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Poster

Art-directable expressive oscillation behavior for rigged characters

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Abstract

We propose a method to enrich the animation of rigged characters with exaggerated oscillation behavior triggered by a sudden velocity change. Our approach is based on the extension of Velocity Skinning to space-time deformation, where the deformation is computed from a time-filtered version of the angular velocity of the skeleton. The time-filter is easy to parameterize by artists with respect to frequency, magnitude and attenuation while remaining fully compatible with standard rigged character.

Figure 1: *A rigged giraffe neck is rotated toward a vertical position. While the* drag *deformer of the Velocity Skinning [RTK*21] only models a single delay (left), our method can model long-term oscillation behavior adding dynamic effects (right).*

1. Introduction

Expressive animation principles depict cartoon characters' flesh with elastic-like deformation [TJ81], thus exhibiting exaggerated drag during motion and oscillation behaviors after rapid motion changes. In standard production, the main motion of the character is generated via SKinning techniques relying on a rigged articulated skeleton. Additional elastic deformation called *secondary motions* are set via procedural deformers that are manually tuned [May18]. While very flexible, such an approach requires substantial manual effort to adapt the parameterization of the secondary motion deformation to each new character and motion.

On the one hand, physically-based approaches have been extensively studied and can automatically compute exaggerated dynamic effects via fast position based dynamics [WU23] or reduced deformation subspace [ZBLJ20, BZC*23]. Still these methods remain hard to parameterize for artists as the physical parameters have non-linear effect on the result. Furthermore, they cannot reach the efficiency level of geometrical skinning reaching real-time results over millions of vertices.

On the other hand, fast kinematics approaches have also been explored to enhance animation with cartoon effects to a subset of the character's limbs [NT06, JyL12]. Recently, Velocity and Acceleration Skinning [RTK*21, KRZ22], proposed a general methodology to enrich skinning animation with expressive deformations such as *drag*, *squash & stretch*, and *follow through*. The associated deformation relying on efficient closed-form procedural deformers automatically adapts to the skeleton hierarchy but remains restricted to immediate deformation in response to the current joint velocity/acceleration. In this work, we propose extending the Velocity Skinning method to space-time deformation modeling long-lasting oscillation behavior. We inspire from the notion of time-filtered deformation [WDAC06] but adapt it to propose a formulation that is easy to parameterize from artistic direction.

Figure 2: *Temporal evolution of our oscillating behavior for the motion depicted in Fig. 1.*

2. Space-time deformation for oscillating behavior

Let us consider a rigged mesh defined by a set of vertices at index i. We call $\alpha_{ij} \in [0,1]$ the skinning weights binding vertex i to joint j. The vertex position obtained after applying a Linear Blend Skinning (or dual quaternion skinning) is denoted by p_i (see Fig. 3-left). The skeleton is defined by N joints at position q_j, $j = 1,\dots,N$, with angular velocity $\Omega_j \in \mathbb{R}^3$. We call $\beta_{ij} \in [0,1]$ *hierarchical weights*

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expressing the influence of the motion of a given joint toward the vertices depending on this joint and all their decendant in the hierarchy such as $\beta_{ij} = \sum_{k \in \mathcal{D}(j)} \alpha_{ik}$, where $\mathcal{D}(j)$ is the set of decending joint indices starting at j included. We then recall the general formulation of Velocity Skinning [RTK*21] as

$$\tilde{p}_i = p_i + \sum_{j=1}^{N} \beta_{ij}\, \psi(\Omega_j, q_j, p_i), \quad (1)$$

$\tilde{p} \in \mathbb{R}^3$ is the deformed vertex position obtained from Velocity Skinning, and ψ is a procedural deformer depending on the angular velocity of the considered joint, its position, and the position of the vertex. In our case we will consider ψ describing the *drag* deformation [RTK*21] and modeled as a rotation around the axis defined by Ω_j, with angle varying as $-\|\Omega_j \times (p_i - q_j)\|$.

