Procedural Techniques for Animating Falling Leaves for Outdoor Scenes

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Abstract: In recent years, it has become a matter of course to use high-vision 3D computer graphics (CG) in video images in movies, computer games, and so on, and the breadth of CG video expressions is growing remarkably. Furthermore, CG contents are also increasing through the introduction of physical simulation, which has made it possible to reproduce real scenes. However, doing everything by hand results in a heavy workload for the creator and excessively high development costs.

This paper examines the development of a method for visually simulating leaves fluttering to the ground while they are affected by external elements such as wind that can be freely created by the user, in an attempt to reproduce scenes of "falling leaves," which are an integral element of conveying a natural sense of seasons in scenery CG. In this method, each leaf is considered as a single particle.

The purpose of this study is to make visual simulations of falling leaves in which each leaf is considered as a single particle that flutters down to the ground as it is affected by wind and other external factors that are freely created by the user. Since the order in which the leaves fall is determined by considering the physiological characteristics of trees in this method, it is possible to reproduce a natural scene of falling leaves while reducing the user's workload. With this method, the user can semi-automatically create a varying scene of falling leaves just by changing the parameters.

Key words: ***Computer Graphics, Visual Simulation, Fallen Leafs, Natural Phenomenon***

1. Introduction

The landscape scenes from autumn coloring of the leaves to their falling, which are a true symbol of autumn, are integral phenomena for expressing a natural sense of seasons in scenery computer graphics (CG). Natural coloring and falling of autumn leaves are spatially and temporally complex, because they are related with various physiologically uncertain factors and environmental factors. Thus, until now there have been no CG works which properly reproduce such phenomena. There are several studies which enable CG expression of the coloring of autumn leaves. However, the falling of autumn leaves is intricately related with external factors such as wind, and in addition, if the animations are created manually by animators, a large amount of labor is needed. For these reasons, fully satisfactory video images of autumn leaves have not yet been created. Furthermore, since in recent years it has become common to use high-vision 3D computer graphics (CG) for video images, manual image production has needed increasing cost for development. Thus, procedural techniques[1] for automatically creating images with an algorithm have been desired.

In this work, we have taken physiologically aging variations as one of the factors for leaf falling. In addition, regarding each leaf as one particle, we have made it possible for the user to freely create external factors due to vector fields such as wind by a spline control method. Thus, we have developed a visual simulation method that reproduces particle (leaf) falling motions (while fluttering) affected by the plant physiological factors and the external factors which are controllable by the user.

This paper is organized as follows: in Chapter 2, some studies related to our work are described, and in Chapter 3 the physiological mechanisms of falling and coloring of autumn leaves are explained. In Chapter 4, a visual simulation method for falling leaves considering plant physiological factors and external factors proposed in this paper is described. In Chapter 5, the results of our simulation and a discussion are demonstrated. In Chapter 6, the summary of our study and future problems are shown.

2. Previous work related to our study

Mochizuki *et al.* reported a study on fractal shading of autumn leaves[1], in which autumn coloring of the entire trees is reproduced by one-to-one mapping the spatial and temporal complexity of autumn leaves to a symbolic space S with Fractal Top Function[2], by shading time-development colors with a shift operator, and further by shading due to mapping of color information between top addresses. The fractal graphics have self-similarity between their entire shapes and partial shapes, even if they are magnified by any scale factor. Using Fractal Top Functions, the complex coloring for autumn leaves has become possible, while they are not responsible for the reduction in the number of the leaves due to falling. In addition, Mochizuki *et al*. reported an artificial coloring system based on a biological and fractal modeling[3], and a fractal modeling of natural autumn leaves[4]. Saotome *et al.* reported a study on the reproduction of autumn leaves based on a biological model considering the color variations in the level of the individual trees. In this model, they introduce plant dye transformation data, which are obtained by calculating the accumulated amount of solar radiation absorbed by the leaves, with an "autumn color logical time" model.[5] Oshida *et al.* reported a simulation of the landscape of trees introducing virtual plant hormones and amount of light income.[6] However, there have been no studies which also take falling leaves.

