Parameterizing Animated Lines for Stylized Rendering

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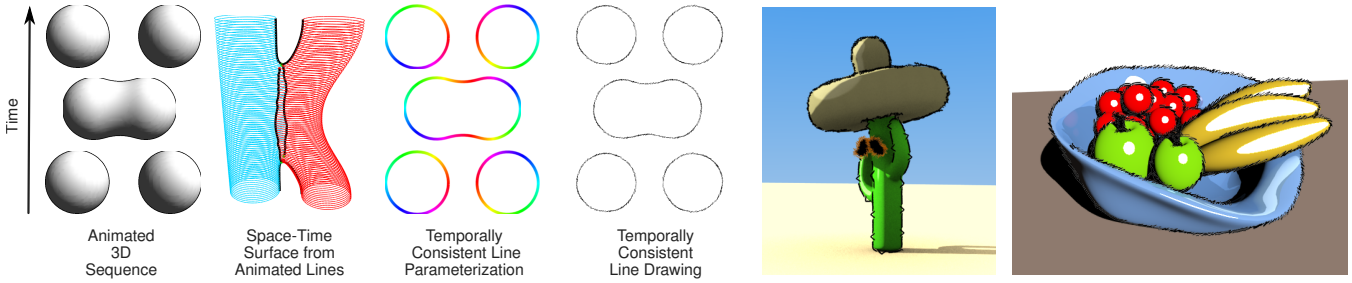

Figure 1: *Our algorithm builds a temporally consistent parameterization for lines extracted from an animated 3D scene.* **Left***: Example sequence of two metaballs joining and parting again, creating the depicted space-time surface including split lines. Lines are then parameterized and textured.* **Right***: Further results.*

1 Overview

We describe a method to parameterize lines generated from animated 3D models in the context of animated line drawings. Cartoons and mechanical illustrations are popular subjects of non-photorealistic drawings and are often generated from 3D models. Adding texture to the lines, for instance to depict brush strokes or dashed lines, enables greater expressiveness, e.g. to distinguish between visible and hidden lines. However, dynamic visibility events and the evolving shape of the lines raise issues that have been only partially explored so far. In this paper, we assume that the entire 3D animation is known ahead of time, as is typically the case for feature animations and off-line rendering. At the core of our method is a geometric formulation of the problem as a parameterization of the space-time surface swept by a 2D line during the animation. First, we build this surface by extracting lines in each frame. We demonstrate our approach with silhouette lines. Then, we locate visibility events that would create discontinuities and propagate them through time. They decompose the surface into charts with a disc topology. We parameterize each chart via a least-squares approach that reflects the specific requirements of line drawing. This step results in a texture atlas of the space-time surface which defines the parameterization for each line. We show that by adjusting a few weights in the least-squares energy, the artist can obtain an artifact-free animated motion in a variety of typical non-photorealistic styles such as painterly strokes and technical line drawing.

On the contrary to previous approaches [2003], we do not seek for real time processing but rather for high quality output from a known animated sequence. Therefore, we introduce a global space-time approach to the line parameterizaton problem.

2 Spatio-Temporal Analysis

Our algorithm takes as input a possibly animated 3D model and a sequence of camera viewpoints. We assume that the model has a temporally consistent 1-to-1 correspondance, that is, for any vertex of the model, we can compute its trajectory during the animation.

Our objective is to parameterize 2D lines generated by typical line drawing methods such as contours and silhouettes. In this work, we seek for a parameterization of the lines that is temporally consistent. First, the lines are extracted independently for each frame of the animation before being grouped as plausible corresponding lines from frame to frame. Second, the so defined 2D+t model takes the form of a space-time surface which acts as our underlying decomposition model for the rest of the algorithm. Third, lines may split or merge during the animation due to occlusion/visibility events. We handle these events by reusing the same cut for several discontinuities to avoid over-segmenting the lines.

With our space-time formulation, the cuts are geodesic lines on the space-time surface and we handle discontinuities by decomposing the space-time surface into charts with a disc topology. In the following step, these space-time charts are parameterized independently – optionally under user control – to provide time-coherent parametric lines.

3 Parameterization

During the animation, a single open line sweeps a portion of the space-time surface resulting in charts with disc topology. We seek for a temporally coherent 1D+t parameterization of the lines by means of a 2D parameterizaton of each chart. The two main constraints are the *temporal* and *spatial* coherence of the parameterization. Intuitively, temporal coherence corresponds to the presevation of the parameterization of a vertex of a line while it moves through space (i.e., "sticking" the parameterization to the line in 3D). Spatial coherence keeps the parameterization coherent on the projected lines (i.e., in image space). Additionally, we aim at preserving a $[0, 1]$ parameterization of each line.

In general, these three constraints cannot be satisfied simultaneously. Therefore, we formulate these constraints as energies and minimize their combination using a least-squares approach resulting in a trade-off which can be intuitively controlled by setting a few weights. Finally, the parameterized lines can be used to achieve a coherent texturing on the lines during the animation and the underlying chart decomposition of the space-time surface allows users to edit space-time lines easily (e.g., selecting a specific texture for a specific animated line).

References

KALNINS, R. D., DAVIDSON, P. L., MARKOSIAN, L., AND FINKELSTEIN, A. 2003. Coherent stylized silhouettes. *ACM Transactions on Graphics 22*, 3 (July), 856–861.

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