Animating Tree Movement with Sound Effects Generation

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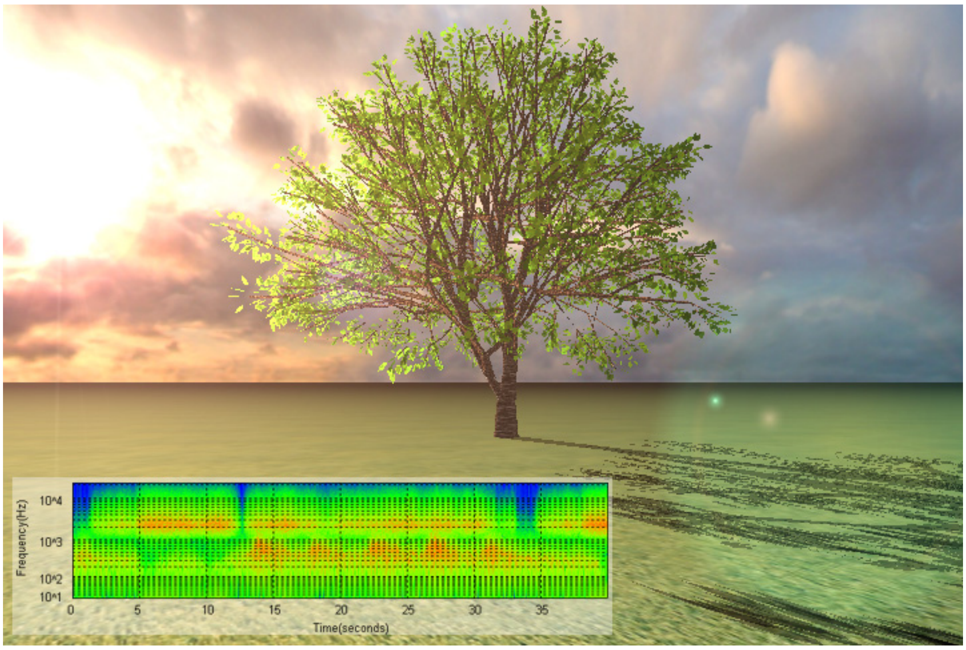
Abstract

This video demonstrates the methods for automatically generating tree motions and sound effects for an animation of branches and leaves moving in the wind.

Natural motions of leaves and branches swaying in a wind field are created in real-time by our efficient method without using time-consuming physical simulation techniques based on the equations of motion. This method utilizes "$1/f^{\beta}$ noise", which is observed in various natural phenomena. Specifically, in this method, the natural motions of leaves and branches are created by calculating appropriate motion angles using $1/f^{\beta}$ noise functions. The realism of the branch motion is enhanced by applying a real-time simple simulation technique based on the spring model.

Sound effects are generated as follows: Each tree is divided into branches and leaves, and an independent sound effect generation process is employed for each element. The individual results are then compounded into one sound effect. For the branches, we employ an approach based on the frequencies of experimentally obtained Karman vortex streets. For the leaves, we use the leaf blade state as the input and assume a virtual musical instrument that uses wave tables as the sound source. All computations can be performed independently for each frame step.

Category: Scientific Research



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1. Motivation and Methods Used for Production

The representation of trees is one of the most important topics in the field of the creation of natural scenes using computer graphics. Our research group developed the methods for automatically generating tree motions and tree sound effects for an animation of branches and leaves moving in the wind.

The developed method for animating tree motions is a noise-based efficient technique[1] to generate a real time animation, and the other method for producing tree sound effects is a sound modeling method that automatically adds sound effects representing the wind-induced movement. It is conceivable to use the sounds recorded from actual trees to generate the required effects. However, it is considered difficult to process or synthesize the sound to match the video if, in particular, the video is determined dynamically. Therefore, the new approach provides an automatic technique that recognizes the individual leaves and branches in the animation. Sound waves have the important properties of period, waveform and amplitude, and people judge the type of sound source by distinguishing these as pitch, tone, and loudness. These are called the three elements of sound and they are each subject to change over time. The generation of a sound can be paraphrased as the determination of these three elements. Our developed system is shown in Figure 1. The approach can be divided into branch sound generation and leaf sound generation processes, and these can be treated as independent except when referring to the branch shape data during leave movement. In the branch sound generating process, branch movement shape data is generated from the branch shape data and the wind-representing noise. The branch sound is generated from the shape data and the wind-representing noise. Leaf sound is generated using the leaf movement shape data and adjacent relational data.

In the reminder of this paper, we will describe the technical outline of our methods used for producing this video. The branch movement and branch sound generating process are described in the section 2, and leaf movement, preprocessing and leaf sound generation processing are described in the section 3. Execution results are described in the section 4.