3. Physiological coloring and falling mechanisms of autumn leaves

In this chapter, we describe the physiological coloring and falling mechanisms of autumn leaves.

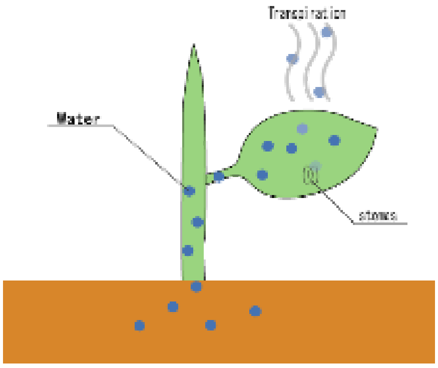

Figure 1. Transpiration

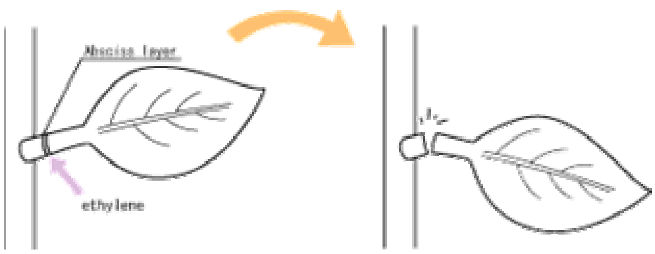

Figure 2. Transpiration

3.1 Leaf-falling mechanism

Leaves produce organic substances by photosynthesis from water and carbon dioxide to maintain life. The leaves actively photosynthesize during summer times, while as daylight hours become shorter from summer to autumn, and the ambient temperature decreases, they evaporate water from the stomas in their rear side. However, to avoid the blight of individual trees due to water evaporation, the trees form a cork tissue called the "absciss layer" between each branch and leaf to cut down the leaf. The absciss layers also block the substance translocation from the branches to leaves to leave only unnecessary substances in the leaves. In the absciss formation process, the color of the leaves turns to red or yellow (Figs. 1 and 2).

3.2 Red and yellow coloring mechanisms of leaves

It is well known that the leaf color of deciduous trees turns from green to red or yellow in autumn. This is seen in a wi de regions from the tropical to frigid zones. However, the red and yellow coloring mechanisms of autumn leaves are different. in autumn. This is seen in a wide regions from the tropical to frigid zones. However, the red and yellow coloring mechanisms of autumn leaves are different.

3.2.1 Red autumn leaves

The translocation of the substances produced in the leaves are inhibited by forming absciss layers, and proteins accumulated in the leaves are decomposed to amino acids which react with sugar to synthesize a red dye called "anthocyanin" (Fig. 3).[7]

