Anisotropic Kuwahara Filtering with Polynomial Weighting Functions

Jan Eric Kyprianidis [1] Amir Semmo [1] Henry Kang [2] Jürgen Döllner [1]

[1] Hasso-Plattner-Institut, Germany
[2] University of Missouri, St. Louis, USA

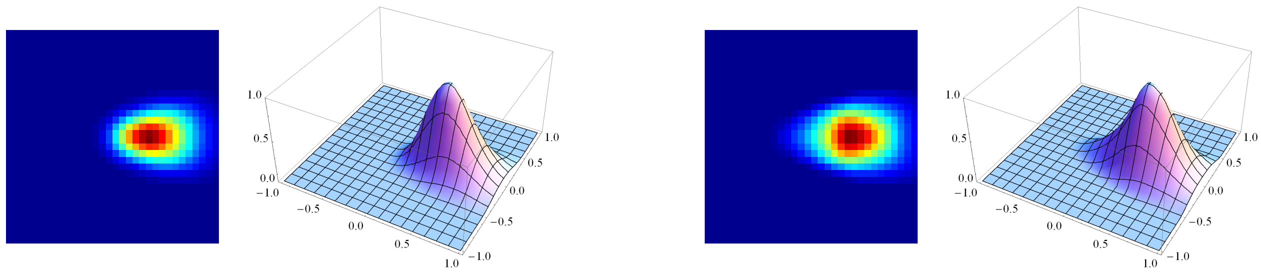


Figure 1: *Left: Weighting function $(\chi_0 \star G_\rho) \cdot G_\sigma$ based on convolution used in the definition of the anisotropic Kuwahara filter [Kyprianidis et al. 2009; Papari et al. 2007]. Right: Proposed weighting function based on the polynomial $[(x+\zeta) - \eta y^2]^2$.*

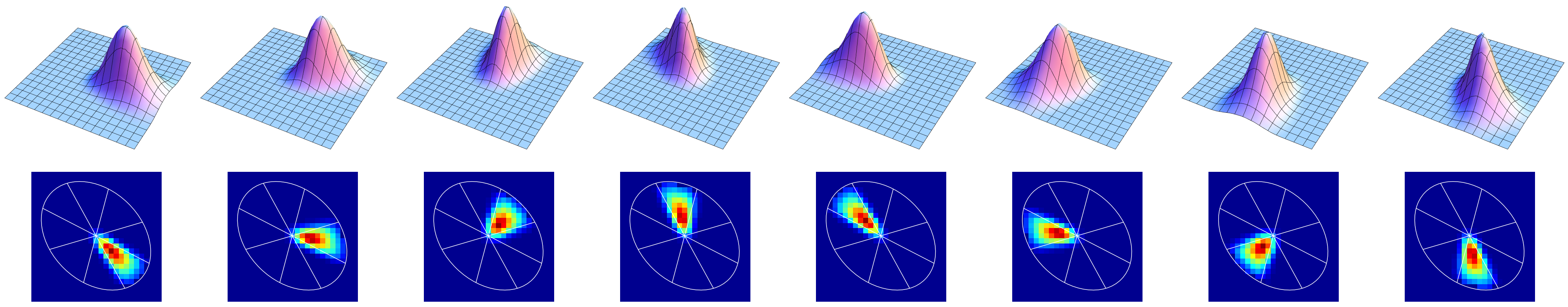
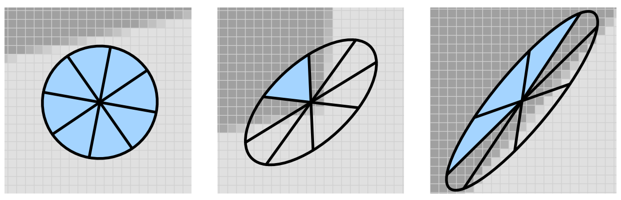
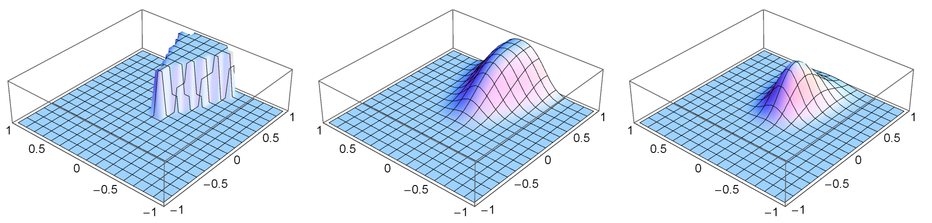


Figure 2: *The weighting functions $K_i = K_0 \circ R_{2\pi i/8}$ (top) and their pullback $w_i = K_i \circ SR_{-\varphi}$ (bottom) for $i = 1,\ldots 8$.*



