Wavelet Transformation For Scanned Image Enhancement

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Abstract

After scanning, a document is typically blurred, and some noise is introduced. Therefore, the enhancement process of a scanned document requires a denoising and deblurring step. Typically, these steps are performed using techniques originated in the wavelet-domain processing. Wavelet enable us to represent signals with high degree of sparsely. This is the principle behind a non- liner wavelet based signal estimation technique known as *wavelet denoising*. One main reason for the success of wavelet is that wavelets adapt automatically to smooth and non-smooth parts in an image due to the link between wavelets and sophisticated smoothness spaces.

Keywords— Image enhancement, Wavelet Transformation, Scanned image enhancement

التحويل المويجي لتحسين صور الماسح الضوئي

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الخلاصة

بصورة عامه فان الوثائق او الصور بعد القيام بعمليه المسح الضوئي لها بواسطه الماسح الضوئي تتعرض الى بعض التشويه والضوضاء التي سوف تدخل على بياناتها كصورة. لذلك فان عمليه التحسين التي تتم على هده الصور تتضمن القيام بعملية ازالة التشويه و ازالة الضوضاء الناتجة عن المسح، يتم تنفيذ هذ الخطوات عادة باستخدام تقنيات معروفه في مجال التحويل المويجي. التحويل المويجي يمكننا من تمثيل الاشارات بدرجه عاليه من التفصيل، هذا المبدا هو المبدا الاساسي الذي يعتمد عليه التحويل المويجي في تخمين الاشارة والذي يعرف بازالة الضوضاء. ان تكيف التحويل المويجي الاوتوماتيكي مع الاجزاء الناعمة وغير الناعمة في الصورة يعتبر من الاسباب الرئيسية في نجاحه في مجال التحسين للصورة ودلك بسبب الارتباط الوثيق بين مبدا التحويل المويجي وفضاء النعومة في الصورة.

1. Introduction

Digital imaging has become a common part of day-to-day life as consumers have easier access to digital cameras, scanners, printers,…etc. A digital copier consist in part of a scanning unit, an image processing unit and a printing unit and is mainly used for copying documents. Without processing a document between the input and output unit the visual quality of the copied document is greatly reduced. Scanning introduces a blurring of the original document as well as some scanner noise. Images that have been scanned from photograph prints can be enhanced so that the scanned image looks close to the original photograph but details in shadows are lost, making enhancement of dark areas difficult [1]. During the last decade the use of wavelet bases functions have become very popular in signal and image processing. Wavelets overcome the two disadvantages of Fourier-based methods mentioned above. First, wavelet coefficients contain not global, but local frequency information of the image. Secondly, wavelets form bases in a variety of function spaces that take into account the smoothness of a function [2]. Those function spaces, called *Besov spaces*, can be interpreted as generalized Lp spaces that also consider the differentiability of a function. In the following the main facts about wavelets and wavelet transforms are summarized briefly. Wavelet coefficients are computed similar to Fourier coefficients from inner products of a function with basis functions– the wavelets. Typically, a wavelet system used in the dyadic wavelet transform consists of two functions, the scaling function φ and the wavelet function Ψ. Those two functions are linked to each other via specific scaling equations. The representation of a function *f* in a wavelet basis is given by:[3].

$$f = \sum_{k} c_{jk} \Phi_{jk} + \sum_{j \geq J} \sum_{k} d_{jk} \Psi_{jk} \qquad (1)$$

where φjk and Ψjk are dilates and translates of Φ and Ψ, namely $\Phi_{jk}(t) = 2^{j/2}\Phi(2^{j}t-k)$ and $\Psi_{jk}(t) = 2^{j/2}\Psi(2^{j}t-k)$. The *scaling coefficients* c_{Jk} are computed as $c_{Jk} = \langle f,\Phi_{Jk}\rangle$ and the *wavelet coefficients* d_{jk} as $d_{jk} = \langle f,\Psi_{jk}\rangle$. The scaling coefficients can be interpreted as presenting a low resolution version of the image, whereas the wavelet coefficients capture the detail information at various resolution levels j. The functions φ_{Jk} and Ψ_{jk} ($j \geq J$) form an orthonormal bases in the L^2 space. The wavelets used in this paper belong to the family of orthogonal Daubechies wavelets. Those wavelets have compact support, have D vanishing moments and a Hoelder regularity σ [4]. If a function or signal is given in the form of its wavelet coefficients, modifying individual coefficients only affects a region of the entire image. This characteristic in combination with the multiresolution nature of the decomposition has lead to enormous success in various fields of image processing over the last years. Especially, in denoising and compression wavelet-based techniques have become state-of-the-art and outperform classical Fourier-based techniques in most applications [5]. Theoretical results involving modeling of functions in Besov spaces explain the performance of wavelet-based techniques [6].