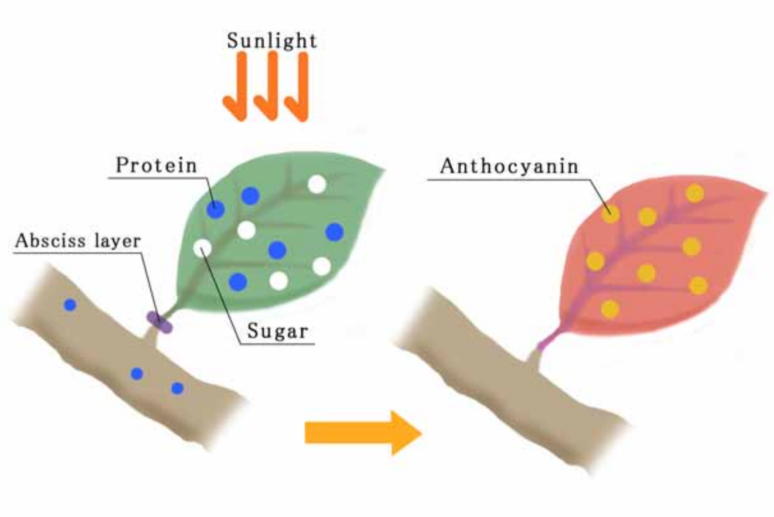

Figure 3. Mechanism of red coloring of leaf

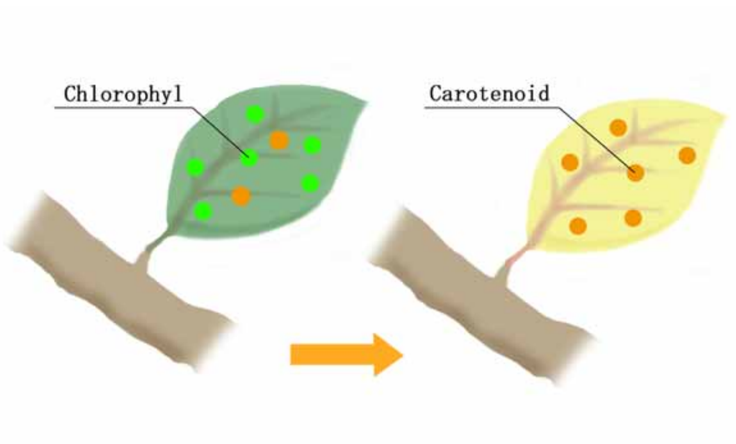

Figure 4. Mechanism of yellow coloring of leaf

3.2.2 Yellow autumn leaves

Leaves contain a green dye called chlorophyl and a yellow dye called carotinoid. The amount of carotinoid is 1/8 that of chlorophyl, and thus the green color is predominant. With decreasing temperature in autumn, both dyes begin to decompose. However, the decomposition rate of chlorophyl is faster than that of carotinoid, and thus finally carotinoid remains in the leaves to changing the leaves to yellow (Fig. 4).[7]

4. Simulation method of falling leaves considering physiological and external factors

As shown in Chapter 3, the sequential processes of the absciss layer formation and color turning and falling of leaves are closely linked with one another, and thus a simulation algorithm for falling leaves considering these factors is needed. In this chapter, we describe a method of simulation of falling leaves which takes physiological and external factors into account to determine the order of falling of the leaves.

4.1 Formation of absciss layers

The formation of absciss layers is related to ethylene, which is a kind of plant hormone. Ethylene is heavily involved in the growth of trees, and can induce their thickening. In this study, we assume that the thicker trunks of model trees have a greater amount of ethylene. Thus, the amount of virtual hormone, H, is distributed to each apex of the polygon forming the cross section of the model tree trunk according to Eq.(1) to determine the order of the absciss layer formation (Figs. 5 and 6). In Fig. 5, the a_n's are the apexes of the polygon. The hormone value decreases with increasing time, and the order of the absciss layer formation is sequentially determined from the site where the value exceeds a threshold, (Figs. 7).

$$H = n\, La_n\, rnd(\,) \qquad \textbf{Eq. (1),}$$

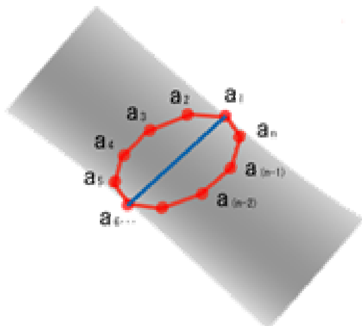

Figure 5. Cross section of tree trunk

where H is the amount of virtual hormone, La_n is the maximal length of the diagonal lines connecting two arbitrary apexes, n is an arbitrary coefficient, and rnd( ) is a random value.

4.2 External factors

4.2.1 Amount of solar radiation

As described in the coloring mechanism of Chapter 3, the absciss layer formation and leaf color change are closely related with the amount of solar radiation which individual leaves receive. In other words, the leaves which receive more solar radiation fall earlier. Thus, placing a light as a virtual sun in space, the amount of solar radiation which individual leaves receive can be pre-calculated with the ray tracing method (Fig. 8and 9).

