicker when the resulting images are animated. To eliminate this flicker, as well as to make strokes "stick" to the surface of the object thus avoiding the "shower door effect", [2] introduced the idea of associating strokes with particles defined on the surface of the object to be rendered. Since the strokes are associated with actual positions (particles) in space, the strokes move smoothly across the screen in a visually pleasing manner as the viewpoint shifts. Particles can be generated directly from a model (e.g., by sampling) or the model can be first converted to some other form, such as triangles, from which particles can be derived. Many systems since [2] have adopted their approach to permit the animation of a particular style.

Stroke Orientation: An artist must have control over how strokes are oriented as well as where they are positioned. [3] applied a user-specified vector field defined on an image to guide the orientation of pen and ink strokes, while techniques such as [4] and [2] rasterize normal and curvature information from a 3-D model.

Stroke Density: Concentrating strokes most densely on the silhouette of an object can suggest a great deal of complexity with relatively few strokes [5]. Too many strokes throughout the image can create a cluttered effect, while too few strokes may fail to convey the underlying shape. In styles such as pen-and-ink, stroke density also controls tone, so that too many strokes will create a darker drawing with a completely different look [3]. Simply associating strokes with (view-independent) particles does not solve the problem, since the screen-space particle density increases as objects recede into the distance.

Stroke Visibility: Determining stroke visibility is an essential ingredient to producing comprehensible shapes for NPR. Several approaches have been proposed, including adaptations of Appel's software hidden line removal algorithm, hardware z-buffering with triangle primitives, and the simple painter's algorithm [1]. Often, a particular style will mandate a particular visibility algorithm.

Hardware acceleration: As demonstrated by [6], there is a growing trend to applying hardware acceleration to various styles. As the demand increases for applications requiring real-time stylized rendering, hardware acceleration will become a necessity. Because triangles and texture mapping are the fundamental drawing primitives for hardware today, many researchers have explored ways to cast artistic rendering into these elements.

In this sketch, we present a novel framework for NPR based on adaptively sampled distance fields (ADFs) [7]. By representing a model as an ADF, we can interactively and accurately generate view-dependent particles (for stroking and coloring) and view-dependent triangles (for stroking, coloring, and visibility determination) [8]. From these view-dependent elements, many diverse styles can be realized by employing existing techniques [1]. The multi-resolution nature of ADFs provide regulation of stroke (particle and triangle) density, guaranteed frame rates, and optimal use of processing resources in a system that scales both to new hardware and to models of increasing complexity. This approach thus unifies several operations common in artistic rendering. Furthermore, because ADFs can represent both hard surfaces and soft organic volumetric forms, opportunities exist to develop new volumetric NPR techniques in this single framework. We propose such a volumetric style below. Finally, the distance field provides other advantages, such as providing new ways for generating orientation fields, which can be exploited in existing techniques.

Adaptively Sampled Distance Fields

A distance field is a scalar field that specifies the minimum distance to the surface of a shape. When the distance field is signed, the sign can be used to distinguish between the inside and outside of the shape. ADFs adaptively sample the shape's distance field and store the sampled distance values in a spatial hierarchy for efficient processing. This sketch uses octree-based ADFs with trilinear distance and gradient reconstruction functions.

Volumetric NPR With ADFs

Because ADFs represent more than the surface of a model (i.e., the model's interior and the space in which the model sits), they are amenable to volume rendering, thus enabling volumetric styles to be developed. For example, offset surfaces can be trivially computed from the distance field and then used to render variable-width, translucent surfaces. Adding volume texture within the variable-width surface in the form of variations in color or transparency is straightforward. In addition, distance values can provide valuable input to procedural volumetric shaders to achieve effects that vary according to the distance from the surface. Figure 1 shows an ADF alcohol molecule rendered with sampled ray-casting – note the thick, translucent surfaces.

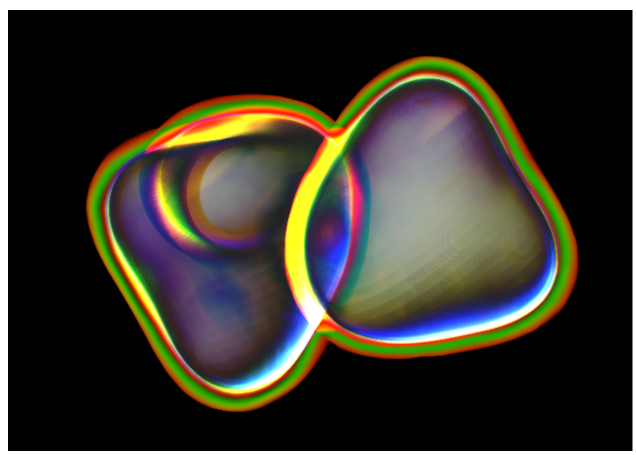

Figure 1 – A volumetric style rendered with ADFs.

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