Color Gradient Map-Oriented Anisotropic Diffusion Filtering

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Abstract

Anisotropic diffusion filtering is a well-established technique for image enhancement that smooths images without destroying edge information. However, when many filtering iterations are applied, edges gradually fade away and are ultimately smoothed by the process. We propose the adoption of a color gradient map to guide the smoothing so that clearly-defined edges are preserved even after many iterations. Preliminary experiments show good results when compared with the regular anisotropic diffusion filter.

1. Introduction

The anisotropic diffusion filter [2, 3] is a powerful image processing technique for noise removal. The filter works by performing smoothing on the image but at the same time preserving the boundaries between different regions. The process is controlled by a diffusion matrix that measures the color variation on the neighborhood of a hot spot.

When the filter is applied over many iterations, the diffusion matrix slowly becomes adapted to the new local colors. When the original image contains tenuous edges, the smoothing process will gradually erase all edge information as iterations are sequentially applied. In this work, we propose an improvement to the anisotropic diffusion filter that introduces a color gradient map, which behaves as static boundary evidence, enhancing the response of the filter when applied several times to an image containing tenuous edges.

2. Orienting the Anisotropic Diffusion Filter

The anisotropic diffusion filter used in this paper has been extensively discussed [2], and can be regarded as a convolution technique with an adaptive matrix-valued kernel that performs a special smoothing on images: It inhibits the smoothing on edge pixels and stimulates it on internal regions. The basic diffusion equation [1] for an image $I(x, y)$ with M channels and a signal initialized with $u(x, y, 0) = I(x, y)$ is

$$\partial_t u_i = \operatorname{div}\left(D\left(\sum_{k=1}^{M} \nabla u_k \nabla u_k^{\mathrm{T}}\right)\nabla u_i\right), \qquad (1)$$

where D is a matrix-valued function, and $i = 1, \ldots, M$ are the individual channels.

As the process of diffusion is carried on through several iterations, the edges of the original image gradually fade away, because the function D takes into account only the results from the previous iteration. After a certain amount of iterations, even edges that were initially well defined may

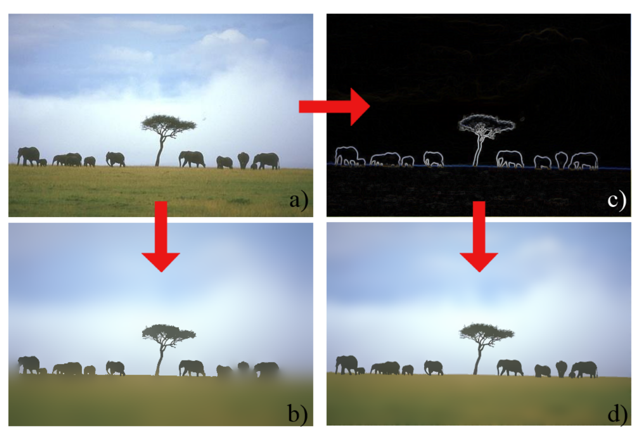

Figure 1. Overview of traditional and gradient map-oriented filtering. a) is the original image; b) is the traditional filtering; c) is the gradient map generated from a); and d) is the filtering oriented by the gradient map.

Figure 2. On the left, original images; on the right, images filtered with the approach we propose.

become blurred. In order to keep well-defined edges present in the original image, we propose the introduction of a static factor G_i in Equation 2 that depends on the original image only, thus avoiding the effects introduced by the repeated application of the diffusion filter. This static factor is calculated from a color gradient map produced from the original image and remains constant throughout all iterations. An overview of this process is shown in Figure 1, where both versions of the filter are applied over 300 iterations.

In order to accommodate G_i, Equation 2 can be rewritten as

$$\partial_t u_i = \operatorname{div}\left(D\left(G_i \sum_{k=1}^{M} \nabla u_k \nabla u_k^{\mathrm{T}}\right)\nabla u_i\right). \qquad (2)$$

The gradient map G is calculated by a convolution operation using the following masks:

$$I_x = \frac{1}{4}\begin{pmatrix} -b & 0 & b \\ -a & 0 & a \\ -b & 0 & b \end{pmatrix} \text{ and } I_y = \frac{1}{4}\begin{pmatrix} -b & -a & -b \\ 0 & 0 & 0 \\ b & a & b \end{pmatrix},$$

where $a = 2(\sqrt{2} - 1)$ and $b = (2 - \sqrt{2})$. The modulus of the vector (I_x, I_y) is then used as an estimation of the gradient for each channel.

Figure 2 shows an example of the color gradient map-oriented filter. While the internal regions were greatly smoothed, the distinction between them remains clear.

3. Conclusion and Discussions

The anisotropic diffusion filter is a powerful tool that enhances an image by smoothing regions while adopting a sophisticated border-preserving scheme. We have shown how this filter can be further improved by using a color gradient map that remains unchanged over iterations. This way, we ensure the preservation of edges that were well defined in the original image.

References

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