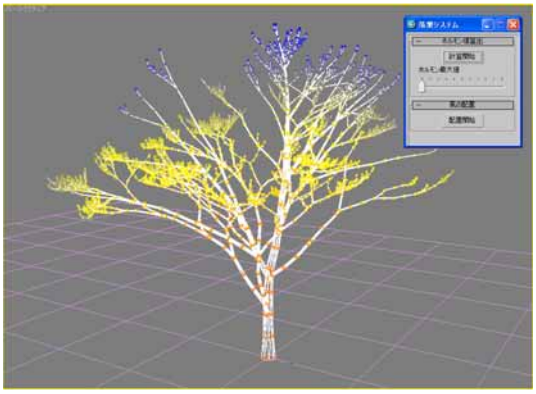

Figure 6. Concentration distribution of virtual hormone; the concentration of hormone decreases as the color of the apex changes from red to blue

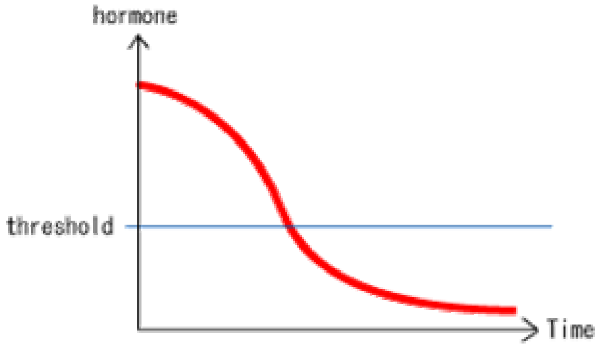

Figure 7. Time dependence of reduction in the amount of hormone

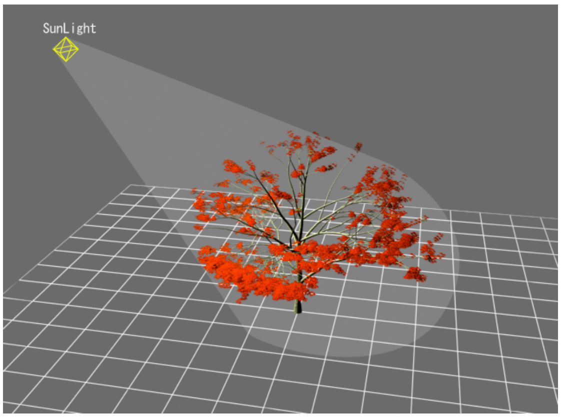

Figure 8. Ray tracing with a virtual sun

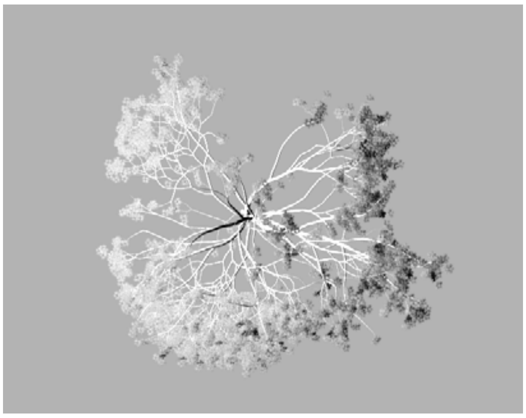

Figure 9. Map of the amount of solar radiation

4.2.2 Wind

Wind can be considered one of the external factors inducing leaf falling. As wind greatly affects the falling path of the leaves, it is essential for the user to freely and easily control wind. In our method, the user draws splines in the virtual space as the path of wind, on which particles likened to wind are arranged (Fig. 10.) Then, the collision of the particles, liken to each falling leaf, with wind particles is judged, because it greatly Thus, from the absciss formation and the particle collision, the order of falling of the leaves is determined.

