

# SMEAR, Stylized Motion Exaggeration with ARt-direction Supplemental Material

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In this supplemental document, we provide in Section 1 a detailed account of how we identified the design guidelines used throughout our paper. We then discuss in Section 2 our experience with existing software for the creation of smear frames in 3D. We finally give additional information on the supplemental video in Section 3, and write a quick user guide for our Blender add-on in Section 4.

## 1 GUIDELINES

As discussed in the introduction of the paper, we identified three guidelines for our smear frame creation tools, which we recall here:

- G1:** Smear frames have two main goals: (1) increase retinal persistence by creating a larger overlap among consecutive frames, and (2) create an effect of surprise (the “snap!” in Richard Williams [2001] words) to direct the observer’s gaze.
- G2:** A motion stylization tool must seamlessly fit in the 3D animation workflow. It must thus be fast enough to provide interactive feedback, toggling the motion effect should be easy, and artists must be able to fine tune the results manually. Moreover, for skeletal animations, the tool should not modify the input poses.
- G3:** Motion stylization effects should be fully customizable by artists, allowing to create unique styles for every production.

In this section, we detail how we came up with these guidelines based on an observational study and an interview.

### 1.1 Observational study

We observed how smear frames were created in traditional animations to better understand their impact on the animation. We studied early cartoons that introduced these effects, such as *The Dover Boys at Pimento Academy* by Chuck Jones [1942]. We observed that elongated in-betweens are common in these works, and extend characters along their motion trajectory, resulting in smooth and dynamic motions. We also observed similar effects for elongated and multiple in-betweens in smear frames from various animation styles [Ruocco 2016]. Smear frames are often used to

simulate motion blur with few drawings, and create startling motion effects [Gurney 2014]. Lasseter [1987] describes a similar effect, where stretching an object along its trajectory to create overlap helps smooth out the animation.

Smear frames have been recently adapted to 3D animations, in movies [Carter 2019; Rothman et al. 2018] and video games [Lendenfeld 2018]. In our observations, smear frames were always used to either smooth motion by stretching objects and creating overlap, or to guide the observer’s gaze, which confirms our guideline **G1**.

We also relied on Richard Williams [2001] tutorials on smear frames creation as a reference. Along with explanations that confirm the objective of creating overlap (**G1**), these tutorials provide step-by-step instructions to create convincing elongated or multiple in-betweens.

### 1.2 Interview with a professional animator

We conducted a one-hour interview with the head of innovation of a 3D animation studio. We focused the interview on their approach to the creation of smear frames, in particular at which step such a stylization usually takes place in the animation pipeline. We also presented an early prototype of our approach. We summarize the main insights that came out of this interview below, and how they were integrated into our guidelines.

Artists use smear frames, specifically elongated and multiple in-betweens, for two main reasons: to increase retinal persistence, and to alert or surprise the observer (**G1**).

Smear frames are seen as dynamical effects that animators may add to give life to an animation. Other similar effects are for example inertia or oscillations. Such effects must be easy to toggle on or off to iterate over the animation (**G2**).

Another approach for adding these dynamic effects is to simulate them to create realistic deformation of muscles or skin, for example. This is known as “Creature Effects” (or CFX), and is aimed at creating realistic creatures for live action movies in big productions, and is thus not suitable for animated movies.

Tools to create smear frames and similar effects must be easily included in existing animation workflows. If the tools break or interrupt the animator’s workflow, it is likely to be abandoned (**G2**). This encourages implementing these approaches inside a common animation software. While most animation studios uses Autodesk Maya, Blender is growing in popularity in small studios and, as an open-source software, it is adapted for distribution of new tools.

Stylization tools must not break the animation created by the artist. This implies that stylization tools must not modify the skeleton pose, e.g., by stretching the bones. They must provide control to the artist and have the option of being toggled off (**G2**).

Creating an animated film requires several steps, from the animation itself to dynamic effects and rendering. Intermediary steps such

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as stylization must not break this pipeline, and their output must be compatible with the next step of the process (G2). Outputting a deformed mesh respects this constraint, and allows the artists to manually refine the result before going to the next step.

Automatic stylization tools tend to give a similar style to all animations, which can be frustrating for animators. Full customization must thus be possible to create new unique styles for different productions (G3).

After the interview, informal discussions with other professional animators helped confirm these guidelines and answer specific questions. Specifically, it confirmed that a computation time of a few seconds is not a strong limitation for artists, who are used to such pre-processing timings, usually referred to as “baking”. These exchanges also confirmed the interest of the artistic community for such stylization tools.

## 2 EXISTING SOFTWARE

We studied existing add-ons for smear frame creation in traditional animation software (Autodesk 3ds Max and Blender).

