Stroke based Painterly Inbetweening

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PROBLEM

Traditional paint-on-glass animation use a technique called *under the camera*. The artist creates a first frame and captures it on film. The next frame is obtained by slight modifications of the first one, and so on for the whole sequence. Each frame of the animation only exists when it is captured and is then destroyed to produce the next frame. The artist has to anticipate the entire sequence, there is no option to go back.
On the other hand, cell animation artists usually think the animation in term of keyframes and then refine the animation with intermediate frames. Each frame can be drawn and modified independently.
Our goal is to provide an approach with the look and feel of the under the camera technique and the level of control of the keyframe approach.

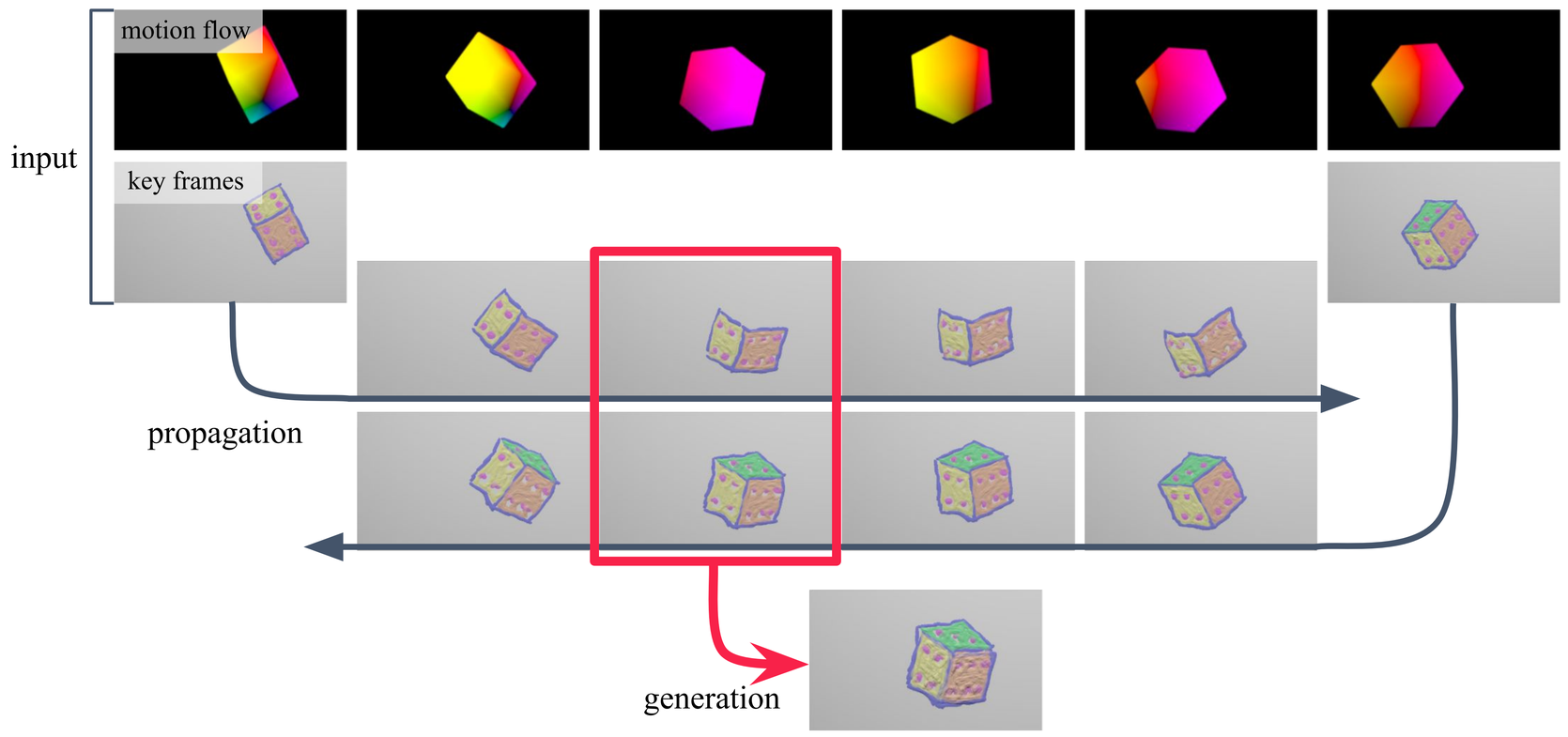
RELATED WORK

2D automatic inbetween methods focus on contour and silhouettes sketches [DBB*17, WNS*10]. Previous work on filled region by stroke based rendering focus on temporal coherence, and attach painting strokes to 3D surfaces [SSGS11, BBS*13]. We propose to generate all the strokes in 2D, without specific temporal coherence, taking inspiration from traditional paint-on-glass style, and giving controle with key frame authoring.

OVERVIEW

From a set of key frames and a motion flow, our methods automatically generates intermediate frames. The set key frames defines the style of intermediate frames. The motion flow captures the motion of the animation and drive the stroke generation process.

METHODOLOGY



Step 1: Propagation

- Strokes from the first keyframe are advected forward
- Strokes from the second keyframe are advected backward

Each intermediate frame has two sets of advected strokes.

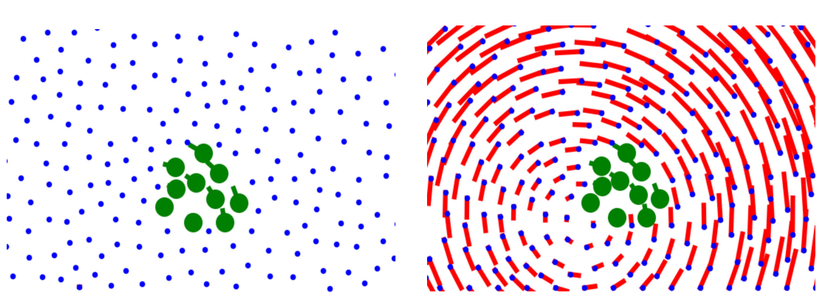
Step 2: Generation

Each intermediate frame is generated from the two strokes sets computed in step 1.