4.3 Autumn-leaf creation system

Using the amounts of hormone and solar radiation described above, we have reproduced the change of leaf color with age. As mentioned in Chapter 3, estimating the order of the absciss layer formation from the value of hormones and the amount of light received by the individual leaves from the map of solar radiation, the order of autumn coloring of the leaves is determined. Moreover, adding a random value to the estimated values, the texture of the leaf objects is animated to reproduce the complex variation of the leaf color.

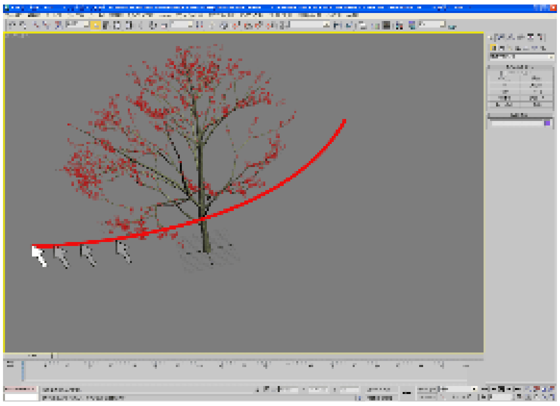

Figure 10. Arrangement of wind spline

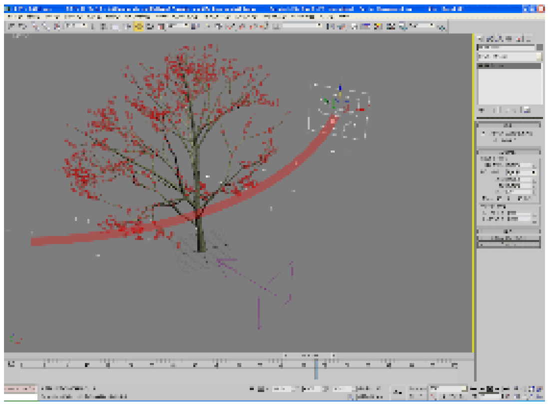

Figure 11. Generation of wind particles

5. Production of simulation images and discussion

In this chapter, simulation images produced by our method are compared with an animation created manually. The details of our production environment are as follows; PC used: Intel Xeon (TM) CPU 3.20 GHz, RAM 3.99 GB, and software used: 3ds Max 9 and Maxscript.

5.1 Production of simulation images

The simulation images are produced using the method described in Chapter 4, and are shown in Fig. 12, where the frame rate is 30 fps, and rendering time is approximately 2 hours (all frames).

5.2 Production of manual animation

To compare with animations created by our method, we also manually created an animation (Fig. 13).

