

# Non-linear Rough 2D Animation using Transient Embeddings – supplemental material –

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After analyzing traditional 2D animation practices on our own (Section 1), we collaborated with a professional 2D animator and animation software developers from the [Praxinos](#) company to guide the design of our system. We established a first set of guidelines (see Table 1) through informal discussions, summarized in Section 2. We then refined and completed those by conducting an observational study followed by interviews, as described in Section 3.

## 1. Preliminary observations

We started this project by studying the “bibles” of 2D animators from Johnston and Thomas [JT95] and Richard Williams [Wil01] to fully understand the traditional animation pipeline and animators’ practices.

In the early days of traditional animation, a single animator would generally draw all frames in a scene. In the 1920s, animation studios started distributing the work between “key” animators and “inbetweeners”. Nowadays this method has been standardized and many studios follow variations of the following simplified pipeline. Starting from a storyboard establishing the narrative flow of the scene, the key animator produces rough key drawings that lay down the core of the action. She or he may then refine the animation by adding additional breakdown keyframes. Eventually, the animator controls the dynamics of the motion by defining the timing and spacing, i.e., how many drawings should be produced between two keys, and at what intervals. Spacing charts are commonly used to specify those. During an optional “tie down” pass, the same animator refines the rough drawings to make sure volumes remain constant and to avoid any ambiguities in where to place the inbetween strokes, adding annotations when needed. From these drawings, spacing charts and annotations, the inbetweeners draw the intermediate frames to produce seamless motion. In a final pass, a “clean up” artist produces the drawing with the final line art.

At this point, we made two founding observations: (1) key animators are supposed to design motion without any previsualization until the inbetweening step; (2) the traditional animation process is fundamentally linear, any modification at an early stage of the pipeline (even changing the timing or spacing) requires redrawing all the intermediate frames.

<b>G1</b>	Groups of strokes are units of motion; their number may change depending on motion complexity
<b>G2</b>	Topological changes (e.g., parts of the drawing appearing, disappearing, splitting or merging) happen at keyframes; they are not interpolated
<b>G3</b>	Artists use different workflows that must be supported; they can provide indications (e.g., correspondences), but their creative flow should not be interrupted.
<b>G4</b>	Control over timing, spacing and interpolation trajectories is crucial to design motion.

**Table 1:** System design guidelines extracted from our observational study and discussions with a professional 2D animator and animation software developers.

## 2. Discussions with practitioners

**Previsualization.** Our discussions with our Praxinos partners confirmed these observations. They insisted on the fact that the main creative part of the animation process is the rough stage during which the motion is designed with a sparse set of sketches and spacing charts. However, transcribing the intended motion into a set of sketches is a very difficult task which takes years of practice to develop. Furthermore, experimenting with different motion can only feasibly be done in the artist’s mind since visualizing this motion would require drawing and redrawing many frames, losing precious production time.

Therefore, there is a clear need for a tool to previsualize motion at the rough stage. It would allow animators to design and test out different motions without relying on years of experience to envision the final motion. Such a tool would also help communicate the intended motion to the inbetweeners or to the art director for validation.

**Artistic workflows.** Animators may use different workflows when it comes to drawing keyframes and breakdowns. The two main ones are the “shift-and-trace” and “pose-to-pose” workflows. The former consists in tracing a new key drawing over a deformed version

of the previous key moving forward in time. In the latter case, all the key drawings are created independently of each other in an arbitrary order. Animators may use a different workflow depending on the scene they are working on, and might even switch between workflows for certain parts of the scene.

As a result, our system must be able to accommodate various workflows within a single unified approach so that artists are not bounded to a specific workflow (guideline (G3)).

**Artist intervention.** One recurring point during our discussions was the importance of not interrupting the animator’s *creative flow* when drawing. In general, user intervention should be kept minimal during the drawing process. Nevertheless, animators are used to annotate correspondences or to draw hidden parts for the inbetweens since it is sometimes necessary for disambiguation.

Consequently, if user-provided annotations (such as correspondences) are possible, they should not interrupt the drawing process. Moreover, the animator should only have to input the essential amount of annotations (guideline (G3)). Since we are dealing with rough sketches, annotations at the stroke level would lead to a lot of tedious work. Therefore our system should not focus on dealing with groups of strokes (guideline (G1)).

### 3. Observational study and subsequent interviews

Following these discussions, we reviewed approximately 10 hours of live-commentated recording showing our collaborating professional 2D animator at work. The footage starts with the illustration of basic animation principles such as timing, spacing and breakdowns on a simple example (a single stroke). It is followed by a complex character animation example (8 keyframes) at the rough and tie down stages. We then conducted another set of interviews to clarify some points raised in the videos.

**Annotations.** We observed that the animator used color-coded strokes to indicate how and if strokes need to be retraced. In general he used many annotations to specify intermediate positions, correspondences, arc trajectories and hidden parts to avoid any “guess” from the inbetweens.

Since user annotations mostly deal with motion, groups of strokes should represent units of motion that can be refined at any time (merged or split) based on motion complexity (guideline (G1)). The system should provide spatial and temporal controls over the animation of these groups of strokes in the same way animators use spacing charts and trajectory arcs (guideline (G4)).

**Topological changes.** The animator mentioned that since key animators want to retain control over the animation as much as possible, the appearance or disappearance, merging or separation of drawing parts (i.e., topological changes) should occur at keyframes and are thus not interpolated by the inbetweens.

It implies that groups of strokes may only persist between a pair of keyframes. The number of stroke groups might then be made to change *at* keyframes, granting the ability to introduce topological changes (guideline (G2)). Breakdown keyframes represent a special case, as they are usually employed to refine motion without

changing the drawing topology. A breakdown keyframe thus reuses the same groups of strokes as the previous keyframe in our system.

**Spacing.** The animator insisted on the fact that all the frames between two keyframes should be displayed on a spacing chart. In addition, spacing charts should provide control at the frame level, or through standard animation patterns (e.g., “halves” or “thirds”).

In a non-linear system, the timing between keyframes may be changed at any point in the animation process. Yet, the spacing of the intermediate drawings must be preserved during such operations. It implies that we need a spacing representation that abstracts absolute frame numbers while still providing control over the position of a single frame (guideline (G4)).

### References

- [JT95] JOHNSTON O., THOMAS F.: *The illusion of life : Disney animation*. Disney Press, 1995. 1
- [Wil01] WILLIAMS R.: *The animator’s survival kit*. Faber and Faber, 2001. 1