A Texture Synthesis Approach to Elastica Inpainting

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We have combined these two techniques to accelerate and constrain the solution of the 4th order PDE. Instead of a stiff minimization, we have a combinatorial optimization problem that is much quicker to solve and more stable.

Texture Synthesis Constrained Inpainting

For a given inpainting region, $D$, in an image, filling the region using the Euler’s elastica formulation means finding the minimization of

$$J_2[u] = \int_D \left( a + b \left( \nabla \cdot \frac{\nabla u}{|\nabla u|} \right) \right) |\nabla u| dx$$

where $u$ is a pixel value and $a$ and $b$ are positive constant weights for tuning. Minimizing this energy functional will smoothly fill the inpainting region while connecting features on the edge of the domain across the repaired region according to their curvature.

To minimize the impact of this numerically stiff equation, we made the observation that, like texture synthesis, the values of the pixels $u$ that minimize the equation probably already exist in the image. In fact, if some of the pixels neighboring an unknown pixel are known, they can be used, in a texture synthesis sense, to reduce the possible pixel value candidates for the unknown pixel.

In this fashion, we have turned the minimization problem into a combinatorial optimization problem. For every unknown pixel $u$, we build a list of pixel value candidates from the local neighborhood of the pixel. If neighboring pixels are marked “known,” these are used to refine the candidate pixel values by removing pixels that do not satisfy a neighborhood match heuristic.

Then, from the edge of the inpainting region $D$ inward in an upwind sense, we choose the pixel value from the candidate list that minimizes the Euler’s elastica formula in the local neighborhood. This process is iterated until pixel values no longer change or a steady-state solution is reached. In the later case, we choose the state with the lowest overall energy.

The definition of the neighborhood can be extended to include images forward and backward in time. Often, the exact pixel value for repairing the wire is visible in either the previous or next frame because of motion of the wire, the camera or the background. The combinatorial optimization will quickly choose the replacement pixel because it will satisfy both the Euler’s elastica equation and the texture synthesis heuristic.

Using these techniques, we have produced an algorithm that works on both moving and static wire and scratch removal and accelerates the solution of the Euler’s elastica inpainting method from hours to less than a minute.

References
