Tonal Art Maps with Image Space Strokes

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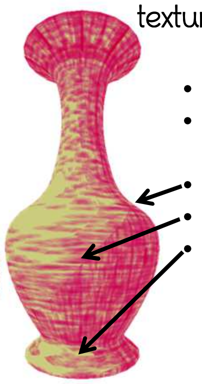


texture space hatching + fitting image space strokes

- robust visibility testing
- real-time performance

- hard silhouettes
- clipped strokes
- UV distortion

- strokes running over outlines
- strokes stopping short of occluders
- unique strokes
- full strokes

Curve fitting

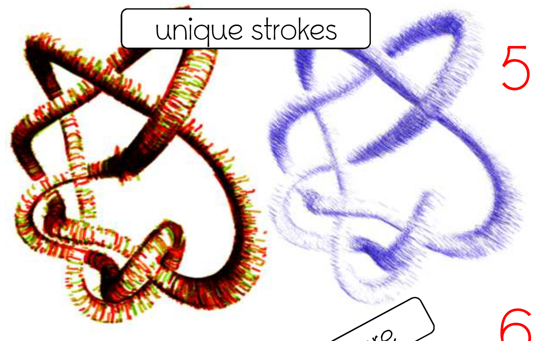
We are looking for a cubic curve that fits the fragments of a stroke as:

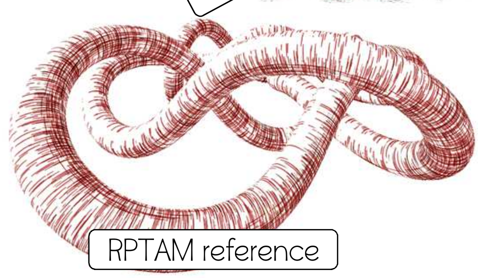
$$\mathbf{r}(t) = \begin{pmatrix} d_x & c_x & b_x & a_x \\ d_y & c_y & b_y & a_y \end{pmatrix} \cdot \begin{pmatrix} 1 \\ t \\ t^2 \\ t^3 \end{pmatrix}$$

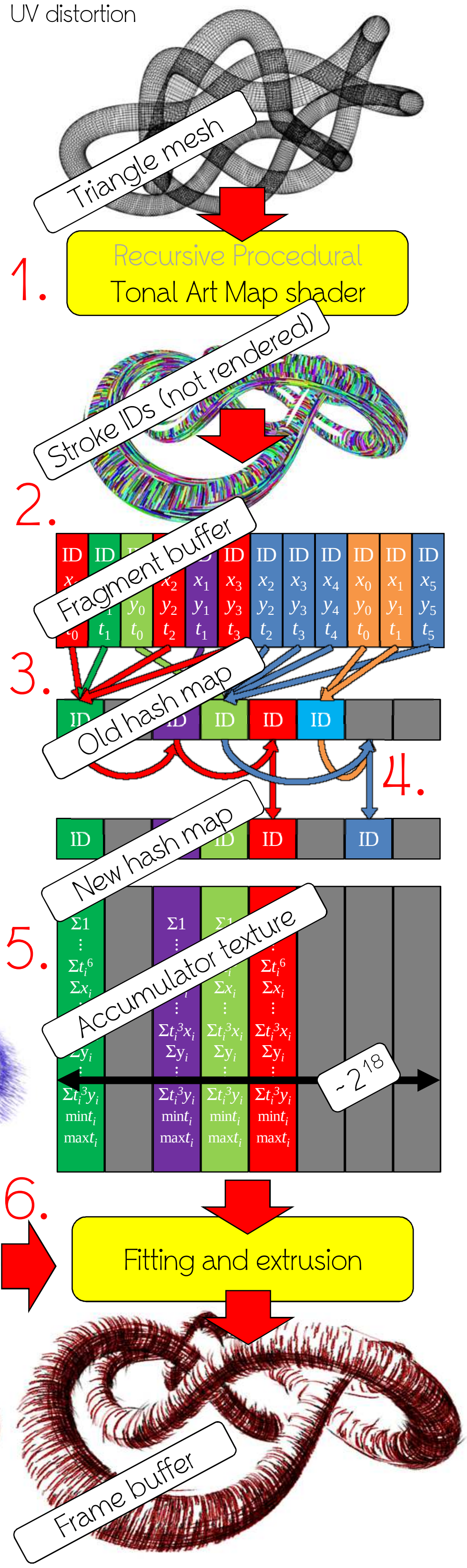
Finding the coefficients is a linear regression problem. Given n samples, using Ordinary Least Squares, we get the following linear system:

$$\sum_{i=0}^{n-1} \begin{pmatrix} 1 \\ t_i \\ t_i^2 \\ t_i^3 \end{pmatrix} \cdot x_i = \sum_{i=0}^{n-1} \begin{bmatrix} 1 & t_i & t_i^2 & t_i^3 \\ t_i & t_i^2 & t_i^3 & t_i^4 \\ t_i^2 & t_i^3 & t_i^4 & t_i^5 \\ t_i^3 & t_i^4 & t_i^5 & t_i^6 \end{bmatrix} \cdot \begin{pmatrix} d_x \\ c_x \\ b_x \\ a_x \end{pmatrix}$$

and similarly for y. The elements of the known vector and matrix have to be found by summing values computed for fragments. This is robustly and efficiently solved by the Conjugate Gradient Method. The useful parameter range is $[\min t_i, \max t_i]$.

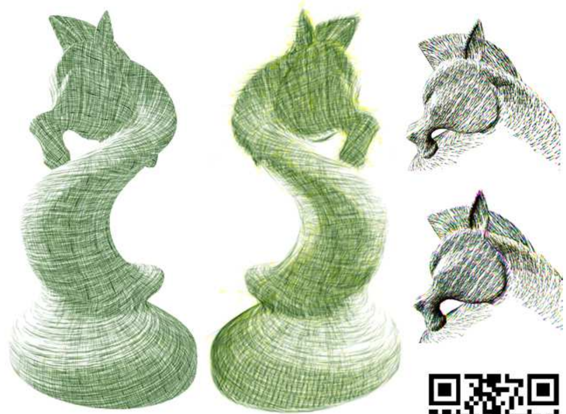






Algorithm Outline

1. Tonal Art Map shader renders scene. Every stroke, on any surface, appearing at any detail level, has a globally unique ID. 32 bits are sufficient in practice.
2. No target buffer, but pixel shader appends an item to a fragment buffer for every overlapping stroke.
3. Fragments are routed by ID into an accumulator texture. Double hashing with a static map is used.
4. Hash map entries looked up are written to a new version of the hash map, to be used in the next frame. Thus, strokes no longer visible vacate their slots. New strokes may race for empty slots. The loser tries again next frame.
5. Fragment values needed for regression are computed. Values are accumulated into the texture with additive/maximum blending.
6. The regression equation is solved for every stroke. Then, triangle strips are extruded along the fitted curve, and displayed with per-stroke stylization and texturing.



http://cg.iit.bme.hu/~szecsi/tamiss

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Knight model courtesy of Autodesk