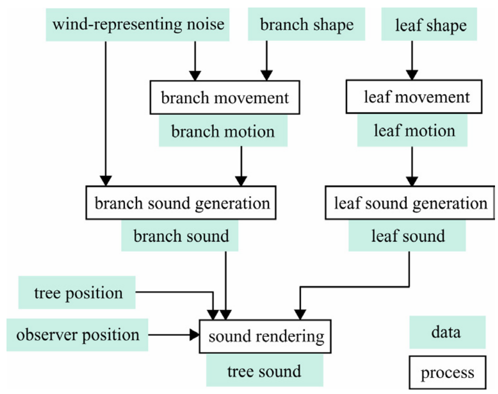

Figure 1. Overview of proposed system

2. Technical Outline of the Methods

To develop a technique to automatically generate tree movement and sound effects, it is necessary to implement a tree shape model. For the generation of wind-induced tree branch and leaf movement, an efficient noise-based technique is used. This section explains the technique for generating the movement and sound of the tree branches.

2.1. Branch shape model

In the branch model, the branch internodes are approximated as cylinders or truncated circular cones. The data for the entire tree is tree-structured and the parent and child internodes are linked as shown in Figure 2. This simplifies the process of obtaining the accumulated movement of the individual branches. Each branch is defined by the diameter and vector from the root to the branch tip with start point P_s and end point P_e as shown in Figure 2.

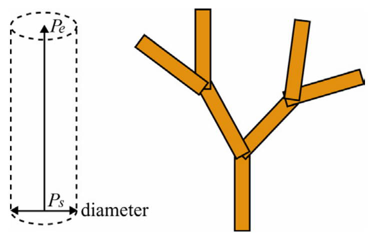

Figure 2. Tree branch model

2.2. Branch movement

Branch movement is represented by a noise-based real time simulation of tree movement due to wind. In our method, we use $1/f^{\beta}$ noise to represent the wind-induced load (This means that the wind-induced load is represented by applying $1/f^{\beta}$ noise to the spring model of a cantilever). Of course, one can use Perlin noise[2] instead of $1/f^{\beta}$ noise.

We take the x- and y-axes in a plane perpendicular to the branch with the origin at the lower branch node, and show the movement amplitude on both axes. The deflection amplitude δ when load P is imposed on the branch is as follows:

$$\delta_x(t) = P_x(t)/k \tag{1}$$

$$\delta_y(t) = P_y(t)/k \tag{2}$$

k: spring constant

For each branch, let the loads $P_x(t)$ and $P_y(t)$ in the x- and y-axis directions be as follows:

$$P_x(t) = F_x(t) + P_B N_x(t) \tag{3}$$

$$P_y(t) = F_y(t) + P_B N_y(t) \tag{4}$$

$F_x(t)$ and $F_y(t)$ represent the directional loads, and P_B is the maximum load. $N_x(t)$ and $N_y(t)$ are $1/f^{\beta}$ noise functions and represent nondirectional loads.

2.3. Generation of branch sound

We generate branch sounds from the directional wind obtained in the previous subsection and the branch movement due to the wind. The branch sound effect is actually a vortex-emitted sound. The frequencies of Karman vortex streets were obtained experimentally.[3] The technique for adding the sound effect is based on these frequencies for a sound emitted from a cylinder of diameter *D* in flow of velocity *U*.

The frequency *f* of a Karman vortex street can be described by the following formula.[3]

$$f = StU/D \tag{5}$$

St : Strouhal number

The sound intensity *I* is:

$$I \propto U^6/r^2 \tag{6}$$

r : Distance from branch to observer

To find the flow velocity, we determine the relative velocity between the wind and branch and generate a sound using the relative velocity as a parameter. Therefore, using the branch velocity and wind direction and intensity for each epoch, we calculate the component of the velocity perpendicular to the branch. It will become possible to add the sound once the tone is determined. High frequency sound components are added.

3. Generation of leaf movement and sound

In the section 2, we presented the method for automatically adding sound effects for the movement of tree branches, a method that can be operated as an independent system. In this section, we describe methods for creating movement and sound effects for leaf movement.

3.1. Leaf shape model

In the proposed leaf model, leafstalks are approximated by a line segment and the leaf blades by a rectangle, as shown in Figure 3. The leaf blade is created based on leafstalk data and its size is proportional to the length of the leafstalk. A leafstalk coordinate system is defined to represent leaf movement, with the origin at point P_0, and the vector from points P_0 to P_1 is the *z*-axis. The normalized cross product of the *z*-axis and a vertical upward vector is the *x*-axis, and the normalized cross product of the *z*- and *x*-axes is the *y*-axis. The leafstalk coordinate system is static. The movement of the leaf is described in the leafstalk coordinate system.