OverMorpher is aimed at experienced artists, and allows the sculpting of animated objects to create different effects such as smear frames or *squash-and-stretch*. This tool gives full control to the artists (G3), but manual sculpting makes iterations over the effect and the animation quite tedious, in contradiction with guideline G2.

motionFX proposes four smear frame stylization effects that can be applied to animated objects in Blender. This tool is very easy to use by novice animators to apply stretching in one click, but the stylization presets cannot be customized to create new styles (G3), and cannot be applied to rigged characters.

We also tested tutorials and tools to create smear frames using Blender “Geometry Nodes”. First, we re-implemented the node network of Alaniz [2023] following their tutorial. This approach gives very good results with real-time elongated in-between following noise textures. However the created elongated in-between stretches the object in the direction of its velocity as an approximation of its trajectory. While this gives good results for small elongation and straight motions, this creates artifacts when creating wide elongated in-betweens for curved motions. Moreover, selection of the parts of the objects that are stretched is based on the dot product between vertex velocities and normals, which can create artifacts for concave and highly detailed objects as discussed in the paper.

We also tested Blender add-on of 3Dan [2023]. Similarly to our approach, this node network allows the creation of elongated, multiple in-betweens and motion lines after a short pre-processing step. However, similarly to [Alaniz 2023], their elongated in-betweens are stretched along the direction of vertex velocities based on the dot product of the velocity and vertex normal.

## 3 VIDEO AND SUPPLEMENTAL RESULTS

Richard Williams [2001] describes how to use elongated in-betweens to put emphasis on an impact with step by step tutorials. We followed these instructions to create two animations with stylized impacts that we present at the end of the accompanying video.



(a) Elongated in-betweens computed with  $\beta_i = S_E^{\text{speed}}(\delta_{i-}; \mathbf{v}_i, 15)$



(b) Elongated in-betweens computed with  $\beta_i = \omega_i S_E^{\text{speed}}(\delta_{i-}; \mathbf{v}_i, 15)$  and weights from Paper’s Figure 15

Fig. 1. Elongated in-betweens for a sword slash motion, with (a) and without (b) weights to control the stylization gradient.

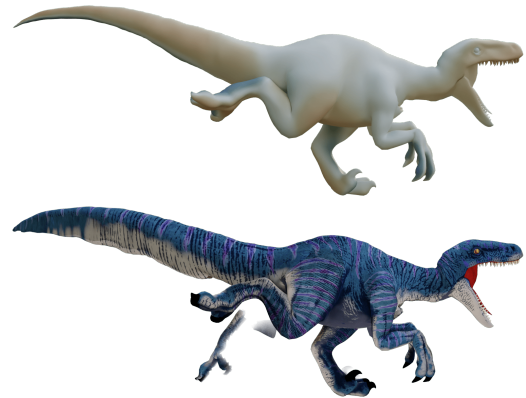


Fig. 2. Motion offsets (top) and stylization (bottom, elongated in-betweens on the tail and multiple in-betweens on the legs) for a running velociraptor. Positive (resp. negative) motion offsets are painted red (resp. blue).

In Figure 15 of the main paper, we present smear frames on a sword slash motion, using manually-painted weights. In Figure 1, we compare the stylization obtained with or without these weights, and show that they allow refining the intensity of the stylization along the sword edge.

Our method can also be applied on non-human articulated characters, as shown in Figure 2 and in the supplemental video (model downloaded from [Absol 2024]). In this result we applied elongated in-betweens on the tail with  $S_E^{\text{noise}}(\delta_{i-}; \mathbf{v}_i, 8.5, 5)$  where  $\delta_{i-} = \min(\delta_i, 0)$ , and multiple in-betweens on the legs. Multiple in-betweens are positioned with the overlap constraint for retinal persistence,

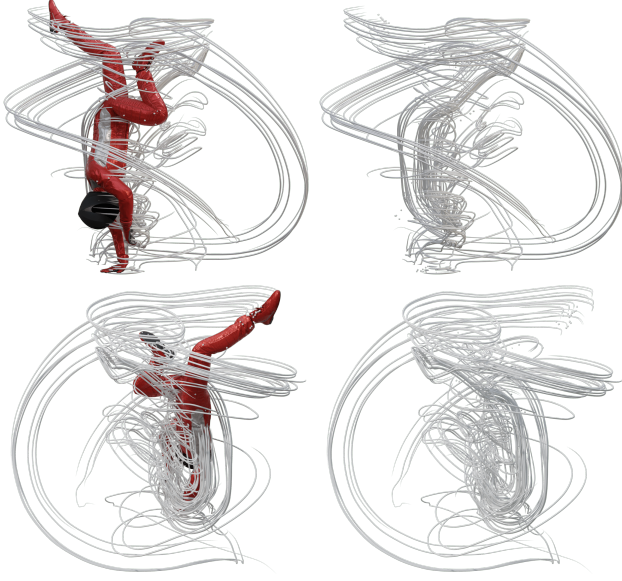


Fig. 3. Static depiction of motion with motion lines, seen from two different viewpoints.

using  $N_\Gamma = 1$ ,  $m_p = 1$  and  $m_n = 0$ . Opacity is controlled by the following stylization function using warped motion offsets introduced in Section 5.2 of the main paper:  $\alpha_{i,m} = \mathcal{S}_M(\delta_i^*(0.8, 0.5), m; 1)$ .