This initial formulation only considers the instantaneous angular velocity $\Omega_j(t)$ at a given time t. In this work, we propose to extend it to time-based deformation in considering a time-filtered value $\mathcal{F}(\Omega_j, t)$ (see Fig. 3-right), where Ω_j is now seen as a time-varying signal. The modified formulation for space-time deformation is then

$$\tilde{p}_i(t) = p_i(t) + \sum_{j=1}^{N} \beta_{ij}\, \psi(\mathcal{F}(\Omega_j, t), q_j(t), p_i(t)). \quad (2)$$

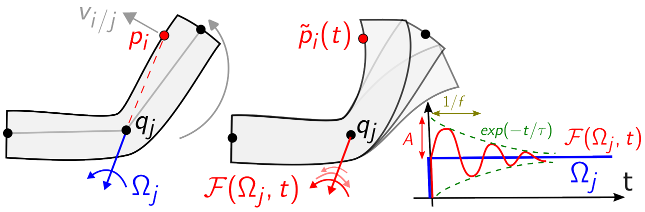

Figure 3: *A rotation applied to a cylinder using standard LBS along an angular velocity Ω_j at joint j (left) is converted to an oscillation using a time filter $\mathcal{F}(\Omega_j, t)$ (right).*

We aim at designing a time-filter $\mathcal{F}$ that will allow to model an oscillating behavior after a sudden change of velocity. To this end, we to define its expression as the response of a linear filter to a unit impulse $U(t)$, where $U(t) = 0$ for $t < 0$ and $U(t) = 1$ for $t \geq 0$. Calling $h(t)$ such a response, we propose the following formulation

$$h(t) = (1 + A\, \exp(-t/\tau) \sin(2\pi f t))\, U(t), \quad (3)$$

where A is the magnitude of the oscillation, τ is a characteristic damping time, and f is the oscillation frequency. The time-filtered applied to an arbitrary angular velocity variation is then obtained by convolving the angular velocity signal with the derivative of the response to the unit response, leading to

$$\mathcal{F}(\Omega_j, t) = (\dot{h} \star \Omega_j)(t) = \Omega_j(t) + A \int_{u=0}^{+\infty} \exp(-u/\tau) \left(2\pi f \cos(2\pi f u) - \frac{u}{\tau} \sin(2\pi f u)\right) \Omega_j(u - t)\, \mathrm{d}u \,. \quad (4)$$

3. Results and Future Works

We show in Fig. 1 the comparison of a time evolution between the results obtain with a *drag* deformer from Velocity Skinning (left), and our oscillating behavior (right) from the same joint motion that applies a rotation toward the left side and then stops. While the Velocity Skinning simply applies a bending before stopping all deformation, our method is able to model a long term oscillation which is further illustrated in Fig. 2. The method can be implemented in real-time in first, computing Eq.(4) for each joint along a finite time window W, before applying Eq. (2) to each vertex in parallel, possibly via a vertex shader. The limited time window W can be set such as $W > 5\tau$ corresponding to the time needed for an oscillation to be fully attenuated. Our GPU implementation performed on a desktop equipped with an NVIDIA RTX3090 led to a computational time of 30ms per frame for 1.5 million triangles.

The key advantage of our method is the art-directability of the oscillation parameters as independant sliders. We typically considered $\tau = 1\,s$, $f = 1.5\,Hz$, and $A = 0.2$ as default values, but these can be adjusted independently, at the opposite of the use of mass-spring models that would couple magnitude and frequency. Thanks to the hierarchical weights, the per-vertex deformation is automatically distributed along the mesh, while multiple oscillations triggered from different joints can be summed over seamlessly.

In conclusion, we have presented a real-time method able to represent per-vertex oscillation behavior triggered by a sudden change of velocity that can be applied on existing rigged character. The oscillation is computed from a simple procedural filter that can be easily parameterized by artists with respect to frequency, magnitude and attenuation.In future research, we aim to introduce more filter-based deformations to simulate different types of oscillations and time-varying effects in adapting the procedural deformers, as well as including local control over the space-time propagation of the deformation.

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