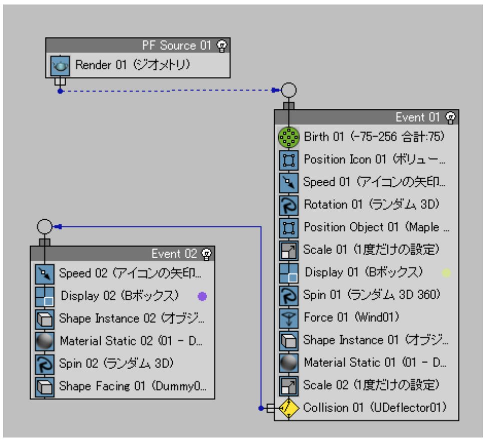

Figure 14. Particle flow

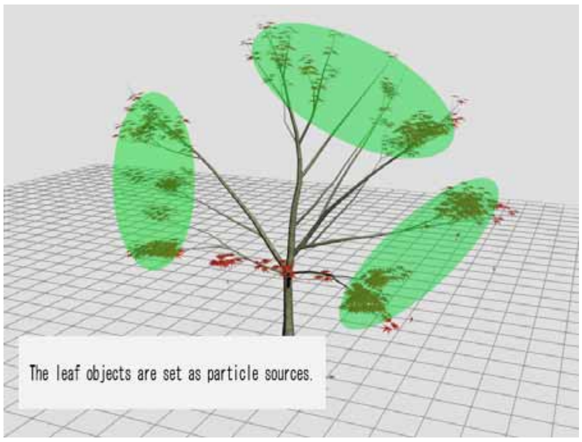

Figure 15. Arrangement of particles

5.2.1 Production process of manual animation

In the production of manual animations, first, the modeling of the objects such as trees and other elements are executed, and next, the flow programming of the particles, which corresponds to the falling leaves, is made. The particle flow is created by a programmable system in which the user can introduce various events, and freely control the direction of the flow (Fig. 14). The meaning of the terms in Fig. 14 is as follows; “Birth” is the generation of particles, “Speed” means the velocity of particles, “Rotation” is the moving direction of particles, “Position Object” is the arrangement of particle sources on the objects, “Scale” means the size control, “Spin” is the setting of rotational axes and rotational speeds, “Force” is to give space warp to the particles, “Shape Instance” is the control of the particle shape, “Material Static” is to give materials to the particles, and “Collision” is the judgment of the collision of the particles with the objects specified.

The leaf objects are set as the particle sources (Fig. 15), and parameters such as the falling velocities and rotations are adjusted. The wind space warp is adjusted to influence leaf falling. After judging the collision of the leaves with the ground, they are set to accumulate on the ground. The branches of actual trees exhibit complex motions, and thus the branches of the model trees are divided into blocks to be controlled as bones. To express the natural swaying of the branches, the bow of the branches is introduced using a spring model where the apexes of the branch polygons are weighted (Figs. 16 and 17).

The work flow, described above, is as follows (Fig. 18):

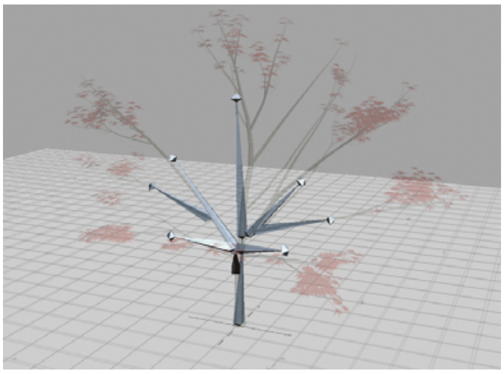

Figure 16. Control of bones

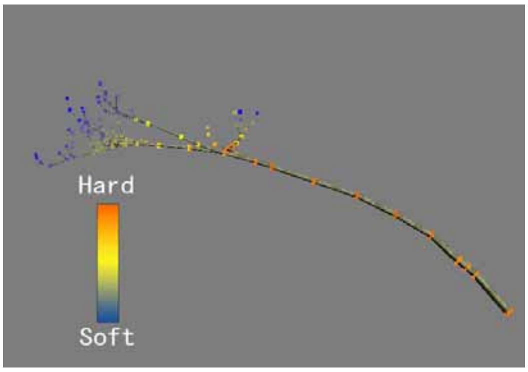

Figure 17. Swaying of the branches

- Modeling of trees
- Setting of particle sources
- Adjustment of parameters
- Setting of external factors such as wind
- Setting of environment factors such as judgment of collision
- Animating trees

Figure 18. Work flow

5.3 Discussion

We compared an animation produced using the visual simulation algorithm we have proposed for falling leaves (Fig. 13) with an animation produced manually (Fig. 12), and found that our method can more naturally reproduce falling leaves. Moreover, when comparing with the work flow of the manual animation, the working efficiency for the particle control is drastically enhanced by our method.

In conclusion, to determine the order of falling of the leaves, it is very effective to introduce a virtual hormone as a plant physiological factor and the judgment of the collision of the wind particles with the leaves as an external factor.

Also, we have considered the amount of light received by the individual leaves so that the change with aging of their colors and the order of the absciss layer formation look natural.

6. Conclusion

In this paper, we have proposed a visual simulation method of falling leaves which considers plant physiological and external factors. Applying a particle system to the leaves falling while fluttering, and a spring model to the branches, we have succeeded in reproducing natural movements of the falling leaves. Furthermore, we have proposed an algorithm for determining the order of falling of the leaves by introducing hormone values and the map of sunlight received for the absciss layer formation, and the judgment of the collision with wind.

