Improved Gamma Ton Tracing Technique Using Height Field Profile Tracing

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This paper focuses on simulating weathering effects on surfaces that employs displacement mapping to achieve fine details. To solve this problem, we introduce a two-reference-surface height field profile tracing model and integrate it with the gamma ton tracing technique, which is widely used to simulate multiple, continuing weathering effects in virtual scenery. By using the two-reference-surface height field profile tracing model, the existence of the intersection between the extruded surface and the gamma ton can be easily distinguished. With this improved gamma ton tracing technique, we can introduce weathering effects that customized to the surface geometry that disturbed by the displacement map. Our technique can be helpful in the fields such as digital heritage recovery to enhance the sense of reality by introducing weathering effects to the scenery with models using displacement mapping to achieve complex ornamentations.

Keywords: Rending, weathering simulation, gamma ton tracing, displacement mapping.

1. Introduction

This article presents an improved gamma ton tracing technique to simulate weathering effects on models using displacement mapping to achieve complex details. By using the two-reference-surface height field profile tracing model, which is a variation of the original method (NATALYA, 2006), weathering effects introduced by displacement mapping can be taken into consideration in processes of calculating the surface properties and the propagation of gamma tons.

The two-reference-surface height field profile tracing model presented in this article is employed for intersection detection. Besides the original upper reference surface, a lower reference surface is used to quickly distinguish the existence of the intersection between the test ray, which do not intersect with the upper reference surface, and the extruded surface. It is different from ray tracing in which the original height field profile tracing model is used since the directions of rays from a surface point can be random in some processes of the gamma ton tracing technique. The improved gamma ton tracing technique is to integrate this new model with two main procedures of the gamma ton tracing technique, one is the surface properties calculation, and the other is the gamma ton propagation.

It is an important cue in photo-realistic rendering that to introduce weathering effects in the virtual scenery. Scenes with all the objects that are brand-new may make us feel artificial. The traditional gamma ton tracing technique, although it can yield satisfied result of weathering simulation, does not support displacement mapping, which means that high-poly models need to be used to calculate weathering effects for rich detailed surface. A high-accuracy model is expensive both for building and rendering and it is common to use displacement mapping to render fine-scale geometric features without increasing the complexity of the underlying surface mesh. Therefore, it is necessary to make some changes to the traditional gamma ton tracing technique to support the usage of displacement mapping.

One important application is in the field of digital heritage recovery. For cultural relics that no longer exist, or could not be scanned, we need to build models manually. But it is difficult, even impossible to build a high-accuracy model with rich details by hand, so displacement mapping is necessary. Displacement map can be calculated from pictures or photos of the cultural relic, and can produce accurate details of the surface. Thus, the improved gamma ton tracing technique can be used to simulate the weathering effects on cultural relic models with displacement mapping.

2. Related work

Procedural texturing (COOK, 1984; EBERT *et al.*, 1998) is a traditional approach for creating irregular patterns and shapes. Other Procedural texture approaches that are widely used include Perlin noise (PERLIN, 1985), Reaction diffusion textures (WITKIN and KASS, 1991) and 3D surface cellular automata (GORBON and CHIBA, 2001).

Fractal subdivision techniques and relatively simple distribution models are used to model blemishes (BADLER and BECKET, 1990). MILLER (1994) and HSU and WONG (1995) found out that the distribution of blemishes is strongly geometry-dependent and related to the accessibility and exposure maps respectively.

Physically-based simulation fully automates the simulation of weathering and obtains realistic results. Some representative approaches include (DORSEY *et al*., 1996), that simulated surface appearance changes as the result of rainwater flowing over surfaces over a long period of time. (PAQUETTE *et al*., 2002) captured paint cracks and peelings. (MERILLOU *et al*., 2001) examined metal corrosion. (BOSCH *et al*. 2004) studied scratches. (DESBENOIT *et al*., 2004) modelled lichen growth.

In this paper, a visual simulation technique named gamma ton tracing technique (CHEN, Y. *et al*., 2005) is used for the reasons that this technique can readily capture several effects that are challenging for existing techniques. These effects include global transport effects, or "stain-bleeding" and visual simulations of complex multi-weathering effects.

