Propagated Image Filtering

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Image filtering is a process of updating pixel values in an image to achieve particular goals like denoising, smoothing, enhancement, or matting. It typically requires the extraction of particular image characteristics, while undesirable patterns like noise or irrelevant textural regions need to be disregarded. If *cross-region mixing* occurs during the filtering process, i.e., the characteristics of adjacent image regions are blended, the output image would contain blurry regions which result in degraded visual quality.

Many edge-preserving filters, like bilateral filters [3], guided filters [2], and geodesic filters [1] have been designed to alleviate cross-region mixing problems. They observe and process neighboring pixels with similar pixel values, so that the image context of interest can be preserved. Due to such abilities, edge-preserving filters have been successfully applied to a variety of applications such as noise reduction, tone management, and image fusion. However, bilateral and guided filters use predefined pixel neighborhood regions (via spatial functions or kernels), which are typically difficult to determine beforehand. On the other hand, geodesic filters consider only photometric distances between pixels, and thus they cannot be easily applied to filtering tasks where spatial relationships need to be preserved (e.g., image smoothing). As shown in Figure 1, these characteristics can lead to cross-region mixing, which would degrade the performances of such edge-preserving filters.

In this paper, we propose a *propagation filter* as a novel context preserving filter. Our propagation filter is able to observe and preserve image characteristics without the need to apply explicit spatial kernel functions. We will show that our filtering process essentially cooperates the merits of bilateral and geodesic filtering and can be regarded as a robust estimator, which minimizes the expected error between the filtered and desirable image outputs. Our propagation filter utilizes the idea that the relationships between pixels can be observed and propagated along a path in an image. And, for any two pixels to be related, all the intermediate pixels along the path should be related as well. We determine pixel relationships based on photometric distances between pixels. Instead of using predefined spatial kernel as bilateral and guided filters do (or completely relying on photometric relationship as geodesic filters do), our filter directly determines pixel relationships based on spatial and photometric information in the images. We achieve this by differentiating photometric relationships between the two adjacent pixels and two remote ones, and we formulate such relationships in a probabilistic fashion via Bayes rules. In addition to robust estimator, we will show that our filtering process can be viewed as belief propagation. We will also show that our algorithm can efficiently prevent information crossing image edges and further alleviate cross-region mixing problems.

We perform experiments on several image processing applications such as image denoising/smoothing, image fusion, and high-dynamic-range (HDR) imaging. We find that our propagation filer is able to preserve image edges from blurring under heavily smoothing conditions. Our experimental results confirm that our propagation filter performs favorably against state-of-the-art image filters on these tasks. This supports the use of our filters for various practical image processing tasks.

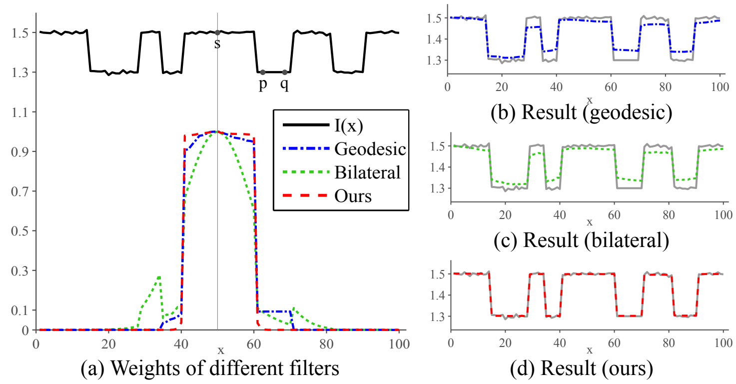

Figure 1: Illustration of cross-region mixing (in 1D) for pixels in textural image regions. The value of pixel x is denoted as $I(x)$, and the dotted lines indicate the weights derived by different filters (we choose $\sigma_s = 10$ for the bilateral filter, and $\sigma_r = 0.1$ for all filters). Note that we intentionally disregard noisy pixels between pixels p and q, so that the characteristics of geodesic filters can be better illustrated. It can be seen that both bilateral and geodesic filters suffer from cross-region mixing.

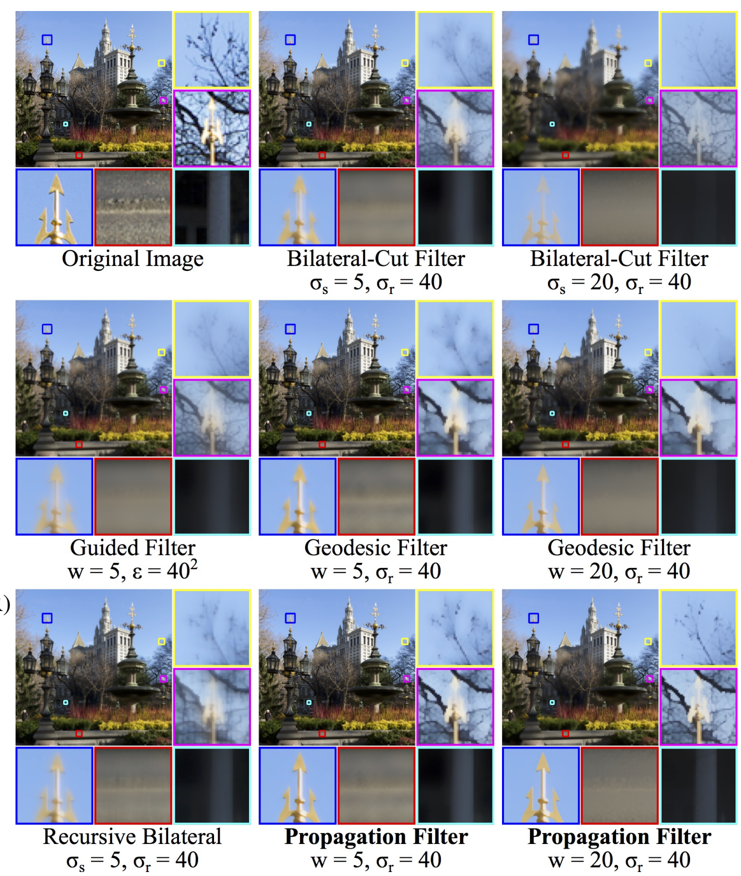

Figure 2: Examples of color image smoothing of various filters. It can be seen that our propagation filter is able to prevent the gold spire and the blue sky from mixing even under intensive smoothing setting.

[1] Jacopo Grazzini and Pierre Soille. Edge-preserving smoothing using a similarity measure in adaptive geodesic neighbourhoods. *Pattern Recognition*, 2009.

[2] Kaiming He, Jian Sun, and Xiaoou Tang. Guided image filtering. In *ECCV*. 2010.

[3] Carlo Tomasi and Roberto Manduchi. Bilateral filtering for gray and color images. In *ICCV*, 1998.

This is an extended abstract. The full paper is available at the Computer Vision Foundation webpage.