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NON-PHOTOREALISTIC RENDERING FOR OUTDOOR SCENE

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INTRODUCTION

Advance rendering technique in computer graphics include non-photorealitstic rendering. Non-photorealistic Rendering (NPR) has become an important area of research in computer graphics. One interesting fact in this area is that many of the techniques developed over the years in computer graphics research can be used here to create specific effects. Many NPR images created from 3D models and combine many different algorithms to yield exactly the image that user wants.

In computer graphics, photorealistic rendering attempts to make virtual images of simulated 3D environments that look like "the real world". So NPR is any technique that produces images of simulated 3D world in a style other than "realism". Non-photorealistic rendering is a representation of style for computer imagery using non-photorealistic techniques to create artistic illustration (sketch, pen and ink, hatching, etc), paintings (painterly rendering) or render 3D scenes in styles which match the "look" of traditional animated cartoon, which conveys hand-drawn artistic illustration of art.

There is an overall reason why NPR might continue to expand its influence within 3D graphics and perhaps eventually grow to rival the importance of photorealistic rendering: realism is expensive. We need a vast amount of detail to faithfully represent and animate a realistic natural scene. When a human (designer)

creates that scene by hand, the process necessarily requires great time and effort. One strategy to avoid this inherent cost of realism is to capture details from the real world. Examples include image-based rendering, 3D scanning and motion capture. But these strategies have limitations, which they require that the desired data be presented in the real world at a suitable scale. For many applications, including storytelling, this might not be the case. When scanning is not an option, the alternative currently is to hire a team of trained experts and let them painstakingly model and animate the needed 3D content by hand. While this strategy works, it is only feasible for high-budget industries such as games and movies. For 3D graphics to reach new applications and attract new users, something must be changed. We believe NPR has the potential to solve the content creation problem because non-photorealistic images can be far simpler to create by hand than photorealistic ones.

Much of the research in NPR has targeted a particular style of imagery and developed algorithms to reproduce that style when rendering appropriately-annotated 3D scenes and photographs. When comes to the context of 3D scene rendering, it is usually involving non-photorealistic rendering on 3D characters, technical illustrations, virtual environment and geometrical objects. There is not a deep insight on rendering a 3D outdoor scene which depicts non-photorealism.

An outdoor scene consists of a combination of many objects and geometrical elements such as trees, plants, buildings, road, sky and vehicles, which are complex in structure and sizes that is not easy to be rendered. Many considerations on the different characteristics of every element has to be done before rendering the scene because various types of rendering techniques will be used on different types of geometrical objects.

DIFFERENCE BETWEEN PHOTOREALISM AND NON-PHOTOREALISTIC

Photorealism is one representational form of images to represent the outside world in an "objective way". It creates images which depicts realism. Non-photorealistic rendering exhibits a non-realistic image. Table 1 shows the comparison between photorealism and non-photorealistic.

Table 3.1 Comparison of photorealism and non-photorealistic rendering (NPR)

	Photorealism	**NPR**
Approach	Simulation	Stylization
Characteristic	Objective	Subjective
Influences	Simulation of physical processes	Sympathies with artistic processes; perceptual-based
Accuracy	Precise	Approximate
Deceptiveness	Can be regarded as "dishonest"	Honest
Level of detail	Constant level of detail	Can adapt level of detail across an image to focus the viewer's attention
Good for representing	Rigid surfaces	Natural and organic phenomena

Application of NPR

In many applications, such as architectural, industrial, automotive and graphics design, non-photorealistic is preferred than photorealism. Non-photorealistic conveys information better by omitting extraneous details, by focusing attention on relevant features, by clarifying, simplifying and disambiguating shapes and showing parts that are hidden. It also provides more natural vehicle for conveying information at different level of details. Besides that, the resulting images are more attractive as they add a sense of vitality difficult to capture with photorealism.

