ARTIFACT REDUCTION IN COMPRESSED IMAGES AND VIDEOS

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ABSTRACT: A fuzzy filter adaptive to both sample's activity and the relative position between samples is proposed to reduce the artifacts in compressed multidimensional signals. For JPEG images, the fuzzy spatial filter is based on the directional characteristics of ringing artifacts along the strong edges. For compressed video sequences, the motion compensated spatiotemporal filter (MCSTF) is applied to intra frame and inter frame pixels to deal with both spatial and temporal artifacts. A new metric which considers the tracking characteristic of human eyes is proposed to evaluate the flickering artifacts. Simulations on compressed images and videos show improvement in artifact reduction of the proposed adaptive fuzzy filter over other conventional spatial or temporal filtering approaches.

ARTIFACT:

artifact is the result of an aggressive data compression scheme applied to an image, audio, or video that discards some data that may be too complex to store in the available data-rate, or may have been incorrectly determined by an algorithm to be of little subjective importance, but is in fact objectionable to the viewer. Artifacts are often a result of the latent errors inherent in lossy data compression. Datamoshing is a technique of video editing employed in video art and music videos which deliberately exploits these compression artifacts.

Technically speaking, a compression artifact is a particular class of data error that is usually the consequence of quantization in lossy data compression. Where transform coding is used, they typically assume the form of one of the basis functions of the coder's transform space.

Compression artifacts occur in many common media such as DVDs, common computer file formats such as JPEG, MP3, or MPEG files, and Sony's ATRAC compression algorithm. Uncompressed media (such as on Laserdiscs, Audio CDs, and WAV files) or losslessly compressed media (FLAC, PNG, etc.) do not suffer from compression artifacts.

IMAGE ARTIFACT REDUCTION:

Various approaches have been proposed to reduce the effects of image compression, but in order to utilize standardized compression/decompression techniques and to retain the benefits of the compression (for instance, lower transmission and storage costs), many of these methods have focused on "post-processing" that is, processing the images when they are received or viewed. No post-processing technique has been shown to improve image quality in all cases consequently, none has garnered widespread acceptance, though some have been implemented and are in use in proprietary systems. Many photo editing programs, for instance, have proprietary JPEG artifact reduction algorithms built-in.

JPEG:

JPEG stands for Joint Photographic Experts Group, the name of the committee that created the JPEG standard and also other standards. It is one of two sub-groups of ISO/IEC Joint Technical Committee 1, Subcommittee 29, Working Group 1 (ISO/IEC JTC 1/SC 29/WG 1) - titled as Coding of still pictures. The group was organized in 1986,[4] issuing the first JPEG standard in 1992, which was approved in September 1992 as ITU-T Recommendation T.81and in 1994 as ISO/IEC 10918-1. The JPEG standard specifies the codec, which defines how an image is compressed into a stream of bytes and decompressed back into an image, but not the file format used to contain that stream.[6] The Exif and JFIF standards define the commonly used formats for interchange of JPEG-compressed images.

JPEG compression:

The compression method is usually lossy, meaning that some original image information is lost and cannot be restored (possibly affecting image quality.) There are variations on the standard baseline JPEG that are lossless; however, these are not widely supported. There is also an interlaced "Progressive JPEG" format, in which data is compressed in multiple passes of progressively higher detail. This is ideal for large images that will be displayed while downloading over a slow connection, allowing a reasonable preview after receiving only a portion of the data. However, progressive JPEGs are not as widely supported, and even some software which does support them (such as some versions of Internet Explorer) only displays the image once it has been completely downloaded. There are also many medical imaging systems that create and process 12-bit JPEG images. The 12-bit JPEG format has been part of the JPEG specification for some time, but again, this format is not as widely supported.