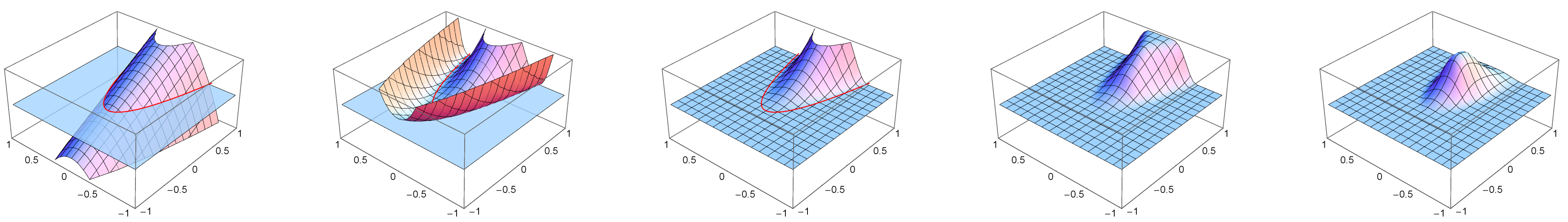
(a) Homogeneous (b) Corner (c) Edge

Figure 3: *The anisotropic Kuwahara filter uses weighting functions defined over an ellipse, whose shape is based on the local orientation and anisotropy. The filter response is defined as a weighed sum of the local averages, where more weight is given to averages with low standard deviation.*



(a) (b) (c)

Figure 4: *Construction of the weighting functions of the anisotropic Kuwahara filter: (a) Characteristic function χ_0. (b) $\chi_0 \star G_\rho$. (c) $K_0 = (\chi_0 \star G_\rho) \cdot G_\sigma$.*



(a) (b) (c) (d) (e)

Figure 5: *Construction of the proposed weighting functions: (a) Polynomial $(x+\zeta) - \eta y^2$. (b) Squared polynomial $[(x+\zeta) - \eta y^2]^2$. (c) $\tilde{k}_0$. (d) Normalized $\tilde{k}_0$. (e) Weighting function $\tilde{K}_0$.*

Figure 6: *Left: Overblurring is avoided in low-contrast regions [Kyprianidis et al. 2009, Figure 10]. Right: Application to an image with 2% Gaussian noise and 5% impulse noise [Kyprianidis et al. 2009, Figure 11]. Directional image features are preserved and enhanced [Kyprianidis et al. 2009, Figure 7].*

Overview

Within the field of non-photorealistic rendering, a classical area of research is the stylization and abstraction of photographs using edge-preserving smoothing and enhancement filters. Prominent techniques in this area have in common to remove detail in low-contrast regions without filtering across discontinuities and thus leave the overall structure of the input image unaffected. Popular examples are the bilateral filter and mean shift. Another popular filter in this field is the Kuwahara filter [Kuwahara et al. 1976]. The general idea behind this filter is to divide the filter kernel into four rectangular subregions which overlap by one pixel. The filter response is then defined by the mean of a subregion with minimum variance. The Kuwahara filter produces clearly noticeable artifacts. These are due to the use of rectangular subregions. In addition, the subregion selection process is unstable if noise is present or subregions have the same variance. This results in randomly chosen subregions and corresponding artifacts. A more detailed discussion of limitations of the Kuwahara filter can be found in [Papari et al. 2007].

The anisotropic Kuwahara filter [Kyprianidis et al. 2009] builds upon the generalized Kuwahara filtering concept by [Papari et al. 2007] and replaces the weighting functions defined over sectors of a disc by weighting functions defined over ellipses. By adapting shape, scale and orientation of these ellipses to the local structure of the input, artifacts are avoided. Due to this adaption, directional image features are better preserved and emphasized. This results in overall sharper edges and the enhancement of directional image features.

In this work, we present a modification of the anisotropic Kuwahara filter. We introduce new weighting functions that are not based on convolution. Consequently, they are applicable for calculation on the fly and can be computed at real-time rates. In addition, the proposed weighting functions are parameterizable. The eccentricity and expansion can be adjusted, which allows to control the overlapping areas to adjacent sectors.

References

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Kyprianidis, J. E., Kang, H., and Döllner, J. 2009. Image and video abstraction by anisotropic kuwahara filtering. Computer Graphics Forum 28, 7, 1955–1963. Special issue on Pacific Graphics 2009.

Papari, G., Petkov, N., and Campisi, P. 2007. Artistic edge and corner enhancing smoothing. IEEE Transactions on Image Processing 16, 10, 2449–2462.