We select a subset of strokes from each strokes set. The ratio of strokes is defined such that at least one strokes set is fully selected for every intermediate frame. This assumption helps conveying the keyframe information during the animation.
The ratio is $\alpha(i) = \min(\frac{2*(n-i)}{n}, 1)$ for the set corresponding to the first keyframe. Where i is the intermediate frame indice, and n the total frame count between the two keyframes. The ratio for the second set is $\alpha(i) = \min(\frac{2*i}{n}, 1)$

To advect strokes we compute an extended motion flow from the input motion flow following these steps:

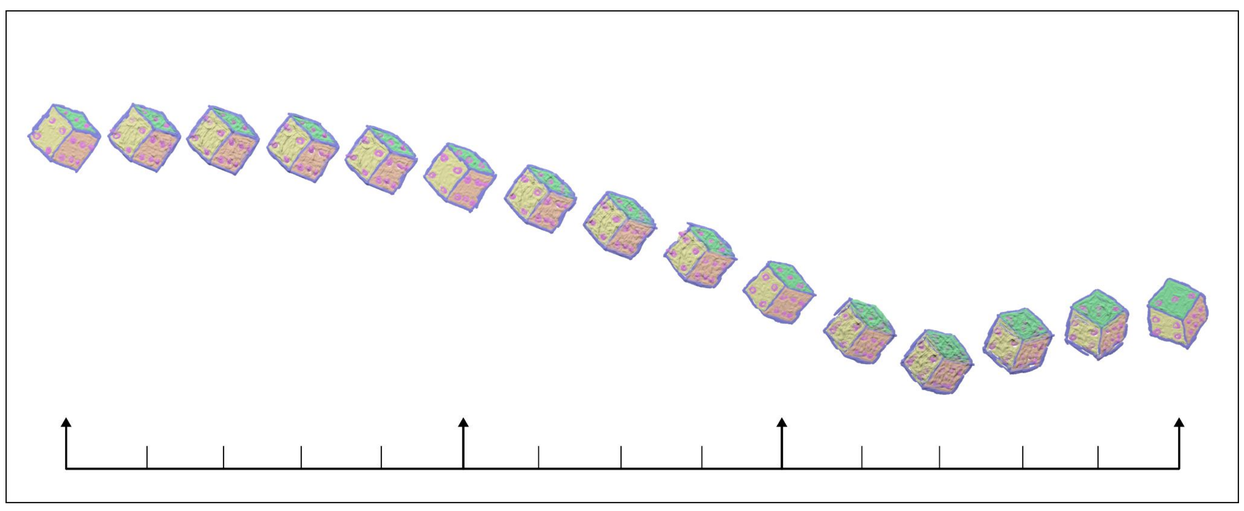
- Triangulate image space using a Delaunay triangulation with max edge length to evenly distribute motion samples
- Extrapolate valid motion samples using bi-harmonique diffusion to each triangulation vertices
- Interpolate motion vectors from vertices to each pixel of the motion flow.

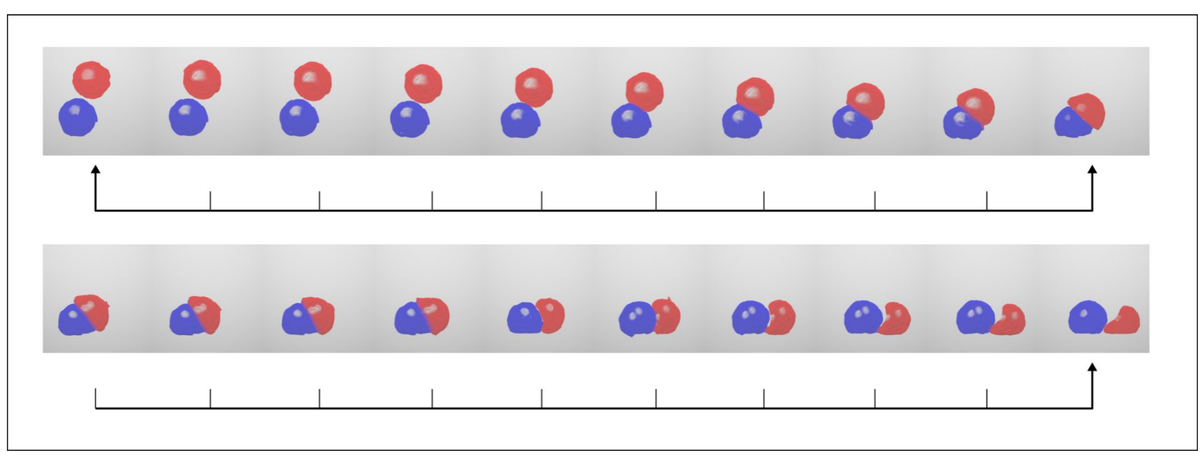


input motion samples only green sample have valid motion

extrapolated motion samples

RESULTS





In these examples, key frames are marked with arrows on the timeline. Intermediate frames convey the styles given by the key frames.

The time needed to render a frame depends on the number of advected strokes and the number of pixel covered by the generated strokes. These two examples took less than one second per frame to render.

On the example on the right the motion flow captures the motion of the shape. The specular highlight should follow another motion. In this example we can see this motion inconsistency creates two highlights for the red and blue spheres instead of one. This limitation could be addressed by providing multiple motion flows and set which strokes follow which flow.

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