Calligraphic Cutting: Extreme Image Resizing with Cuts in Continuous Domain

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Original Image | 33% scaling | Seam carving (SC) | Improved SC | Our method

Figure 1: *Comparison of our method with scaling and seam carving after resizing an image with no low-energy regions. Scaling does not cause discontinuities but does change curvatures and slopes. Seam carving (SC) causes severe discontinuities under extreme resizing. Improved seam carving (ISC) does not eliminate most of these discontinuities. Our calligraphic cutting (CC) can resize the image by preserving geometric properties of the original image without causing severe discontinuities. The method removes high-energy regions effectively by changing topological properties. Note, for instance, the pointed arch above the main entrance door, which moved down to keep its shape and revealed the background part of the facade automatically.*

Seam carving [Avidan and Shamir 2007; Rubinstein et al. 2009] revolutionized the way we think about image resizing by demonstrating that it is possible to obtain significant changes in image sizes with changes in proximity relationships, which we call topological properties of an image. Seam carving can change the size of an image by progressively carving out (or carving in) seams, which are monotonically connected paths of low-energy pixels crossing an image from top to bottom, or from left to right. Unfortunately, it quickly became obvious that seam carving creates geometric discontinuities once low-energy regions start to diminish. As a result, improvements and alternative approaches have been suggested to minimize discontinuities.

In this work, we show that by reformulating the concept of seam carving in continuous domain, it is theoretically possible to eliminate most of the distortions and discontinuities caused by seam carving. Our theoretical approach does not require any user interaction, any importance or saliency map, or any complicated energy function. We simply use the original energy function of seam carving. The paper has three theoretical contributions: (1) generalization of seams to calligraphic cuts, (2) identification of the conditions to preserve tangent continuity, and (3) cutting through minimum and maximum points to resize shapes.

The calligraphic cuts are monotonically connected paths like seams. Nevertheless, calligraphic cuts have one significant advantage over seams. The discretized versions of calligraphic cuts can include a set of pixels that form horizontal lines for top-to-bottom cuts—or vertical lines for left-to-right cuts. Therefore, they can follow the contours of shapes and can effectively reach and remove all possible low-energy regions. Seams do not have this ability and eventually remove high-energy regions even when there exist low-energy regions. Thus, discontinuities caused by seam carving can be avoided by calligraphic cutting.

Our method also preserve the original G^1—i.e. tangent—continuities. We show that avoiding only low-energy regions is necessary but not sufficient since doing so can only preserve G^0 continuity. G^1 continuity preservation requires an additional condition: the calligraphic cuts must be perpendicular to the gradient everywhere except in minimum and maximum points. The minimum and maximum points in high-energy regions usually have very high curvature, and they already look G^1 discontinuous in original images—the most human-made objects, such as roofs of the buildings, usually have such discontinuous maximum points. The cuts that pass through such discontinuous points actually preserve the visual structure of the original shape. Therefore, exploiting this property, we can continue to apply calligraphic cuts even long after all low-energy regions are eliminated.

References

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SIGGRAPH 2012, Los Angeles, California, August 5 – 9, 2012.
ISBN 978-1-4503-1435-0/12/0008