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An animation bilateral filter for slow-in and slow-out effects

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ABSTRACT

In this paper, we introduce a method that endows a given animation signal with slow-in and slow-out effects by using a bilateral filter scheme. By modifying the equation of the bilateral filter, the method applies reparameterization to the original animation trajectory. This holds extreme poses in the original animation trajectory for a long time, in such a way that there is no distortion or loss of the original information in the animation path. Our method can successfully enhance the slow-in and slow-out effects for several different types of animation data: keyframe and hand-drawn trajectory animation, motion capture data, and physically-based animation by using a rigid body simulation system.

1. Introduction

The movements of an object in cartoon animation differ from realistic movements. Cartoon-style movements are expressive and exciting and attract audiences to cartoon animations. The animation principles [1,2] developed from the traditional cartoon animation allow the motion of a cartoon object to be both expressive and funny. Unfortunately, these principles represent artistic suggestions to an animator rather than computational methods. In fact, artists still prefer keyframe-based animation systems to methods that are mainly based on real-world observations, as the former system automatically generates realistic animation data.

Some researchers have studied methods that emulate the traditional animation techniques described in the animation literature [1–3]. Chenney et al. [4] simulated the squash-and-stretch effect for simple rigid bodies by applying non-uniform scaling to the body in accordance with its velocity, acceleration, and collision. Kim et al. [5] developed a method that generates anticipation and follow-through effects by extrapolating changes in joint angles. Wang and his colleagues [6] proposed an innovative method that generates anticipation and follow-through effects through the convolution of a Laplacian of Gaussians (LoG) kernel. They also produced effective squash-and-stretch effects in 2D mesh animations by varying the time-shift term of an LoG filter. Kwon and Lee [7] proposed the construction of a sub-joint hierarchy by subdividing the basic joint of a character and then used it to achieve rubber-like animation effects. The findings from these studies allow the generation of cartoon-style animation from realistic or unskillful hand-made animation data; however, they are usually concentrated on the spatial exaggeration of a motion, while the temporal exaggeration of cartoon animation is also important.

Furthermore, in according to Terra and Metoyer [8], a novice user finds it difficult to specify the keyframe timings rather than to set the spatial values of the keyframes.

This paper introduces a simple and effective method for generating the slow-in and slow-out effect, which is a key animation principle relating to temporal exaggeration. In fact, most keyframe-based animation authoring systems have a function that controls the slow-in and slow-out effect of the object's animation by using a Bézier or cosine curve as the timing curve. Some researchers introduced a method for generating the slow-in and slow-out effect for characters' motions based on keyframe extraction and a time-warping technique [9,10]. However, the previous methods are mostly based on the keyframe information,

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and we cannot use those methods for animation data that does not have keyframe information or where it is difficult to find. For example, animators often use a rigid body simulation system to generate realistic animations of multiple objects that may be very difficult to create manually; however, the slow-in and slow-out cartoon stylization for this animation would be difficult if we use previous methods.

On the other hand, our method does not require the keyframe information for given animation data. It is a simple and fast method based on kernel convolution. Similar to the method proposed by Wang et al. [6], our method can be applied to wide varieties of animation data, including 2D animation, rigid body animation, and character animation. The key idea of our method is to exploit the scheme of a bilateral filter [11], using it as a tool for reparameterization of the animation trajectory.

This paper is organized as follows. We briefly review previous work in Section 2, and present our animation bilateral filter in Section 3. In Section 4, we introduce some applications for our method and discuss the experimental results of each application. Comparison between the stylized animation using our filter and that produced by the previous method is discussed in Section 5. Then, we draw conclusions in the last section.

2. Related work

Several researchers have studied the signal processing techniques for animation data to generate exaggerated or attenuated animation. Unuma et al. [12] addressed this problem using relatively simple interpolation and extrapolation techniques for motion data. Bruderlin and Williams [13] introduced a signal processing technique in which motion data is split into several frequency bands, that are then modified and used to resynthesize an exaggerated motion. Lee and Shin [14,15] developed stable methods for processing rotational motions in a similar fashion using quaternions. Similarly, our method can also be classified as an animation signal processing technique.

Several methods use variations in timing to synchronize a set of motion data or to stylize motion data. Witkin and Popovic [16] proposed a motion warping technique for editing animation data based on time-warping of the motion data. Wang et al. [6] produced effective squash-and-stretch effects in 2D mesh animations by varying the time-shift term of an LoG filter. White et al. [9] developed a slow-in and slow-out filter for character motion that is based on a time-warping technique. Tateno et al. [10] used a similar technique to generate stylized motions. Kass and Anderson [17] argue that the self-overlapping effect that occurs when a character is squashed can be modeled mathematically by varying the time phase of the "wiggle spline" they introduced. Coleman et al. [18] stylized skeletal animation using staggered poses keyed into a set of different timings for one pose. We also utilize the time-warping function for the animation signal to enhance the slow-in and slow-out effect for given animation data.

3. Animation bilateral filter

The bilateral filter introduced by Tomasi and Manduchi [11], is a non-linear filter widely used in image processing. The general bilateral filter used for image processing consists of two weight terms: one is a spatial weight term and the other is an intensity weight term that helps the edge preservation of an input image. Assuming that $I(x)$ is the pixel intensity value at position x of image I, we can compute the bilateral-filtered value $I'(x)$ as follows:

$$I'(x) = \frac{\sum_{y \in N(x)} G_{\sigma_s}(x-y) G_{\sigma_v}(I(x)-I(y)) I(y)}{\sum_{y \in N(x)} G_{\sigma_s}(x-y) G_{\sigma_v}(I(x)-I(y))}, \quad (1)$$

where $N(x)$ is a set of positions of neighborhood pixels around x, and $G_\sigma(x)$ is the Gaussian distribution function whose standard deviation is σ. The bilateral filter simultaneously considers the spatial weight $G_{\sigma_s}(x-y)$, which gives a low weight value for a neighboring pixel far from the center pixel, and the intensity weight term $G_{\sigma_v}(I(x)-I(y))$, that generates a low weight value for a neighboring pixel value that differs from the center pixel's value; therefore, an edge-preserved, smoothed image is generated. Fig. 1 provides an example of a 1D signal processed using a bilateral filter.

As observed from Eq. (1), the key factor of a bilateral filter in image processing is the multiplication of the intensity weight term. In other words, the feature-related weight term of the image bilateral filter is formulated using the difference in pixel intensity. As a result, the filtered signal values in the smooth edge tend to move toward the center of planar regions (see the right side of Fig. 1). This effect is closely related to the slow-in and slow-out rule of the animation principles we aim to formulate. The key rule of slow-in and slow-out is achieved by showing the keyframes over a relatively longer period than the inbetween frames [2]. Assume that the 1D signal in Fig. 1 is the animation signal, where the x axis represents the time domain. The object moves from the low position to the high position. In the filtered signal, the values at

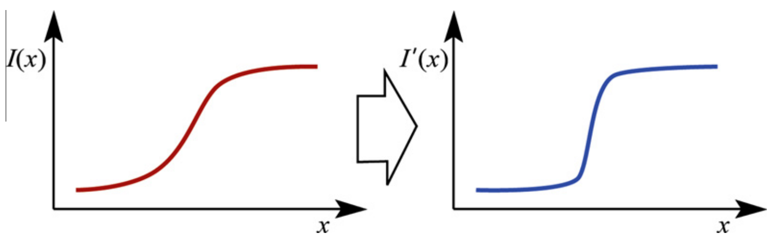

Fig. 1. Example of a 1D signal processed using a bilateral filter.