JPEG 2000:

JPEG 2000 is a wavelet-based image compression standard and coding system. It was created by the Joint Photographic Experts Group committee in 2000 with the intention of superseding their original discrete cosine transform-based JPEG standard (created in 1992). The standardized filename extension is .jp2 for ISO/IEC 15444-1 conforming files and .jpx for the extended part-2 specifications, published as ISO/IEC 15444-2. The registered MIME types are defined in RFC 3745. For ISO/IEC 15444-1 it is image/jp2.While there is a modest increase in compression performance of JPEG 2000 compared to JPEG, the main advantage offered by JPEG 2000 is the significant flexibility of the code stream. The code stream obtained after compression of an image with JPEG 2000 is scalable in nature, meaning that it can be decoded in a number of ways; for instance, by truncating the code stream at any point, one may obtain a representation of the image at a lower resolution, or signal-to-noise ratio. By ordering the code stream in various ways, applications can achieve significant performance increases. However, as a consequence of this flexibility, JPEG 2000 requires encoders/decoders that are complex and computationally demanding. Another difference, in comparison with JPEG, is in terms of visual artifacts: JPEG 2000 produces ringing artifacts, manifested as blur and rings near edges in the image, while JPEG

produces ringing artifacts and 'blocking' artifacts, due to its 8×8 blocks.

FUZZY FILTER:

Fuzzy filters, such as those described and improve on median filters or rank condition rank selection filters by replacing the binary spatial-rank relation by a real-valued relation. The conventional way to define the fuzzy filters is by generalizing the binary spatial-rank relation. In this paper, the fuzzy filter is introduced from the artifact reduction aspect. Assume that a filter is applied to a set of neighboring samples x[m + m' , n + n'] around x[m , n]the input to form the output and its unbiased form with normalization.

y(m,n)=$\sum_{[m',n']eomege} h(x[m+m'n+n',xm,nXx(m+m',n+n']$ (1)

$$y[m,n] = \frac{\sum_{[m',n']\in\Omega} h(x[m+m',n+n'],x[m,n])\,x[m+m',n+n']}{\sum_{[m',n']\in\Omega} h(x[m+m',n+n'],x[m,n])}. \quad (2)$$

In (1), h(x[m + m', n + n'],x[m, n])controls the contribution of the input x[m +m', n +n'] to the output. For a linear filter, h is fixed and input-independent. In the case of a nonlinear filter, h is a function of the input, such as for median filter.

$$h(x[m+m',n+n'],x[m,n]) = \begin{cases} 1, & \text{if rank}(x[m+m',n+n']) = \text{round}\left(\frac{\text{size}(\Omega)}{2}\right) \\ 0, & \text{otherwise} \end{cases}$$

where round(u) is the nearest integer of u.

Due to the input independence of the filter coefficients, a low-pass filter which is designed to perform effectively in the flat areas may introduce blurring artifacts in detail areas. In artifact reduction, especially for low bit-rate compression, it is desirable to preserve the details while removing the artifacts. This can be achieved by imposing the constraint such that if x[m +m', n +n'] is far from x[m, n], its contribution to the output is small. In that case, the filter coefficients h[k, l] must follow the constraints

$$\lim_{|x[m+m',n+n']-x[m,n]|\to 0} h(x[m+m',n+n'],x[m,n]) = 1 \quad (3)$$

$$\lim_{|x[m+m',n+n']-x[m,n]|\to \infty} h(x[m+m',n+n'],x[m,n]) = 0 \quad (4)$$

and

$$h(x[m+m_1',n+n_1'],x[m,n]) \geq h(x[m+m_2',n+n_2'],x[m,n]) \text{ if } |x[m+m_1',n+n_1']-x[m,n]| \leq |x[m+m_2',n+n_2']-x[m,n]|. \quad (5)$$

The function h(x[m + m’, n + n’],x[m, n]) is referred to as the membership function and there are many functions which fulfill these requirements. For a Gaussian membership function

$$h(x[m+m',n+n'],x[m,n]) = exp\left(-\frac{(x[m+m',n+n']-x[m,n])^2}{2\sigma^2}\right) \quad (6$$

where σ represents the spread parameter of the input and controls the strength of the fuzzy filter. Note that the contribution of the input x[m, n] to the output is always highest compared to the contribution of other samples

$$h(x[m,n],x[m,n])=1 \geq h(x[m+m',n+n'],x[m,n])$$

For the same, x[m + m’, n + n’] - x[m, n] the higher the value, the higher the contribution of x[m + m’, n + n’] relatively compared to the contribution of x[m, n] to the output. This implies x[m, n] that will be more averaged to x[m + m’, n + n’]. Smaller σ values will keep the signal x[m, n] more isolated from its neighboring samples. This spread parameter should be adaptive to different areas which have different activity levels such as smooth or detail areas. For multidimensional signals, the conventional fuzzy filter assigns a fixed spread parameter for every surrounding sample and ignores the relative position between them. In image and video compression, artifacts such as blocking, ringing or flickering artifacts are directional, and, thus, the fuzzy filter should consider the directions between x[n] and its surrounding samples x[m + m’, n + n’]. This can be achieved by an adaptive spread parameter