2. Enhancement Of Scanned Image

The enhancement of a scanned document combines three image processing tasks: deblurring, denoising, and moiré reduction. The most obvious one is perhaps deblurring since the blurring introduced by the scanner is easily recognizable, especially around text characters [7]. In studying the inversion problem it becomes clear that a denoising step has to be coupled with the deblurring step. If no denoising is being performed scanner noise pixels may be enlarged and dominate the overall image appearance. Another category of noise is found in halftone areas. Common halftoning techniques are error diffusion and ordered dither [1]. Whereas error diffusion introduces some randomness into the placement of halftone dots, ordered dither shows periodically, isolated dots. If those dots are enhanced by a deblurring filtering procedure, the enhancement can lead to severe moiré artifacts in the enhanced image. Those might become even worse after printing the enhanced page on a laser printer with a specific resolution (dpi) that interferes with the enhanced halftone frequency. Therefore, a desired enhancement technology should be able to remove scanner and halftone noise while deblurring other areas such as text and photographic content [3].

3. Wavelet Threshoding

Because wavelet provides an appropriate basis for separating noisy signal from the image signal. The motivation is that as the wavelet transform is good at energy compaction, the small coefficient are more likely due to noise and large coefficient due to important signal features[7]. These small coefficients can be thresholded without affecting the significant features of the image. Thresholding is a simple non-linear technique, which operates on one wavelet coefficient at a time. In its most basic form, each coefficient is thresholded by comparing against threshold, if the coefficient is smaller than threshold, set to zero; otherwise it is kept or modified. Replacing the small noisy coefficients by zero and inverse wavelet transform on the result may lead to reconstruction with the essential signal characteristics and with less noise. Since the work of Donoho & Johnstone, there has been much research on finding thresholds, however few are specifically designed for images [8].

Let W and W^{-1} denote the two dimensional orthogonal discrete wavelet transform (DWT) matrix and its inverse respectively. Then Y = Wg represents the matrix of wavelet coefficients of *g* having four subbands (LL, LH, HL and HH) (Vattereli and Kovacevic,1995; Gupta and kaur,2002). The sub-bands HHk, HLk, LHk are called *details*, where k is the scale varying from 1, 2 …… J and J is the total number of decompositions.The size of the subband at scale k is N/2k. The subband LLJ is the low-resolution residue. The wavelet thresholding denoising method processes each coefficient of Y from the detail subbands with a soft threshold function to obtain $\hat{X}$. The denoised estimate is inverse transformed to $\hat{f} = W^{-1}\hat{X}$. In the experiments, soft thresholding has been used over hard thresholding because it gives more visually pleasant images as compared to hard thresholding; reason being the latter is discontinuous and yields abrupt artifacts in the reconstructed images especially when the noise energy is significant [3].