3. Height field profile tracing using two reference surfaces

In this paper, a new model of height field profile tracing with two reference surfaces is introduced to help quickly distinguishing the existence of the intersection between the ray and the extruded surface, as illustrated in fig. 1. In this model, besides the upper reference surface that is commonly used, a reference surface under the extrude surface is introduced to test whether or not a ray started from a point on extruded surface intersects with the extruded surface if there is no intersection between the ray and the reference surface that is above the extruded surface.

The original height field profile tracing is used to determine whether a point on the extruded surface is in the shadow or not. In this case, only when the angle between the light vector and normal vector of point on the upper reference surface is acute angle, the light source will be calculated. Thus, the ray from the point on the extruded surface to the light source can only intersect with the upper reference surface. However, in the gamma ton tracing technique, the direction of the ray from an extruded surface point is random, which means it may not have an intersection with the upper reference surface. To detect the intersection under this situation, the lower reference surface needed to be employed.

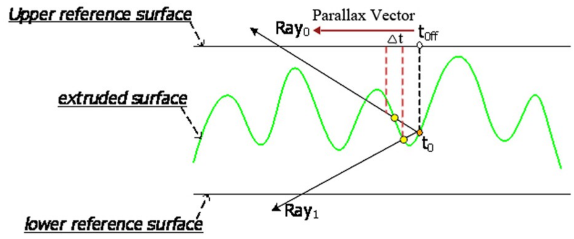


Figure 1: *This figure illustrated the model of Height field profile tracing with two reference surfaces.*

As showed in fig.1, the upper reference surface is the original surface that is not been disturbed, and the extruded surface is the surface after offset, which is rich in details and will be finally rendered. The lower reference surface is only used to discriminate the existence of intersection between rays from the surface point and the extruded surface. For rays starting from point t0, if the ray intersects with the upper reference surface, then a standard height field profile tracing arithmetic is employed to calculate the real intersection point on the extruded surface; if the ray intersects with the lower reference surface, then it is easy to prove that the ray intersects with the extruded surface, and the real intersection point can also be calculated just by doing a little change to the standard arithmetic.

4. Improved gamma ton tracing technique

In order to support displacement mapping, we need to integrate the two-reference-surface height field profile tracing model with the gamma ton tracing technique. This new model is employed by two main procedures of the gamma ton tracing technique. One is the surface properties calculation, and the other is the gamma ton propagation. For calculating the surface property, a number of rays with random directions are shot from the point in order to calculate the exposure attribute of the point. To support the gamma ton propagation, the problem of detecting the intersection between a parabola ray and the extruded surface must be solved.

4.1. Calculation of surface properties of the extruded surface

By using the two-reference-surface height field profile tracing model, it is easy to calculate the exposure attribute (WONG *et al*., 1997), which is the core of the surface properties, for the extruded surface. The exposure attribute is stored as a texture. For each text of the exposure texture, we can use the corresponding UV coordinate to find the point on the upper reference surface, then the displacement map is employed to find the real position of the point on the extruded surface.

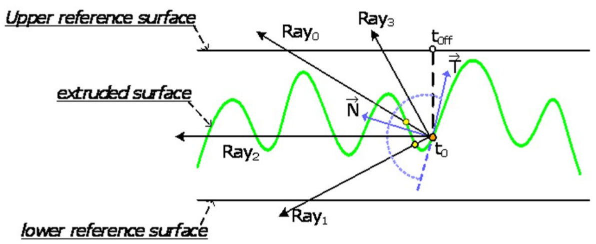


Figure 2: *This figure illustrated the model for calculate exposure attribute of a point on extruded surface.*

As illustrated in Fig.2, the outgoing directions of sampling rays from t_0 are distributed over the upper hemisphere centered at the surface points t_0 in its tangent space based on a certain pattern. If we consider all the rays from t_0 as a series of variations (d_0, d_1,…,d_n), each d_k represents the distance between the intersection point and t_0. If ray_i intersects with the extruded surface, then the value of d_i is the distance, otherwise, the value is constant, which represents the infinity in the scene. Rays in the following two situations can be considered as having an intersection with the extruded surface:

a. The ray that intersects with the upper reference surface and can find a real intersection point on the extruded surface, like Ray_0 in Fig.2.

b. The ray that intersects with the lower reference surface, as Ray_1 shown in Fig.2.

