Simulation of Weathering Representation using Vertex and UV Information

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Abstract

In recent years, three-dimensional computer graphics (3DCG) technology has been developed. In addition, much research has been done on weathering representations such as rust and moss for realistic representation. However, when outputting simulation results on an image, a large number of images are required to display different simulation results in a three-dimensional space. In this paper, a simulation method using vertex information of a 3D model and simple images is proposed. In this method, when the number of vertices is sufficient, the simulation result output does not use images, thus reducing the data increase. This figure is one of the experimental results.

Keywords: Computer graphics, Vertices, Rust, Weathering, Visual simulation

1. Introduction

In recent years, three-dimensional computer graphics (3DCG) have been used in films, games, VR-based education, and medicine. In this context, there is a need to make 3DCG look more realistic. However, it is not subject to interferences such as environment or time and therefore does not degrade as in reality. This is why research into weathering expressions for CG is being conducted to this day.

This study proposes a method to implement weathering representations such as rust and moss using vertex information and UVs, instead of outputting simulation results as images for textures. The simulation results were also applied to a 3DCG model in practice.

2. Research Background

To date, a plethora of research has been done on weathering representations related to computer graphics. However, most of them require the simulation results to be output as images for textures. However, when simulations are performed on multiple models, images are required for the number of models, resulting in a large amount of data. With the aim of being flexible enough to deal with existing models and real-time representations, a simulation method using vertex information and UVs of 3DCG models was developed in this study.

In this study, the UV map used for the material representation of the original 3DCG model is called the base UV map, and the UV map for simulation is called the simulation UV map.

3. Development Environment

The development environment is shown in Table 1, with C# used as the programming language for Unity and Python for Blender.

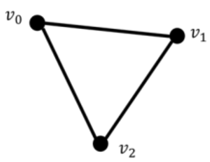
Table 1. Development Environment.

OS	Windows10
Software	Blender 3.6
	Unity 2022.3.14f1
	Visual Studio 2019
	Adobe Illustrator 2023

4. Simulation Method

4.1. *Adjacency list*

In this study, simulations are performed using vertex information in 3DCG. Vertex adjacency information was obtained, and an adjacency list was created to represent the phenomenon of rust and moss propagating locally in weathering simulations. The method for creating the neighborhood list used vertex information constituting polygons and edges, although the method of searching for neighborhood information differs from software to software. The adjacency list of vertexes v_i at index number i is Fig. 1.



vertex	adjacent to
v_0	v_1, v_2
v_1	v_0, v_2
v_2	v_0, v_1

Fig. 1. Adjacency list at vertex.

4.2. *Initial condition setting*

The susceptibility to rust and moss varies with the environment, such as humidity and sunlight, but also with the material of the object, just as there is a difference in the probability of rust between metal and plastic. Few previous studies have considered the material of the object and conducted simulations, and most of them assume that the entire object is made of the same material. In this study, the user can control the erosion probability of the initial state like a mask image by painting directly using the base UV map.

4.3. *Dynamic environment acquisition*

Most of the previous studies assume a situation where the object is in the same environment and in the same shape at every step. However, some objects may change dynamically, such as changing orientation over time or increasing obstacles. Therefore, in this study, by incorporating vertex information into the local transition rules, real-time changes such as changes in orientation and up/down can be managed.

4.4. *UV-based erosion representation*

Determine UV coordinates from the degree of rust and moss erosion at the vertices using the adjacency list. The color of the eroded object is also determined by the user entering a gradient image. In addition, as multiple UV maps are used, they can be used in conjunction with the base colors of existing 3DCG models as shown in Fig. 2 and Fig. 3.

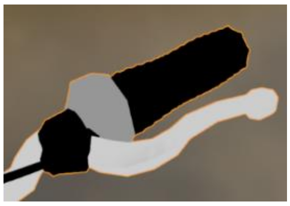


Fig. 2. Base color.

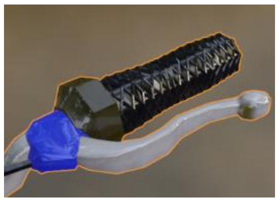


Fig. 3. Initial condition.

5. Experimental Results

This paper describes some of the experimental results, mainly related to rust formation. The transition conditions for rust generation are as follows, based on previous studies [1], [2], [3].

- Rust progression from 0 to the maximum rust value R_{MAX} determined by the user.
- Rust progression is assigned to each vertex.
- Vertex v as the initial rust occurrence has a low probability of rust progression R_v increases by 1.
- Vertex adjacent to a vertex with progression greater than 1 has its R_v increased by 1 by a function that takes gravity and probability into account.
- Vertexes above a certain level of progression are peeled off.
- UV placement of vertex v at index number i in step t is determined by $R_{v_i^t}/R_{MAX}$

In this experiment, simulated UVs are applied to the mask textures in Fig. 4 and the color textures in Fig. 5. The mask texture is a grayscale image and can be used to express textures such as the metallic feel and roughness of the surface of the 3DCG model by inputting the simulation results into software shaders. Besides, it can also be used to control the range of application of noise textures to represent uneven and rusty surfaces or the base color of an existing 3DCG model. Color textures represent color scales. In addition, alpha values can be set, and the expression of peeling and holes above a certain value is implemented.