4. Denoising

One of the first applications taking advantage of wavelet was denoising studied by Onoho and Johnstone and is known as *wavelet-shrinkage*. The two most commonly known shrinkage techniques are *hard-thresholding* and *softthresholding*. For hard-thresholding, all coefficients with magnitudes below a given threshold are set to zero. For softthresholding, in addition, all coefficients with magnitudes above the threshold are shrunk by the thresholding amount [9]. If the noise is modeled as Gaussian white noise, the threshold is derived only from the number of samples and the noise variance and is independent of the function and the wavelet system. A big advantage of wavelet shrinkage in applications is its simplicity. The theoretically derived threshold for hard- or softthresholding is computed usually from one level of wavelet coefficients at fine scales and then applied to all coefficients [1]. In general the noise pixels have a smaller amplitude than most of the real image edges. For dithered halftone patterns, this is not necessarily true, since halftone patterns usually consist of black and white dots of some diameter. The jump between black and white is considered to be a big edge. If a threshold had to be chosen such that wavelet coefficients associated with those edges disappear, a lot of text edges and real edges in images would be thresholded out. Therefore, the question has to be asked of how to distinguish real text and image edges from ordered dither dots in the wavelet domain such that those halftone wavelet coefficients can be thresholded, whereas coefficients associated to text or real image edges are maintained. A method for inverse halftoning in the wavelet domain has been presented that uses edge information across scales to derive a thresholding scheme [8]. The difference between ordered dither halftone and real text or image edges in the spatial domain is that a real edge consists of a chain of points with rapidly changing intensity, where halftone is composed of isolated points of strong intensity change. In addition, ordered dither patterns are very periodic, including some offset in two neighboring rows of isolated dots. In order to derive criteria for characterization of halftone in contrast to text in wavelet coefficients we first consider the examples of horizontal, vertical and diagonal lines. A vertical line in the image produces large wavelet coefficients of the same sign along a vertical line in the HL band, whereas the coefficients away from the line are small. A horizontal line produces large wavelet coefficients of the same sign along a horizontal line in the LH band. A diagonal line produces medium sized wavelet coefficients of the same sign along a diagonal line in the HL, LH and HH band. On the first level of decomposition a halftoned area produces large coefficients of positive and negative sign in the HL and LH band. These coefficients are not connected, but rather isolated. In the HH bands a halftone area produces isolated large size coefficients [1].

5. Estimation of Parameters for NormalShrink

This section describes the method for computing the various parameters used to calculate the threshold value (T_N), which is adaptive to different subband characteristics.

$$T_N = \frac{\beta \hat{\sigma}^2}{\hat{\sigma}_y} \qquad (2)$$

Where, the scale parameter β is computed once for each scale using the following equation:

$$\beta = \sqrt{\log\left(\frac{L_k}{J}\right)} \qquad (3)$$

L_k is the length of the subband at k^{th} scale. $\hat{\sigma}^2$ is the noise variance, which is estimated from the subband HH1, using the formula:

$$\hat{\sigma}^2 = \left[\frac{median(|Y_{ij}|)}{0.6745}\right]^2, Y_{ij} \in \text{ subband } HH_1 \qquad (4)$$

and $\hat{\sigma}_y$ is the standard deviation of the subband under consideration computed by using the standard MATLAB command. To summarize, the proposed method is named as *NormalShrink* which performs soft thresholding with the data driven subband dependent threshold T_N [10].

6. Hard And Soft Thresholding

Hard and soft thresholding with threshold λ are define as follows[1]:
The hard thresholding operator is defined as

$$D(U,\lambda) \begin{cases} =U \text{ for all } |U|>\lambda \\ =0 \text{ otherwise} \end{cases} \qquad (5)$$

The soft thresholding operator on the other hand is define as

$$D(U,\lambda) = \text{sgn}(U)\max(0,|U|-\lambda) \qquad (6)$$

Hard threshold is a "keep or kill" procedure and more intuitively appealing. the alternative, soft thresholding shrinks coefficients above the threshold in absolute value. While at first sight hard thresholding may seem to be natural, the continuity of soft thresholding has some advantages. It makes algorithms mathematically more tractable. Sometimes, pure noise coefficients may pass the hard threshold and appear as annoying in the output. Soft thresholding shrinks these false structures [12].