If a ray has an intersection with the upper reference surface, but cannot find a real intersection point on extruded surface, then we can discriminate that the ray does not intersect with the extruded surface, like Ray_3 shown in Fig.2. If a ray has no intersection with neither of these two reference surfaces, then the ray is considered as having no intersection with the extruded surface, like Ray_2 shown in Fig.2. Although in this situation, the ray is more likely to have an intersection with the surface, since the ray has no intersection with the two reference surfaces, it is impossible to calculate the parallax vector, which is necessary in testing the real intersection point. Thus, to consider it as no intersection, we can simplify the calculation while do not influence the result too much since it is a small probability event.

The exposure attribute value can be simply defined by the function below:

$$\omega(d_i) = \frac{d_i}{d_h + d_i} \quad \text{where } d_h > 0$$

$$G_\varepsilon \approx \frac{1}{n}\sum_{i=1}^{n} \omega(d_i)$$

The $G\varepsilon$ is the exposure attribute value at t0, n is the number of rays from t_0. The constant d_h is the half-exposure distance, which is roughly the average spacing between t_0 and other obstacles that would reduce the exposure to 0.5.

4.2. Gamma ton propagation with the two-reference-surface height field profile tracing

Gamma tons propagate in a scene following four basic motion states: propagating in space along a straight line, propagating in space along a parabolic trajectory, adhering and flowing on a surface, or settling on a surface. For each time, one gamma ton can only have one motion state.

For motion states like bounce and flow, it is crucial to discriminate whether a parabola that starts from t0 intersects with the extruded surface or not.

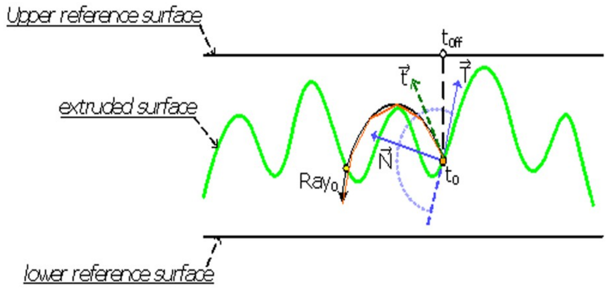


Figure 3: *This figure illustrated the model for discriminate whether or not a parabola started from t_0 intersects with extruded surface.*

As shown in Fig.3, the parabola Ray_0 is represented approximately by a series of straight lines. Therefore, instead of finding an intersection point between the parabola and the extruded surface, finding intersections between those straight lines and the extruded surface is much easier. If, for one line, the intersection exists and the distance between the intersection point and the starting point of the line is not over the length of the line, then the parabola intersects with the extruded surface; otherwise, if for all the short lines, the intersection does not exist, then the parabola does not intersect with the extruded surface.

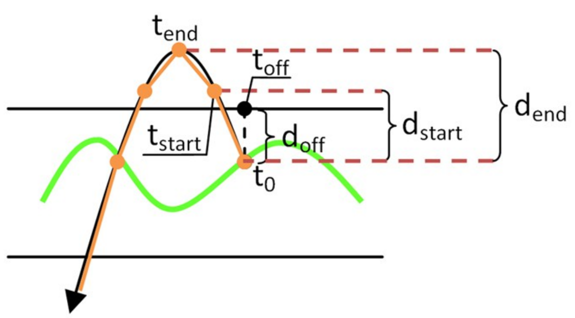


Figure 4: *This figure shows the situation when a parabola is above the upper reference surface.*

When a parabola is above the upper reference surface, the methods of calculating intersections between straight lines and the extruded surface should be discussed under different conditions. The straight lines can be divided into three different types based on their starting and ending points position:

a. $d_{start} \leq d_{off}$, which means the starting point of the straight line is between the upper and the lower reference surface. This is the normal situation, so the regular calculation method can be used.

b. $d_{start} > d_{off}$ and $d_{end} > d_{off}$. In this situation, both of the starting and ending points of the straight line are above the upper reference surface. Since the extruded surface is between the two reference surfaces, there is no intersection between the straight line and the extruded surface.

c. $d_{start} > d_{off}$ and $d_{end} \leq d_{off}$. Under this condition, we need to replace the starting point with the intersection point between the straight line and the upper reference surface. After that, the regular calculation method can be employed.