As future topics, we plan to consider the decrease in the number of the leaves due to factors neglected in this study and human factors, and the applications to various simulations for forests, mountains, etc.

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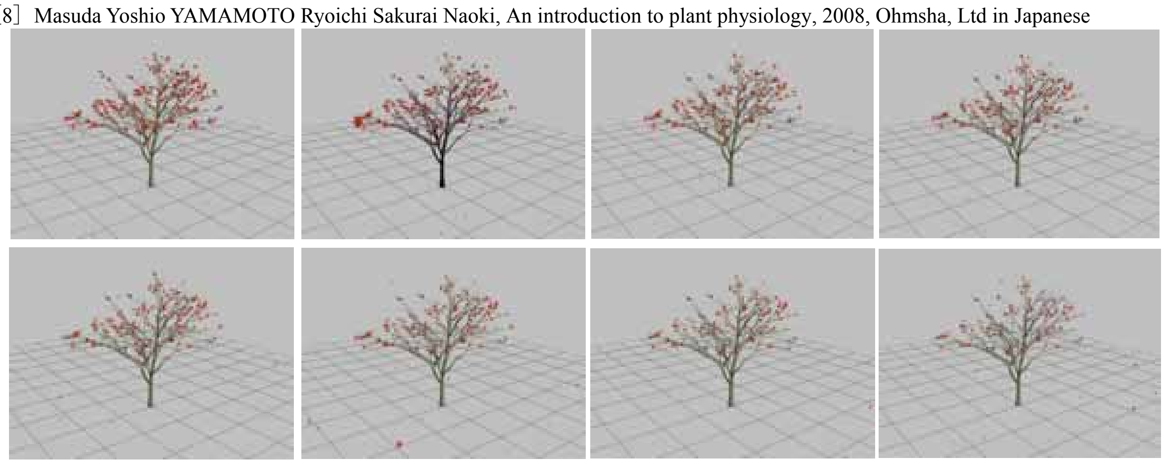

Figure 12. A sequence of simulation

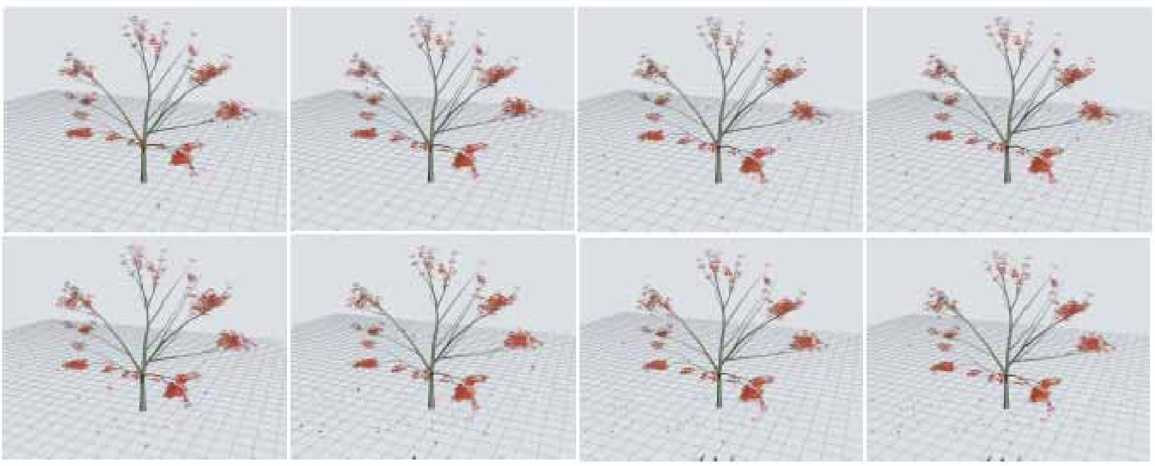

Figure 13. A sequence of manual simulation