In architectural designs, for example, an architect presents the client with a preliminary design for a house not yet built. An imprecise pencil sketch that omits many details suggests to client that the design remains open for revision, providing the exchange of ideas and keeping the client happy.

Another example of the use of drawings instead of photographs is the case of medical textbooks. Medical textbooks employ schematic line drawing to illustrate anatomical structures. It is because photographs tend to imply an exactness and perfection of the scene to a real object. Hand-drawn illustrations can better communicate 3D structure, elide the unimportant details and emphasize important features only.

In paintings, a scene represents an artist's view of the world. All the information he wants to convey with his image has to be assembled by strokes of a brush. Therefore, to create a work of art, the artists would have to understand their subject matter so that they could include their interpretation of the important details in rendering.

In the film production industry, most of the non-photorealistic rendering work centers around the "toon-shading" or the rendering of 3D objects to match the look of traditionally drawn 2D artwork. For example, in the cartoon animated movie Tarzan, where the painterly 3D jungle, through which the 2D ape man swings, designed in non-photorealistic style albeit in a recognized cartoon-like style. By using "toon-shading", a form of

non-photorealistic rendering, to render 3D objects, graphics designers can create more complex props, objects, and scene with thousands of characters that would be far too complex or costly to draw. Apparently, this allows them to produce things in volume and at scale that would be otherwise impossible.

Outdoor Scene

The term "outdoor" is antonymous with the term "indoor". Outdoor refers to things that that exist in the open air, which involves scenery view of sky and land. It does not relate to things in a closed-space area, such as in a building or in a room. Outdoor scene exhibits geometric complexity, which defines the environment of an open-space, conveying information of the atmosphere of the real world. Outdoor environments are typically flat and sparsely occluded, so the area that can be observed by humans is rather large. Therefore, the sheer scale of outdoor scenes is significantly larger than that of indoor scenes. Outdoor scenes can be categorized in several characteristics, which are:

i. **Natural scenery** – scenery consists of natural resources and beauty. For example, scene of a forest, jungle, waterfall, seaside, ocean, and a garden of flowers.

ii. **Buildings** – scenery contains buildings, which is usually common for the architectural designs. For example, the view of Petronas Twin Tower, offices and shop houses, shopping complexes and architectural building designs.

iii. **Urban scenery** – scene that reflects the real city life and environment with skyscrapers, buildings, vehicles and other elements found in urban city areas. For example, New York city has various styles of buildings and complex structures of lifestyle.

iv. **Countryside scenery** – scene that indicates the lifestyle in countryside and its atmospheric landscape with barns, cottages, coconut trees, mountains or hills, paddy fields, farms and many more.

OVERVIEW OF NON-PHOTOREALISTIC RENDERING

The field of non-photorealistic rendering (NPR) involves various techniques in rendering many types of applications, namely in cartoon animations, film productions, architectural designs, artistic paintings and in technical illustrations.

The emerging applications of non-photorealistic rendering have basically focused on rendering human and cartoon characters, artwork masterpieces, and technical tools. There is not a clear focus on rendering non-photorealistic outdoor scenes. Apparently, most of the researches are based on the rendering the realistic of an outdoor environment in virtual reality environment (Debeyec, Taylor & Malik 1996). The traditional strategy for immersive virtual environments is to render detailed sets of 3D polygons with appropriate lighting effects as the camera moves through the model (Manocha 2000). With this approach, the primary challenge is constructing a digital representation for a complex, visually rich, real-world environment.

In recent years, a few researchers have turned their attention away from photorealism and towards developing non-photorealistic rendering techniques in a variety of styles and simulated media, such as impressionist painting (Haeberli 1990; Litwinowicz 1997; Meier 1996), pen and ink (Winkenbach & Salesin 1996), technical illustration (Gooch et al. 1998), watercolor (Curtis et al. 1997) and the style of Dr. Seuss (Kowalski et al. 1999). Most of these works have focused on creating still images either from photographs, from computer-rendered reference images, or directly from 3D models, with varying degrees of user-

direction. One of their goals is to make their system work in conjunction with any of these technologies, particularly those that are more automated, to yield virtual environments in many different styles.