5. Results compare

In this article, we present an improved gamma ton tracing technique to support the displacement mapping. The following results can show the differences between the original and the improved technique. There are two groups of result comparison, one is employed to show the difference between the two exposure attribute maps achieved by the original and the improved technique; and the other is used to show the difference of the weathering map.

Fig.5 illustrates that the improved gamma ton tracing technique can recognize the surface properties that are introduced by the displacement mapping.

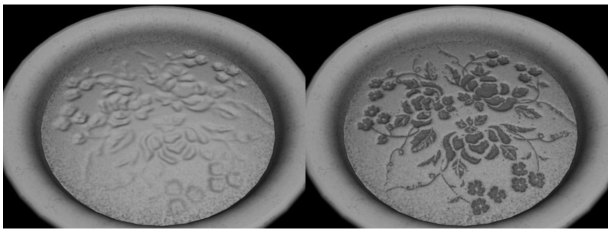


Figure 5: *A compare of exposure map created by the original (left) and the improved gamma ton tracing technique (right).*

Fig.6 shows that the two-reference-surface height field profile tracing can finely support the gamma ton propagation and produce the final weathering map by recording the distribution of the settled gamma tons.

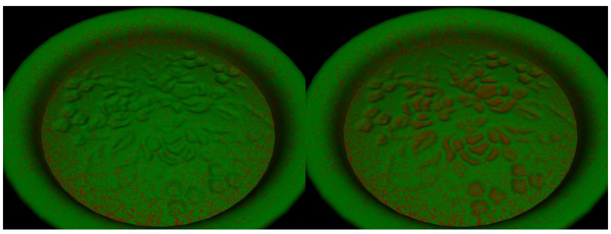
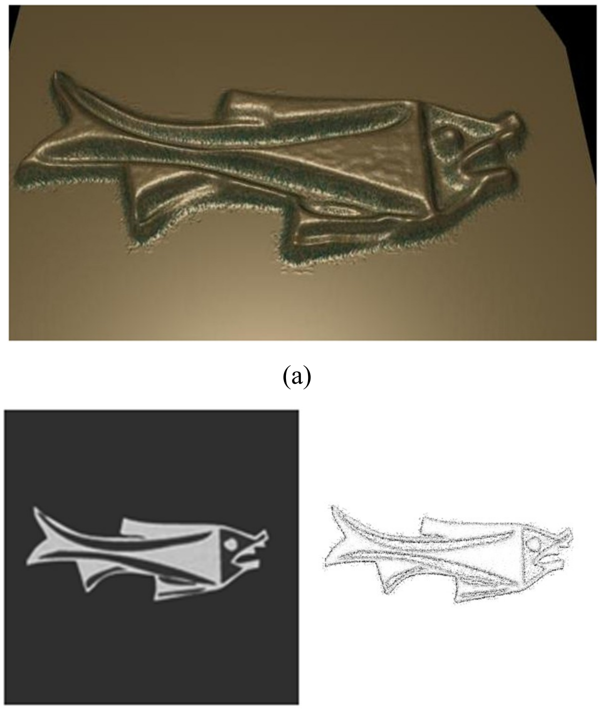


Figure 6: *A compare of weathering map created by the original (left) and the improved gamma ton tracing technique (right).*

Fig.7 illustrates the final rendering result of a fine detail on a plane achieved by using the displacement mapping with a fish pattern and the rusting effect generated by the improved gamma ton tracing technique.

Through the weathering map, we can clearly notice that the distribution of gamma tons is influenced by the displacement map. In the rendering picture, the weathering effect distributes according to the weathering map, on surface regions with details achieved by displacement mapping.



