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New Adaptive Filters as Perceptual Preprocessing for Rate-Quality Performance Optimization of Video Coding

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***Abstract*—In this paper, we introduce two perceptual filters as pre-processing techniques to reduce the bitrate of compressed high-definition (HD) video sequences at constant visual quality. The goal of these perceptual filters is to remove spurious noise and insignificant details from the original video prior to encoding. The proposed perceptual filters rely on two novel adaptive filters (called BilAWA and TBil) which combine the good properties of the bilateral and Adaptive Weighting Average (AWA) filters. The bilateral and AWA filters being initially dedicated to denoising, the behavior of the proposed BilAWA and TBil adaptive filters is first analyzed in the context of noise removal on HD test images. The first set of experimental results demonstrates their effectiveness in terms of noise removal while preserving image sharpness. A just noticeable distortion (JND) model is then introduced in the novel BilAWA and TBil filters to adaptively control the strength of the filtering process, taking into account the human visual sensitivity to signal distortion. Visual details which cannot be perceived are smoothed, hence saving bitrate without compromising perceived quality. A thorough experimental analysis of the perceptual JND-guided filters is conducted when using these filters as a pre-processing step prior to MPEG-4/AVC encoding. Psychovisual evaluation tests show that the proposed BilAWA pre-processing filter leads to an average bitrate saving of about 19.3% (up to 28.7%) for the same perceived visual quality. The proposed new pre-filtering approach has been also tested with the new state-of-the-art HEVC standard and has given similar efficiency in terms of bitrate savings for constant visual quality.**

***Index Terms*—Video Coding; Pre-processing; Image Filtering; Adaptive Weighting Average (AWA) Filter; Bilateral Filter; Just Noticeable Distortion (JND); Image Quality.**

I. Introduction

It is well-known that removing spurious noise or attenuating perceptually insignificant details by video filtering prior to encoding can improve the rate-quality performance of encoders [1]. Traditional noise filtering approaches using linear filters which compute the value of the filtered image as a weighted average of pixel values in the neighborhood are often employed [2], [3], [4], [5]. To cite a few examples, in conventional Gaussian low-pass filtering, the weights decrease with the distance from the filtered pixel. Nearby pixels generally share a similar value due to slow variations of luminance over space. Averaging them is a way of increasing the spatial correlation, hence compression efficiency, while introducing a negligible distortion.

However, in areas where the assumption of stationarity is not verified (e.g. corners, edges), the linear filtering will not only attenuate noise but will also lead to a strong attenuation of the high frequency structures and introduce blur. Therefore, there has been a remarkable effort to find nonlinear and adaptive operators which would smooth or increase correlation in smooth areas and at the same time better preserve image structures. Most adaptive filtering techniques use the standard deviation of those pixels within a local neighborhood to calculate a new pixel value. These methods include anisotropic diffusion [6], bilateral filtering [7], [8] and adaptive weighted averaging [9]. Anisotropic diffusion uses the gradient of the image to guide the diffusion process, avoiding smoothing the edges [6]. Bilateral filtering first introduced in [7] is a non-linear filtering technique utilizing both the spatial and photometric distances to better preserve signal details. The link between anisotropic diffusion and bilateral filtering has been established in [10]. Bilateral filtering is actually the product of two local filters, one based on a measure of similarity between the pixel amplitudes - e.g. luminance channel of colored images - in a local neighborhood and the other one based on a geometric spatial distance. Both kernels are Gaussian kernels. An Adaptive Weighted Averaging (AWA) filter is proposed in [9] and used for motion-compensated filtering of noisy video sequences. Given its use in the temporal dimension, the dimension of the AWA filter support is in general small. It has also been successfully used in adaptive filtering [11].

This paper addresses the question of choosing a real time adaptive pre-processing filter prior to encoding which would maximize the bitrate saving while preserving the visual quality. The out-loop prefiltering approach applied prior to the encoding stage has been retained in the present work because it has the great advantage to be *universal*, i.e. it can easily be applied to any video encoder. Note here that we stress the term 'real time' as the chosen implementation is expected to meet high performance (30 or 60 fps high-definition video filtering) on a standard workstation. This is the reason why recently proposed denoising filter methods, such as the Non Local Means algorithm [12], will not be considered as they provide very high performance but at the cost of even higher computational time. Wavelet based methods will also not be accounted for [46], as they provide a complexity which is much higher than conventional spatial filtering. On top of that, any successful filtering done in the spatial domain can also be applied to the wavelet domain as it was successfully done in [13] with bilateral filtering.

The contributions of the paper are two-folds:

1) We first consider the well known AWA and bilateral filters and search for the best compromise between denoising performance (minimal absolute distance to the original) and lowest subjective visual distortion (lack of sharpness). The weights of the AWA filter start decreasing once the difference between the pixel luminance values exceeds a given threshold. Above this threshold, the decaying rate of the AWA filter is slow, which leads to a stronger smoothing effect when increasing the size of the filtering kernel. In contrast, the weights of the bilateral similarity kernel decay faster both in the similarity and geometric dimensions. The bilateral filter therefore better preserves edges and textures than the AWA filter does when the size of the support increases.

These observations naturally led us to introduce two novel adaptive filters designed around the bilateral paradigm (geometric kernel + similarity kernel) with however different approaches. These filters, called BilAWA and Thresholded Bilateral (TBil), improve the paradigm of bilateral filtering, and are fast enough for real-time computation. They combine the good properties of the AWA and bilateral filters and enable a larger filtering support, with the aim

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