Several stroke-based NPR systems have explored time-changing imagery, confronting the challenge of frame-to-frame coherence with varying success. Winkenbach et al. (1994) and later Curtis et al. (1997) observed that applying NPR techniques designed for still images to time-changing sequences yields flickery, jittery, noisy animations because strokes appear and disappear too quickly. Meier (1996) adapted Haeberli's "paint by numbers" scheme (1990) in such a way that paint strokes track features in a 3D model to provide frame-to-frame coherence in painterly animation. Litwinowicz (1997) achieved a similar effect on video sequences using optical flow methods to affix paint strokes to objects in the scene. Markosian (1997) found that silhouettes on rotating 3D objects change slowly enough to give frame-to-frame coherence for strokes drawn on the silhouette edges.

Techniques of NPR

There are many techniques available for non-photorealistic rendering (NPR). Examples of the techniques used in NPR are water-colour technique (Curtis et al. 1997), silhouettes rendering techniques (Hertzmann 1999), real-time rendering (Markosian 1997), hatching, charcoal rendering, stylized sketching (Winnemoller & Bangay 2003) and pencil drawing techniques (Sousa and Buchanan 1999).

Different style of rendering produces different effects to the rendered scene and images. Considerations are made upon to the decision on rendering what kind of objects relatively to its purpose, time and the usage capability. For outdoor scene, pen-and-ink illustration is usually used in architectural designs where the ink outline of the image gives a clear picture of the structure of the designs and the texture tone effects resembles hand-drawn. As for

the water colour and painterly rendering, they are commonly used to depict outdoor natural scenery which involves natural resources. A sketchy artwork of outdoor scene with black and white features is created using halftoning techniques. Cartoon rendering is preferred in cartoon film production to produce background scenes in movies which convey cartoon resemblance.

RENDERING FRAMEWORK

There are several phases that should be implemented in order to achieve the intended cartoon-shaded outdoor scene, namely input of the 3D scene, which is then rendered with silhouette and cartoon rendering techniques.

Silhouette

A silhouette is an edge that connects one back-facing (invisible) polygon to a front-facing polygon. Therefore, an edge is marked as a silhouette edge if a front-facing (visible) and a back-facing (invisible) polygon share the edge as illustrated in Figure 3.1.

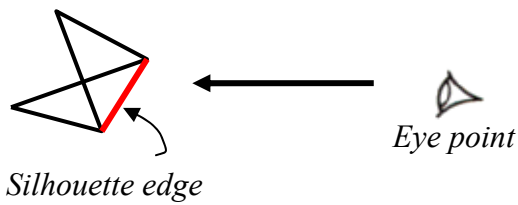

Figure 3.1 Silhouette edge detection. A silhouette edge is an edge between a front-facing and a back-facing polygon

Generally, the silhouette set of a model can be computed into two methods: in object space and in screen space. The object

space algorithms involve computations in three dimensional (3D) views and produce a list of silhouette edges or curves for a given viewpoint. The screen space algorithms, on the other hand, involve image processing techniques and are useful if rendering silhouettes is the only goal. There are many approaches in extracting and detecting silhouette edges in object space (Gooch 2003).

The Brute Force method of silhouette extraction simply tests each edge in the polygonal mesh sequentially to verify whether or not it is a silhouette. Brute Force approach extracts the silhouette edges of the scene as the approach is simple and its performance is faster than edge buffer. Probabilistic method is usually used in animation rendering where temporal coherence is considered. Whereas Gauss Map Arc Hierarchy is only suitable for orthogonal view, and Normal Cone Hierarchy is more complex and difficult to be implemented.