(a)

(b) (c)

Figure 7: *Patina on a plane with displacement pattern. (a) is the final rendering result, (b) is the displacement map, (c) is the weathering map.*

Conclusions

In this paper, an improved gamma ton tracing technique is presented to achieve weathering effects on models having used displacement mapping. By replacing the basic ray tracing with the two-reference-surface height field profile tracing, the gamma ton tracing technique can be used to simulate weathering effects for rich detailed surfaces without using high-poly models.

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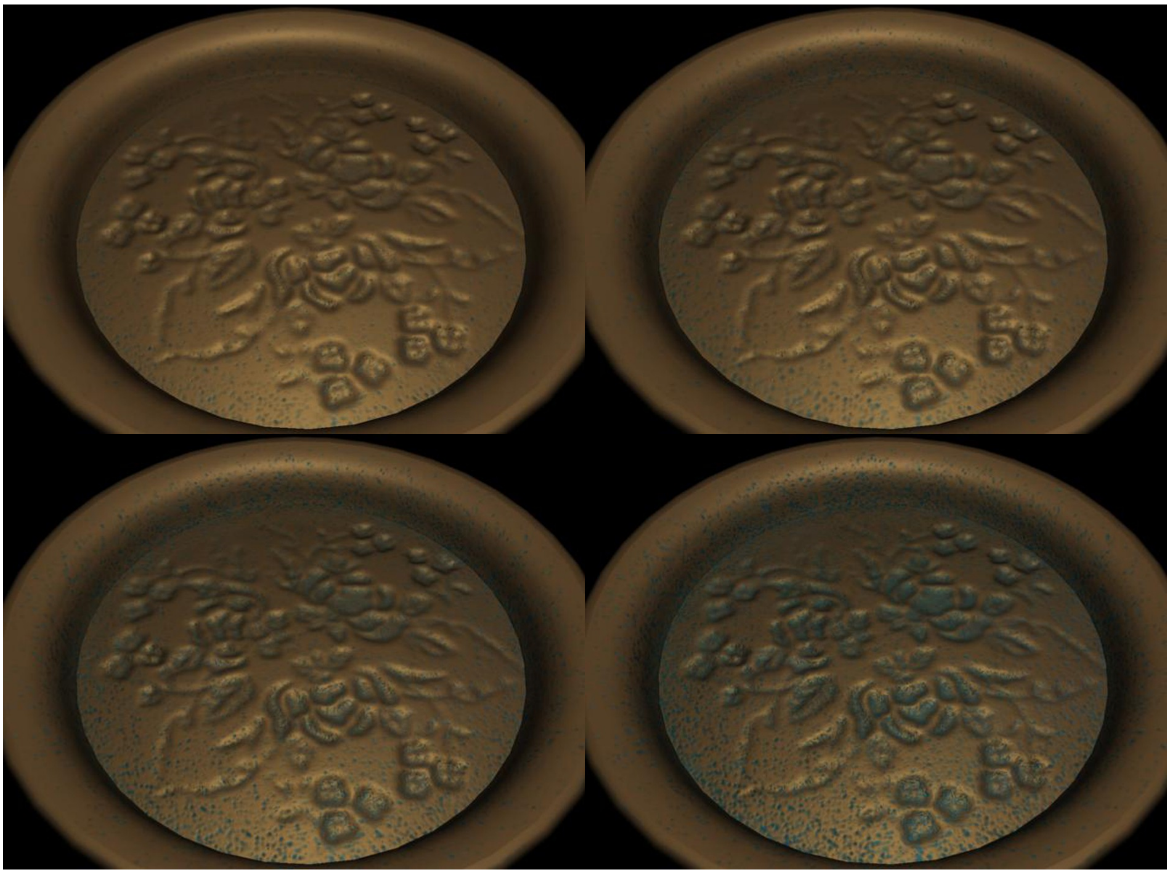

Figure 8: *Continuous weathering effects example1, a rusty bronze basin. The flower patterns on the bottom are achieved by displacement mapping.*

Figure 9: *Continuous weathering effects example2, a rusty bronze pen container. The ancient patterns on the outside surface are achieved by displacement mapping.*