Our method could also be used for artistic depiction of motion on static images, such as with motion lines in Figure 3.

We document in Table 1 keyframed parameters used for the animations in the accompanying video, when applicable.  $\beta_{max-}$  (resp.  $\beta_{max+}$ ) corresponds to a scaling factor applied only to negative (resp. positive) motion offsets.

## 4 OUR BLENDER ADD-ON

In this section, we provide instructions to use our approach on Blender scenes provided with our supplemental material, and how to install and use it on new animations.

The provided scenes come with pre-computed motion offsets and a “Geometry Node” stylization preset with parameters corresponding to those presented in the paper. The installation of the add-on is **not** required to play with the stylization parameters.

### 4.1 Installation

Our add-on has been developed and tested with **Blender 3.6.0**. Instructions to install the add-on for new animations are as follow:

- (1) Download “Smear.zip” from the supplemental material.
- (2) Open Blender. In the Add-ons tab of Blender preferences, press Install and navigate to “Smear.zip”. Select it, and click Install Add-on.
- (3) In the Add-ons search bar, search for “Animation: Smear”, and enable the add-on by clicking the checkbox.
- (4) If your Blender Python install does not include the numpy package, it will be installed when enabling the add-on, which can take a few seconds.

Table 1. Keyframed parameters values for the animations presented in the supplemental video, when applicable.

Figure 1 elongated in-betweens							
Frame number	0	5	10	27	29	33	35
$\beta_{max}$	0	1	10	4	2	1	0

Figure 1 motion lines				
Frame number	0	19	26	30
$\tau_{max}$	/	10	7	/
Min speed	5	0.6	/	1.3

Figure 16								
Frame number	6	7	10	13	14	16	30	41
$\beta_{max}$	/	/	/	/	/	2	0	/
Multiple min speed	0.3	0.25	0.2	0.1	/	/	/	2
Lines activated	/	/	/	1	0	/	/	/

Richard Williams impact tutorial 1			
Frame number	17	20	27
$\beta_{max}$	0	3	0

Richard Williams impact tutorial 2						
Frame number	7	8	10	11	12	13
$\beta_{max}$	/	0	/	0.917	1.28	0
$\beta_{max-}$	1	/	0	/	/	/
$\beta_{max+}$	/	1	6.840	2.630	1	/

### 4.2 Usage

In this section, we first present how to compute motion offsets for new animations using our add-on. As a reminder, motion offsets are pre-computed in the provided scenes showing the paper results and do not need to be recomputed, except if the input animation is edited. We then describe the stylization parameters available in our node networks.

#### *Motion offsets computation.*

- (1) To create smear frames on a keyframe-based animation, select the animated mesh. For rigged characters, make sure the mesh of the character is selected and not just its armature.
- (2) In the toolbar on the right, go to “Misc” to find the “Smear Frame Generation” panel.
- (3) With the animated mesh selected, press Bake Smears to run the motion offsets computation pre-process.
- (4) The “Ignore skeleton” option can be used for articulated characters if you want smear frames to depend on the full body movement (e.g., for fast motion) instead of the skeleton.
- (5) The “Temporal smoothing window” parameters control the number of frames to consider for temporal smoothing described in Section 3.1 of the paper;  $N = 2$  gave satisfying results in all presented results.

After computing the motion offsets, the add-on will automatically apply the “Smear Frames Controller” node group to the animated object, which creates elongated in-betweens with the default stylization. Parameters of the node group can be changed in the modifiers tab. Other types of smear frames can be applied by changing this