The focus is on Brute Force as it is the simplest form to determine silhouettes. The implementation of silhouette edge detection is based on the algorithm described by Adam Lake et al (2000). The equation of the formula is shown in Equation 1, which $faceNormal_1$ and $faceNormal_2$ represent normal of two polygon faces adjacent to an edge, and *eyeVect* indicates the viewing vector from the eye point. If the result of the computation is less than or equal to zero, the edge is a silhouette edge and it is flagged for rendering.

$$(faceNormal_1 \bullet eyeVect) * (faceNormal_2 \bullet eyeVect) \leq 0$$

Cartoon Rendering

Cartoon rendering is done to enhance the scene to look like cartoon. The brunt of cartoon rendering lies in the shading algorithm. Rather than smoothly interpolating across an object as the Gouraud or Phong shading models do, to give the object a three-dimensional appearance, cartoon rendering typically uses solid colours that do not vary across the material they represent, which helps add lighting cues, cues to the shape and context of the object in the

scene, and even dramatic cues. Figure 3.2 illustrates a production of 3D cartoon rendered outdoor scene which is rendered using hard shading technique.

Figure 3.2 A scene of City of Birmingham (UK) in 1066 (Studio Lidell 2000)

For shading, we need to calculate the directional light which to find how much light each vertex receives by calculating the dot product of the light vector and the normal vector of a vertex. The dot product function calculates the angle between two vectors and results a value with a maximum of 1. The result of the function $\overline{L} \bullet \overline{n}$ is actually the cosine of the angle formed between the two vectors. Since the result of a dot product has a maximum value of 1, we can use the result of the dot product as the texture coordinate to map to greyscale texture map. If the result of the dot product is less than 0, then the texture coordinate is considered as 0. It is because texture coordinates are stored between 0 and 1($0 \leq x \leq 1$), which happens to be that the dot product of the normal and the lighting direction vector actually gives us the texture coordinate. The resulted numbers are used as the index for the 1D texture mapping

coordinates. The dot product function generating texture coordinates is shown in Figure 3.3.

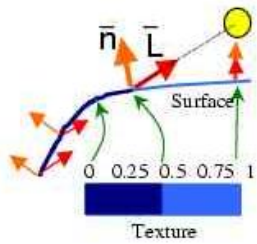

Figure 3.3 Generation of texture coordinates from $\overline{L} \bullet \overline{n}$. In this case, the colour boundary occurs at the point where $\overline{L} \bullet \overline{n}$ equals to 0.5

CONCLUSION

Many techniques of NPR have been introduced over these years, namely stylized sketching, pen-and-ink illustration, water-colourization, cartoon-shading, hatching, painterly rendering and silhouette rendering. These techniques are useful many applications in industrial designs, architectural drawings, medical and scientific visualizations, film production, cartoon animations, games development and computer graphics designs. Creating a non-photorealistic scene in the graphics applications is commonly known as virtual environment.

Virtual environments allow us to explore an ancient historical site, visit a new home with a real estate agent, or fly through the twisting corridors of a space station in pursuit of alien prey. They simulate the visual experience of immersion in a 3D environment by rendering images of a computer model as seen

from an observer viewpoint moving under interactive control by the user. If the rendered images are visually compelling, and they are refreshed quickly enough, the user feels a sense of presence in a virtual world, enabling applications in education, computer-aided design, electronic commerce, and entertainment.

While research in virtual environments has traditionally striven for photorealism, for many applications there are advantages to non-photorealistic rendering (NPR). Artistic expression can often convey a specific mood (e.g. cheerful or dreary) difficult to imbue in a synthetic, photorealistic scene. Furthermore, through abstraction and careful elision of detail, NPR imagery can focus the viewer's attention on important information while downplaying extraneous or unimportant features. An NPR scene can also suggest additional semantic information, such as a quality of "unfinishedness" that may be desirable when, for example, an architect shows a client a partially-completed design. Finally, an NPR look is often more engaging than the prototypical stark, pristine computer graphics rendering.

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