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A Deferred Rendering Pipeline Including a Global Illumination Model for Atmospheric Scattering and Transparency

S. Heppner[1], M. Dransfeld[1] and G. Domik[1]

[1]Paderborn University, Computer Graphics, Visualization and Image Processing, Germany

Abstract

This poster presents suitable global illumination models for atmospheric scattering in outdoor scenes combined with a deferred rendering pipeline which offers the possibility of rendering transparent objects. The use case is a HIL simulation for camera based ADAS tests that require a realistic rendering of outdoor scenes.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Picture/Image Generation—Display algorithms I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism —Color, shading, shadowing, and texture I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism —Consumer products J.7 [Computer Graphics]: Real time —

1. Introduction

Testing a camera based Advanced Driver Assistance System (ADAS) during its development by performing real test drives is cost- and time-intensive. as well as dependent on external factors like weather. Thus, a real test drive is not completely repeatable. An alternative is given by HIL (Hardware-in-the-Loop) simulations. Here, the car and the environment are simulated. The simulated environment is rendered onto a monitor captured by the camera sensor. The sensor data is processed by the ECU (electronic control unit) which sends controlling signals to the simulator. The ADAS components (sensor and ECU) and the simulator work interactively, thus a pre-rendered virtual test drive is not sufficient. Our collaborators in industry (called "domain experts" from here on) developed a real-time, interactive renderer based on a deferred rendering pipeline. Two master theses recently enhanced the virtual outdoor scenes with more realism: The first thesis [Hep15] describes the implementation of an illumination model for atmospheric scattering; the second thesis [Dra16] expands this concept by adding correct rendering of transparency. In both cases the requirements asked for best realism possible within real-time frame rates and the need to implement algorithms inside a deferred rendering pipeline.

2. Research and Implementation

There exist several approaches implementing atmospheric scattering into a virtual scene. The approach published by BRUNETON & NEYRET [BN08] is assessed as the most promising one, because of its realistic visual results, its good performance and the possibility to add it to a deferred rendering pipeline [Hep15]. Atmospheric scattering effects (e.g. indirect illumination, blue color of the sky, color gradient on the horizon, coloring of dawn and twilight, aureole and aerial perspective) are based on physically correct models which are precalculated for the most part.

[Dra16] analyzes the integration of transparency into the intermediate concept. The analysis shows that illumination and transparency can be combined trivially. Transparent objects and underlying opaque objects are illuminated separately and their colors are combined by blending. Three techniques fulfill best the given requirements for implementing blending into a deferred rendering pipeline: Weighted Blended Order-Independent Transparency (WBOIT) [MB13], Inferred Lights (IL) [KL09], and A-Buffer/Linked Lists (LL) [YHGT10] [LHL14].

3. Evaluation

The evaluation process was a collaboration with our domain experts based on several ADAS test scenes featuring different complexities.

3.1. Performance

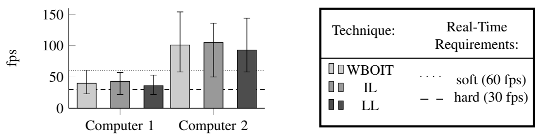

Figure 1: *Average and minimal/maximal performance*
(Computer 1: Intel Core i7 860, nVidia Quadro K2000, 4GM RAM, Computer 2: Intel Core i5 4750, nVidia GTX 660, 16GB RAM)

To evaluate real-time requirements, the performance was measured. The hardware was carefully chosen to cover conditions prevailing in the work environment of our domain expert's customers.

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As the following examples indicate a more powerful hardware would cause an even better performance.

Global Illumination Model: The rendering time on a standard PC (Intel Core i7-3770, 3.40 GHz, nVidia Quadro 600, 8 GB RAM) guarantees frame rates of more than 60 fps. Using a more powerful GPU (nVidia GeForce GTX 660 Ti) decreases rendering time to one fifth. Thus, it is shown that the approach of BRUNETON & NEYRET can be integrated in a deferred rendering pipeline without disadvantages concerning the real-time performance.

Transparency Extension: Figure 1 shows the results of the performance test. It is obvious that all three techniques offer similar results. The weaker computer (1) reaches the hard real-time requirement. In the case of the more powerful computer (2) even the worst measured performance values exceed the number of 60 fps and thus the soft real-time requirement is fulfilled. Because precomputation remains unchanged, its performance is unaffected.

3.2. Visual Quality

To verify if there is an improvement in realism, the visual quality is analyzed concerning the preference of our domain experts.

Global Illumination Model: The visual quality is assessed by the effects of atmospheric scattering. The visual effects caused by atmospheric scattering are implemented directly by [BN08]. Figure 2 contrasts (a) the previous rendering without atmospheric scattering with two atmospheric rendering effects: (b) "morning sun" and (c) "blue hour"caused by absorption through the ozone layer. The domain experts considered the visual quality as an important increase of realism without losing interactive frame rates, so that they see the enhancements as having an enormous positive effect for their products.

(a) *without scattering* **(b)** *morning sun* **(c)** *"blue hour"*

Figure 2: *Comparison - Atmospheric Scattering*

Transparency Extension: Table 1 shows screenshots of the three implemented transparency techniques. Due to the multiple rendering artifacts, WBOIT and IL are rejected by our domain experts, more detail follows below. LL offers a good quality, but demands a suitable graphics card.

WBOIT: For surfaces with low alpha values the results are of desired quality (1a). In case of high alpha values or very saturated colors, rendering artifacts (2a) occur. Furthermore, there exists a problem concerning the perceived ordering (3a).

IL: Low resolution rendering and subsequent upscaling of transparent surfaces cause a very low quality (2b). Lighting fails completely for surfaces with the same stipple pattern rendered on top of each other (1b, 3b).

LL: LL delivers desirable image quality (1-3c), provided that atomare operations (introduced by OpenGL 4.0 and DirectX 11) are supported. Otherwise a flickering effect might appear.

Due to rendering artifacts in the case of WBOIT and IL, LL is the most satisfying technique as long as a suitable graphics card is provided. In the case that the used hardware is unknown and the rendered scenes are known, WBOIT shows a good compromise when using the weight function for fine adjustment.

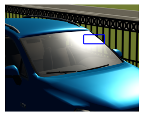
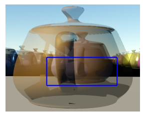
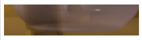
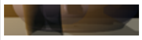
	(1) leaves		(2) windshield		(3) teapots	
						
(a) WBOIT		✓		✗		✗
(b) IL		✗		✗		✗
(c) LL		✓✓		✓✓		✓✓

Table 1: *Comparison - Transparency (✓✓: good, ✓: acceptable, ✗: bad)*

4. Summary & Conclusion

Our solution employs a deferred rendering pipeline which features atmospheric scattering and transparency to be added without noticably slowing down real-time requirements while at the same time providing a pleasing natural effect. Regarding the implementation of transparent objects (e.g. windshield) and realistic rendering of fences and foliage (textures with a dedicated alpha channel), we have found Weighted Blended Order-Independent Transparency, Inferred Lighting and Linked List to be techniques all satisfying the real-time requirements, while only Linked List reaches the visual realism (and Weighted Blended Order-Independent shows a good compromise) required by our domain experts. However, the best visual quality is attained at the cost of sufficient video memory and a modern GPU supporting atomic operations.

Acknowledgment

The models placed in the test scenes are provided and copyrighted by dSPACE GmbH.

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