$$\sigma(x[m+m',n+n'],x[m,n])=K[m+m',n+n'] \times \sigma_m[m,n] \quad (8)$$

where σ_m is a position-dependent amplitude of the spread parameter σ and k is the scaling function controlled by the direction of x[m + m’, n + n’] to x[m, n] . The extensions of membership function σ in (8) will be discussed in Section III for compressed images and Section IV for compressed video sequences.

Fuzzy Logic:

Fuzzy logic works the way that humans think as opposed to the way that computers typically work. For example, consider the task of driving a car. You notice that the stoplight ahead is red and the car ahead is braking. Your mind might go through the thought process, "I see that I need to stop. The roads are wet because it's raining and there is a car only a short distance in front of me. Therefore I need to apply a significant pressure on the brake pedal." This is all subconscious (in general), but that's the way we think - in fuzzy terms. Do our brains compute the precise distance to the car ahead of us and the exact coefficient of friction between our tires and the road, and then use a Kalman filter to derive the optimal pressure which should be applied to the brakes? Of course not. We use common-sense rules and they seem to work pretty well. On the other hand, when we do finally get around to pressing the brake pedal there is some exact force that we apply, say 1.326 pounds. So although we think in fuzzy, noncrisp ways, our final actions are crisp. The process of translating the results of fuzzy reasoning to a crisp, nonfuzzy action is called defuzzification.

DIRECTIONAL FUZZY SPATIAL FILTER:

Directional Spread Parameter:

When highly compressed, the ringing artifacts in JPEG images are prevalent along strong edges and the filter strength should adapt to the edge direction. For example, in Fig. 2(b), the filter should ideally apply stronger smoothing in the horizontal direction, where the ringing artifacts are likely to have no relation with the original value, and a weaker filtering in the vertical direction, which is the edge direction of the image. One general form of cosine-based spread parameter which satisfies this requirement is

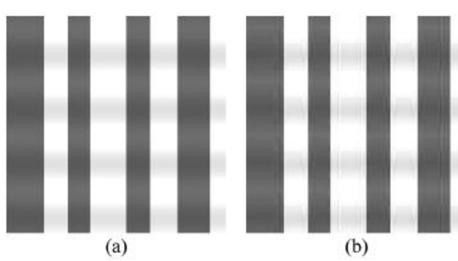


Fig. 1. Example of directional JPEG artifacts with scaling factor of 4 for the quantization step matrix. (a) Original image; (b) compressed.

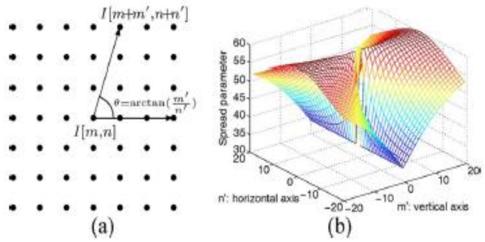


Fig. 2. Angle and spread parameter for directional fuzzy filter. (a) Angle θ; (b) spread parameter.

$$\sigma(\theta) = \sigma_m \left(\alpha + \beta \cos^2(\theta)\right) \qquad (9)$$

where θ is the direction between the pixel of interestI[m,n] and its surrounding pixel I[m+m',n+n,] as shown in Fig. 3(a),σ_m is the amplitude of the spread parameterα *and* β, and are positive scaling factors which control the maximum and minimum strength of the directional filter. In (9) $\sigma(\theta)$, attains the minimum$\sigma_{min} = \alpha\sigma_m$ value in the vertical direction and the maximum value$\sigma_{max} = (\alpha+\beta)\sigma_m$ in the horizontal direction. An example of the directional spread parameter is plotted in Fig. 3(b) with $\sigma_m = 15, \alpha = 0.5$ *and* $\beta = 3.5$

Edge-Based Directional Fuzzy Filter:

For real images with more complicated edges, the strongest filtering is applied to the direction perpendicular to the edge. Based on the Sobel operator with horizontal and vertical derivative approximation of the gradient

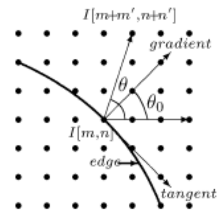
$$G_x = \begin{pmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{pmatrix} * I$$

and $$G_y = \begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix} * I$$

Based on the prewitt operator with horizontal and vertical derivative approximation of the gradient

$$G_x = \begin{pmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{pmatrix} * I \text{and}$$

$$G_y = \begin{pmatrix} 1 & 0 & 1 \\ -1 & 0 & -1 \\ 1 & 0 & 1 \end{pmatrix} * I$$ the edges are detected by using the gradient magnitude G=$\sqrt{G_y^2 + G_x^2}$. Its corresponding direction is determined by $\theta_0 = \text{atan}(G_y/G_x)$. The spread function in this case is determined by the angle $(\theta - \theta_0)$instead of in θ , where the angles θ and $\theta_0$are defined



Angles θ and θ_0 of the edge-based directional fuzzy filter.

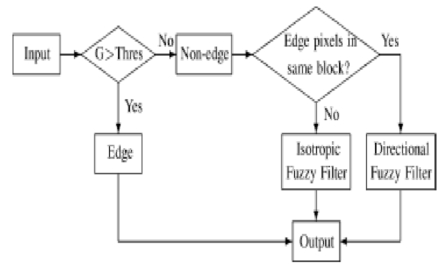


TABLE I
COMPARISON OF PSNR IN UNITS OF dB FOR DIFFERENT METHODS

Sequences	4Q	Chen	Liu	Conventional Fuzzy	Adaptive Fuzzy
News	27.48	27.58	27.55	27.94	**28.05**
Silent	27.84	28.37	28.33	28.33	**28.58**
Foreman	28.06	28.46	28.41	28.78	**28.87**
Mobile	21.22	20.96	21.13	21.50	**21.55**
Mother	31.02	31.83	31.62	31.77	**32.00**
Paris	23.38	23.25	23.31	23.80	**23.84**
Average gain		0.2433	0.2267	0.5200	**0.6483**

Let f(x, y) represent an input image and let f^(x,y) denote an estimate or approximation of f(x, y) that results from compressing and subsequently decompressing the input. For any value of x and y ,the error e(x, y) between f(x, y) and f^(x, y) can be defined as

$$e(x,y) = f\text{^}(x,y) - f(x,y)$$

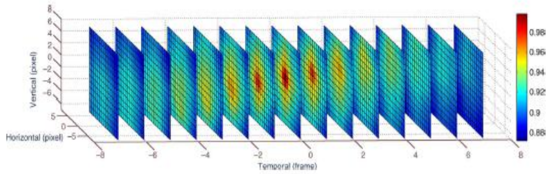
so that the total error between the two images is

$$\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}[f\text{^}(x,y) - f(x,y)]$$

Where the images are of size M x N the mean-squre error, MSE, between f(x,y) and f^(x,y) of the squared error averaged over the M x N

$$\text{MSE} = \frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}[f\text{^}(x,y) - f(x,y)]\text{ ^2}$$

$$\text{PSNR} = \frac{\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}[f\text{^}(x,y)]^2}{\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}[f\text{^}(x,y) - f(x,y)]^2}$$



Correlation between the current frame of compressed mobile sequence and its surrounding frames.

SIMULATION RESULTS:

Enhancement for Compressed Images:

Simulations are performed to demonstrate the effectiveness of the directional fuzzy filtering scheme. The qualities of the different approaches are compared in terms of visual quality and PSNR.a 1-D fuzzy de blocking filter as in [11] is applied prior to the proposed directional fuzzy de ringing-filter directional information between pixels. A future adaptive MCSTF can be considered for segmented.

CONCLUSION:

An effective algorithm for image and video de-noising using an adaptive fuzzy filter is proposed. This novel method overcomes the limitations of conventional nonlinear filters by accounting for pixel's activity and the direction between pixels. It is shown that the proposed adaptive fuzzy filter improves both visual quality and PSNR of compressed images and videos compared to existing approaches. The flickering artifact reduction is evaluated by the proposed flickering metric.

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