For leaf sound generation, it is necessary to know the relative positional change of each leaf blade with time. Therefore, we define the leaf blade coordinate system from the leaf blade position determined in each frame. This is determined dynamically. Let the *y*-axis be in the direction normal to the rectangle and the *z*-axis be towards the tip of the leaf blade. Take the normalized cross product of the *y*- and *z*-axes as the *x*-axis.

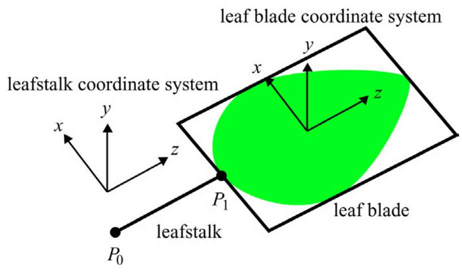

Figure 3. Leaf shape model

3.2. Representation of leaf movement

To represent leaf movement, we employ a method similar to that for branch movement. We divide the leaf movement into longitudinal and lateral movements and a rotational movement around the leafstalk axis, and assign a movement or rotation amplitude to each using noise. The lateral and longitudinal movement directions are the *x*- and *y*-axis directions defined in the branch shape model. Let $\theta_x(t)$ and $\theta_y(t)$ represent the movement amplitudes at time *t* in the respective axis directions and $\theta_r(t)$ represent the rotation amplitude in the rotational direction about the *z*-axis. For the rotation amplitude, consider the case where the leaf moves laterally because such movement is accompanied by a rotation about the leafstalk axis. Thus, the torsion angle is defined by the following formula using the *x*-*r* coupling coefficient *α*. These are determined by the following formulae.

$$\theta_x(t) = W_x N_x(t) \tag{7}$$

$$\theta_y(t) = W_y N_y(t) \tag{8}$$

$$\theta_r(t) = W_r N_r(t) + \alpha\theta_x(t) \tag{9}$$

W_x and W_y represent the maximum waving amplitudes, W_r represents the maximum rotation amplitude, and $N_x(t)$, $N_y(t)$ and $N_r(t)$ represent noise functions.

3.3. Leaf sound generation

Leaf sound is generated by the collisions and friction between the leaves. The output data obtained from the leaf movement algorithm is used to represent the position and posture of the leaves. Here, using the leaf position and posture data, we compute the sound generated from the leaf blades. We propose a technique to generate sound effects using a virtual musical instrument, which will use the leaf state as an input and the wave tables as a sound source. This means creating a virtual synthesizer, which uses tones of the 3 elements of sound as a sound source, and assigning it to a leaf. Frequency and sound intensity are inputs and are computed from the motion of the leaf.

We employ a technique for creating a number of wave tables first and assigning one of the wave tables to each individual leaf. As the wave tables are reproduced directly, we must be attentive to the waveform. In this technique, collision and friction are distinguished by altering the reproduction speed of the wave table. In our method, multiple wave tables are created using a noise whose frequency spectrum forms a pink noise and altering its basic frequency.

This process forms a sound source and reproduces a sound when a collision or friction signal is entered. We use a "stylus" to represent the reproducing position and initial value of the current wave table. This corresponds to a record stylus, and sound is reproduced as the stylus proceeds. By this process, continuous reproduction of the signals is made possible. For friction, the relative leaf velocity is used as an input and the sound reproducing speed is altered according to the relative leaf velocity. A higher sound can be reproduced for a higher leaf velocity in such a manner.

A state transition is then performed according to the results of the comparison and the threshold established according to the leaf blade size. We consider five states for each leaf: contact state, non-contact state, Key on, Key off and initial state.

4. Results and Technical Data

The tree models in this video is animated in real-time. The environments of the computer we used are OS: Windows2000, CPU: PentiumIII/933MHz, memory: 512MB, graphic card: GeForce3. The animation is obtained by about 15fps.

We implemented the sound effects algorithm with C++, and executed it on a machine with a 2.53-GHz Pentium(R) 4 CPU and 1.5 Gbyte RDRAM memory. We set the reproduction frame rate to 30 fps and the audio sampling rate to 44100 Hz.

Figure 4 is excerpt from the animation. Figure 5 shows the spectrum of the compound sound made by compounding the branch and leaf sound together. Checking the attached movies, one might convince that the proposed method has an ability to generate considerably realistic sound effects.

Figure 4. A waving tree

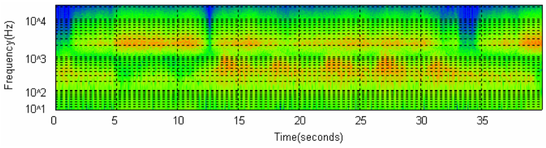

Figure 5. Spectrum obtained by compounding branch and leaf sound

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