Fig. 4. Mask texture.

Fig. 5. Color texture.

5.1. *Base experimental*

In this experiment, simulations were performed on a cube that was tilted. The results, shown in Fig. 6 and Fig. 7, show rust propagating according to gravity. In addition, the strongly eroded areas have holes and peeling. The rust-free area in Fig. 6 has no surface irregularity due to the noise texture in Fig. 7, indicating that the mask texture controls the texture of the 3DCG model.

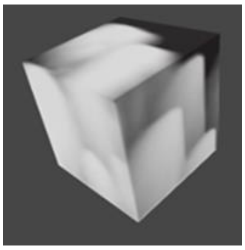


Fig. 6. Ex1 Mask result.

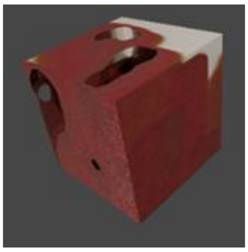


Fig. 7. Ex1 Color result.

5.2. *Verification of randomness*

In this experiment, the same 3DCG model, the same transition rules, and the same textures as in 5.1 were used in the simulation. The results in Fig. 8 and Fig. 9 differ from those in 5.1, indicating that the same image and the same model can output different patterns of results depending on the probability.

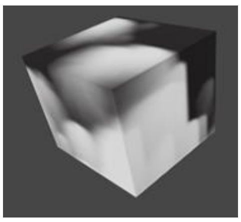


Fig. 8. Ex2 Mask result.

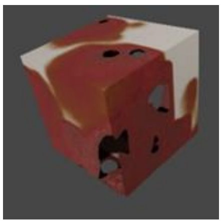


Fig. 9. Ex2 Color result.

5.3. *Shape change*

In this experiment, only the tilt of the object was changed from 5.1 to the simulation. 5.1 shows that rust propagates in the left front direction because the object is tilted in the left front direction. However, in this experiment, the rust propagated in the right-most direction as the object was tilted in the right-most direction as illustrated in Fig. 10 and Fig. 11.

Fig. 10. Mask result in different shapes.

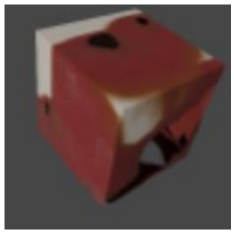


Fig. 11. Color result in different shapes.

5.4. *Initial condition*

In this experiment, the objects and initial conditions were changed and simulated. The initial state is shown in Fig. 3. Fig. 12 and Fig. 13 show that rust only occurs in the most rust-prone white area in the initial state, and no rust occurs in the most rust-prone black area.

Fig. 12. Mask result in another object.

Fig. 13. Color result in another object.

6. Consideration

From 5.1 and 5.2, it was shown that rust propagates in the direction of gravity depending on probability as in previous studies, and that the location of rust and the direction of rust propagation change depending on probability. This indicates that the same mask texture and color texture can output different patterns of results for the same object of the same shape existing at the same time. This means that the simulation results do not need to be output to an image, which may reduce the amount of data when multiple patterns of weathering representation are desired for the same object. In addition, since the simulation results are the erosion degree for each vertex, they can be saved by outputting them to a CSV file or other format.

From 5.3, it was shown that the simulation results can be output in response to tilt even when the object shape is changed. This is because the vertex information is referenced in the transition rule, and it can respond to changes in the tilt and size of the object during simulation. In addition to vertex position information, vertex distance and the number of neighbors can also be referenced. However, if the neighbor information changes, such as when a vertex is deleted or added, it is necessary to reacquire the neighbor information.

From 5.4, it is shown that it is possible to limit the impact of the simulation by setting initial conditions. This allows the base UV map and simple painting to control the strength of the influence of different metals and materials, without the In this study, only rust was mentioned, but by changing the texture and transition rules for each, the propagation of moss can be represented as shown in Fig. 14.

Fig. 14. Simulation results assuming moss in another object.

7. Conclusion

In this study, we performed weathering simulations using vertex adjacency and UV information. As in the

previous study, expressions such as rust and moss propagation could be made without outputting them to the texture. However, the number of vertices needs to be increased for more realistic expressions and detailed patterns. Therefore, if real-time changes are to be observed, it is necessary to optimize the number of vertices and to limit the number of objects to be simulated at the same time.

For future works, it is necessary to pursue the improvement of transition rules and the fields in which this vertex technology can be utilized.

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