SnugBlur!: Constraint-Preserving Motion Blur

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Motion blur on eyelids is a problem for animated characters. Many renderers compute motion blur linearly, which can produce artifacts when an eyelid intersects an eyeball during a blink motion. Many techinques deal with this issue, such as multisample motion blur and paint-overs, but each comes with problems. We present a more robust solution to the eyelid problem by introducing the notion of constraint-preserving motion blur.

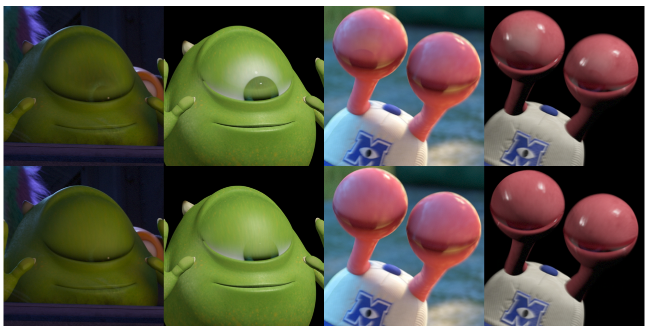

Figure 1: *Linear motion blur produces intersection artifacts. Top Row: linear blur, Bottom Row: constraint-preserving blur.*

1 The Problem

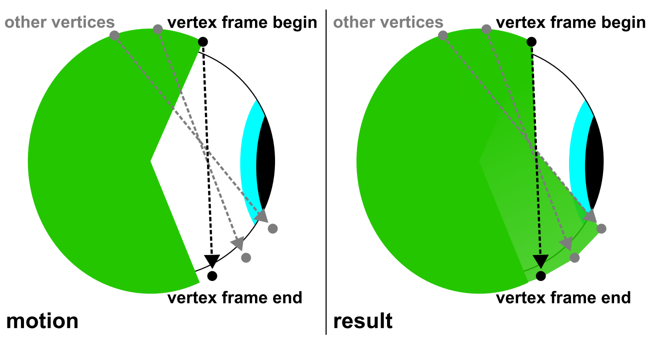

Figure 2: *Diagram of eyelid intersection issues*

In animated films, eyes can be animated from fully open to fully closed in one or two frames. Typically, this animation is sampled per frame, and renderers may linearly interpolate the samples to create motion blur. An eyelid animated this way will cut a linear path through the eyeball if traveling a wide arc, creating artifacts like intersections or occlusion artifacts. This was particlary tricky on *Monsters University*, which features a character which is essentially a large eyeball, and many monsters with eyes on eyestalks.

2 Existing Solutions

There are many solutions to this problem, but with drawbacks.

Multi Sampling One can sample the character geometry at subframes and render the result as multiple linear segments, or a renderer could stochatically sample motion at any point in time. This may fix the eyelid problem, but create others. Notably, when two pieces of geometry have a salient geometric relationship, such as cloth on a body, multi sampling the body but not the cloth will cause intersections due to mismatching motion paths. This can be prohibitively expensive, especially when simulation is involved.

Render Time Reordering Some renderers are capable of enforcing an ordering between pieces of geometry regardless of actual depth order by shuffling fragments. This fails in the presence of complex depth relations, and can also produce artifacts when used with physically based lighting methods.

Displacement One can displace the eyeball or eyelid on a blink. This can be laborious and prone to intersections when displacement is too low or unacceptable shape changes when too high.

Painting Taking a brute force approach, one might find and paint out these artifacts. This quickly becomes prohibitively expensive with many shots or many characters.

3 Our Solution: Constraint Preserving Motion Blur

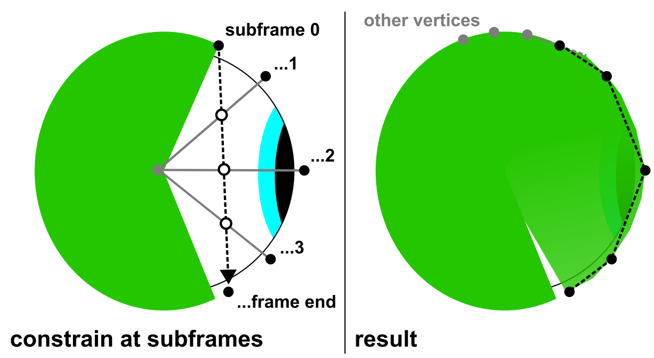

Figure 3: *Diagram of constraint preserving motion blur*

We take frame-sampled geometric data for the eyelid, and at render time craft subframe samples that enforce a non-intersection constraint between the eyelid and eyeball. A user specifies which points on the character mesh need this non-intersection constraint. For example, to generate a constraint-preserving subframe sample for an eyelid point, its position is determined by taking the linear sample, projecting it out to the eyeball surface, and then displacing to preserve distance from the eyeball (Fig. 3). For points that do not need this non-intersection constraint, the subframe samples are simply the linear samples. This fixes the eyelid motion blur problem without forcing subframe sampling on other objects in the scene.

Other Applications This technique can be used in any case where there is a geometric relationship not preserved by linear motion blur such as cloth sliding on a curved body mesh. This technique can also be used for subframe sampling a character with clothing if the cloth itself is sampled only at integer frames, say for instance if an arm gesture requires a curved motion path. In this case, subframe sampling only the body would introduce intersections of the sleeve through the arm which could be fixed by generating subsamples that enforced a non-intersection constraint between the sleeve and the body without additional simulation.

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