Dynamic Texture: Physically-based 2D Animation

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1 Introduction

The physically-based approach is successful in creating realistic motion for 3D objects. Modeling complex 3D shapes is, however, a labor-intensive job and their rendering is computationally expensive. This limits the application of physically-based animation to just top-end full computer animation.

Coupling physically-based techniques and image morphing techniques has the potential to explore new directions in computer animation. In this approach, complex 3D models are not required, and so, it can be applied even to 2D animation. This idea was first proposed by Overveld [2]. Unfortunately, the paper was rather conceptual without strong experimental support and only a little attention has been paid to this approach.

This paper demonstrates successful examples of this coupling approach. We synthesize the stochastic motion of plants under the influence of wind, in which 2D textures are realistically animated based on dynamic simulation. We selected these materials because it is hard to realistically animate them by hand and the necessary simulation techniques have been well developed.

We first specify skeletons of plants and define the correspondence between skeletons and image textures. Dynamic simulation is then applied to the skeletons, which yields the skeleton motion. The images are deformed according to the calculated skeleton motion, producing realistic motion of the textures. Several video sequences were created using this method. The results are very encouraging. Realistic motion of bamboos, trees and grass blades are synthesized from just simple 2D structures.

2 Dynamics

This section describes the techniques used in the dynamic simulation.

2.1 Modal analysis

Modal analysis is a powerful tool with which to simulate vibrating objects, and was successfully applied to motion synthesis of swaying trees [3]. In modal analysis, the deformation of branches is calculated as a linear sum of the mode functions,

$$v(x,t) = \sum_r V_r(x) q_t(t), \tag{1}$$

The vibration, q_t, is given by:

$$\frac{d^2 q_t}{dt^2} + c\omega_r^2 \frac{dq_t}{dt} + \omega_r^2 q_t = K_r f(t), \tag{2}$$

where the coefficients, ω_r, c, and K_r, can be calculated from geometric factors (length, width, etc) and mechanical properties (Young's ratio, math density, etc). These equations can be solved, for example, by Euler's method. The applied force is calculated from a stochastic wind field synthesized by the Fourier method [3].

2.2 Periodic solution

Since our applied force is periodic, Eq. 2 has a periodic solution. Periodic motion is convenient because it can be repeatedly used in long animation sequences. To obtain the periodic solution needed, we adopt the superposition method [4].

First, we calculate the response, $p(t)$, of the system under the condition that the force is applied only during one particular period (e.g., $0 < t < T$). Second, we calculate the summation of shifted patterns of the computed response,

$$P(t) = \sum p(t - nT), \tag{3}$$

for $n = 0, 1, 2, \ldots.$ This summation is, in turn, the periodic solution of the original problem. The validity of this method can be easily proved from the superposition feature of linear systems.

3 Procedure

Input image Input images can be created by using conventional painting tools. To separate the images by component (e.g., trunks, branches), the components of the images are created in different layers.

Skeletons Skeletons are specified for each component. In the current implementation, we manually draw skeletons as line segments on the image via a GUI. However, since our images are already segmentated, it is not difficult to automatically extract skeletons from images by using image processing techniques (e.g.,[1]).

Mechanical properties The coefficients in Eq. 2 for each skeleton can be obtained from the object's mechanical properties such as Young's ratio. However, because these properties are rather hard for most people to directly specify, we instead specify kinematic characteristics, such as natural frequences, amplitudes, and damping time, which are then converted to the mechanical properties.

Dynamic simulation The dynamic simulation is performed by the modal analysis as described in the previous section, and yields the periodic motion of skeletons.

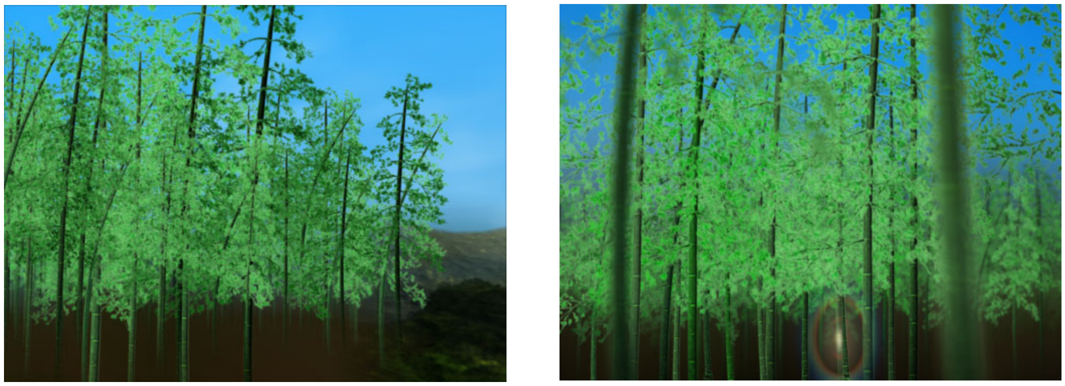

Figure 1: Sample shots from video sequence *Gift from Nature*.

Morphing Following the deformed skeletons, the corresponding textures are deformed by using piecewisely linear mapping functions.

4 Result

We successfully applied the method to texture-based animation, *Gift from Nature*. Although the plants were all modeled using 2D textures, the motion appeared very realistic. Motion synthesis was fast and robust, and an interactive speed (several frames per second for about a thousand skeletons) was achieved in the parameter specification phase. Figure 1 shows example shots from the sequence.

References

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