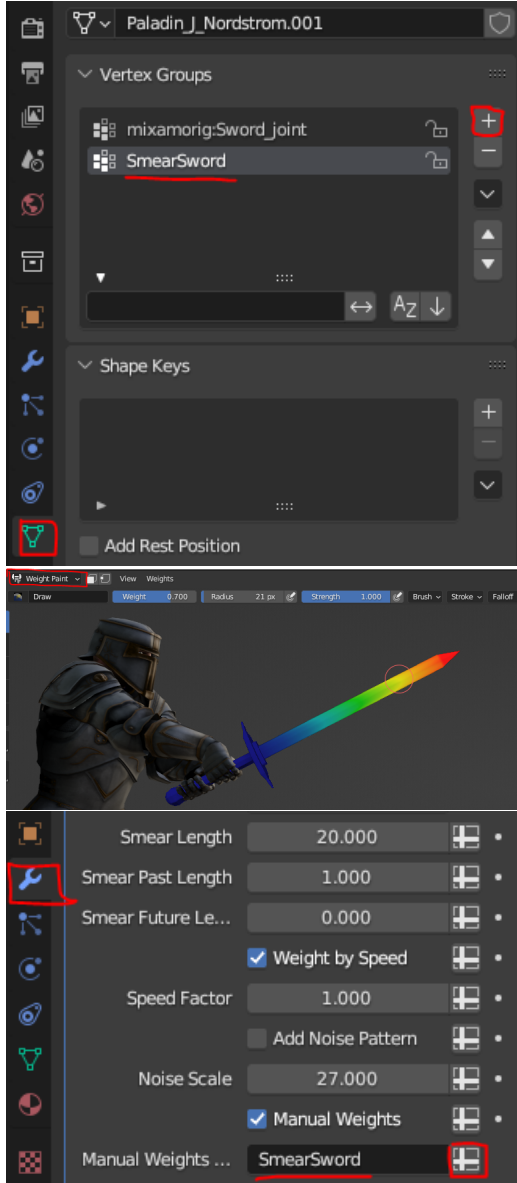


Fig. 4. Setting manual weights to control stylization strength.

node group to “Smear Frames Controller - Multiples” or “Smear Frames Controller - Lines”, and providing the name of the object’s mesh and the “aggregated\_animation\_mesh\_name” to the “Object” and “Aggregated” modifier parameters.

The provided Blender scenes come with pre-loaded node groups.

*Parameters for elongated in-betweens stylization.*

- **Animation Timing:** choose if the animation must run on ones, on twos, ...
- **Smear Length:** controls the general scale of the smear frames (corresponds to  $\beta_{max}$ ).

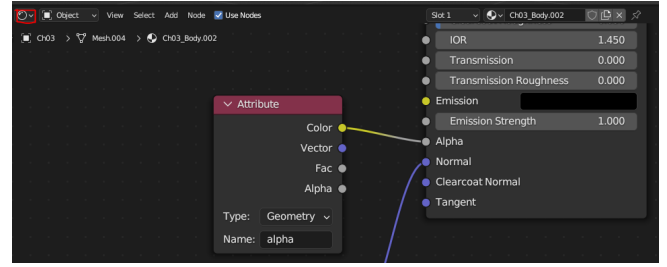


Fig. 5. Adding transparency to multiples created by our approach.

- **Past/Future Smear length:** controls the scale of the smear frames in the past/future of the object trajectory. Corresponds to  $\beta_{max-}$  and  $\beta_{max+}$ .
- **Weight by speed:** when enabled, weights the smear frames by the local speed multiplied by the **Speed factor**. Corresponds to the  $S_E^{speed}$  stylization function.
- **Add noise pattern:** when enabled, weights the smear frames by a noise texture controlled by the **Noise Scale** factor. Corresponds to the noise value  $F_1(p_i(0), \kappa)$  used in the  $S_E^{noise}$  stylization function.
- **Manual Weights:** when enabled, weights the smear frames by the painted weights provided in the **Manual Weights Group** vertex group (more details in Section 4.3 and Figure 4).

*Parameters for multiple in-betweens stylization.*

- **Previous** and **Next:** number of multiple copies to add in the past and future of the trajectory ( $m_p$  and  $m_n$ ).
- **Overlap:** when enabled, multiples are placed with overlap constraint described in Section 4.2 of the paper.
- **Number of overlaps:** if **Overlap** is enabled, corresponds to  $N_\cap$  from Section 4.2 of the paper.
- **Displacement:** if **Overlap** is not enabled, corresponds to the multiple displacement  $\Delta f$  from Section 4.2 of the paper.

In order to apply the transparency controlled by our approach to the created multiples, change the animated mesh material in the Shader Editor so that its alpha value is controlled by an attribute node “alpha” as in Figure 5.

*Parameters for motion lines stylization.*

- The same parameters as elongated in-betweens control the length of the lines.
- **Seed:** random seed used to select seed points for lines.
- **Probability:** probability for each vertex to be selected as a seed point for lines.
- **Speed threshold:** vertices going slower than this threshold will not be selected as seed points.
- **Radius:** radius of the speed lines.
- **Material:** material applied to the speed lines.

### 4.3 Customizing new styles

As shown in the accompanying video, the node network can be modified to create new custom stylizations. The most straightforward way to do so is to control the motion offsets, that are represented in

the node network as per vertex parameters named “delta\_i” with i the index of the corresponding frame.

Manually painted weights can be used to control stylization intensity. To do so, create a new vertex group to the animated mesh in the “data” tab. With this vertex group selected, go to weight paint mode to create the weights. In the node networks parameters, activate the “Manual weights” checkbox and provide the name of the vertex group in “Manual weights group”. This is illustrated in Figure 4.

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