7. Suggested Method

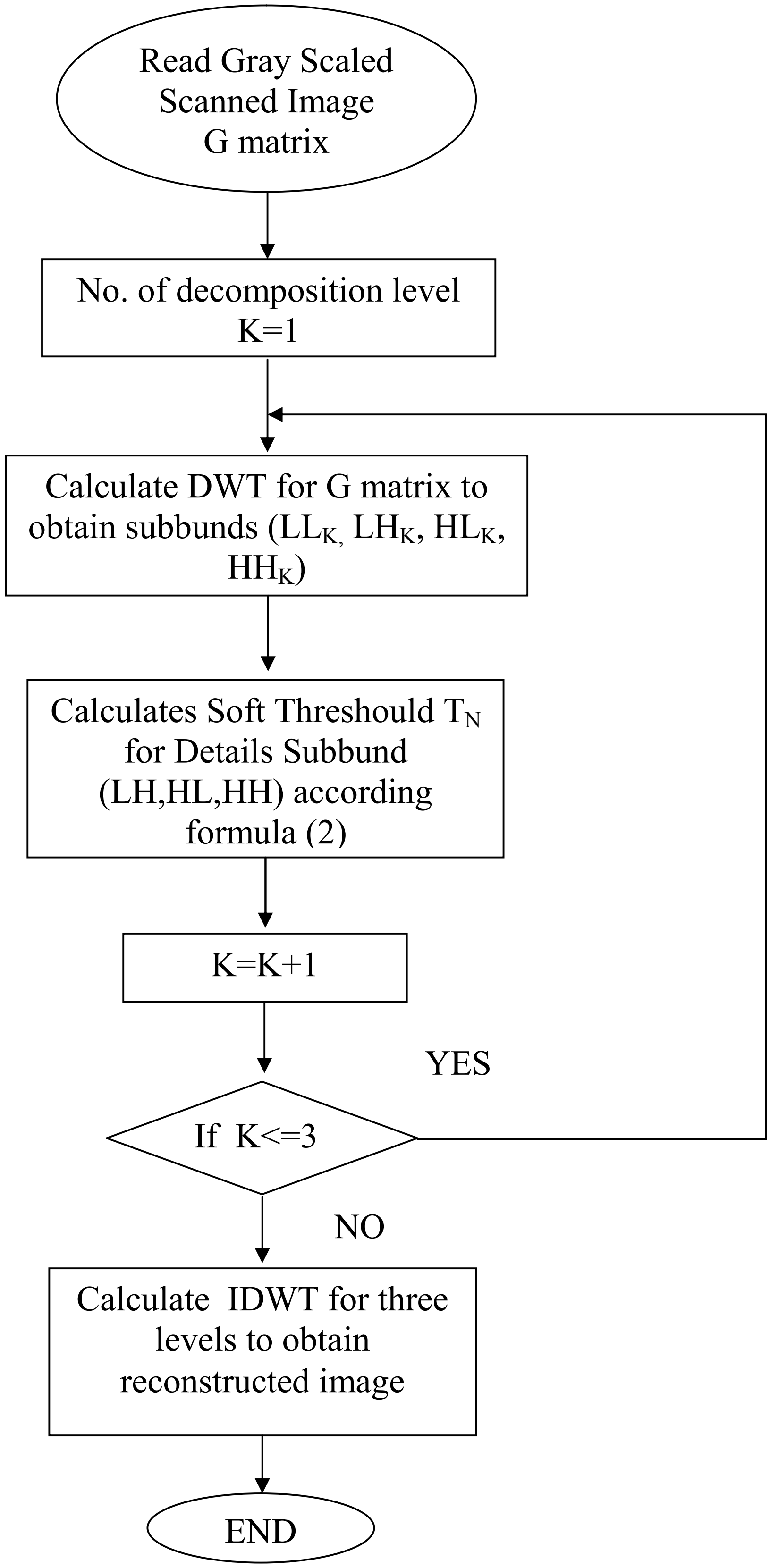


Fig (1) Flow Chart For Suggested Method

8. Experimental Results

Experiments have been performed using a 300 and 600 dpi scanner (canon) and variety of document text, image contains text and object, and image contains object and background. The result of the enhancement scanned book cover and book page are displayed in the following figures, the enhancement algorithm compute forward wavelet transform (compute over complete Harr transform (only adds and subtracts) and three level of decomposition), To evaluate the performance of the suggested method , the quality of the enhancement result image obtained by the method has been compared with the original image by Peak Signal to Noise Ratio (PSNR) and evaluate the similarity between tow images. They measure the difference between the pixels corresponding to every position of the result image and original image.

$$PSNR = 10\log_{10} \frac{(L-1)^2}{\frac{1}{NM}\sum_{X=0}^{N-1}\sum_{Y=0}^{M-1}\left[I'(X,Y) - I(X,Y)\right]^2}$$

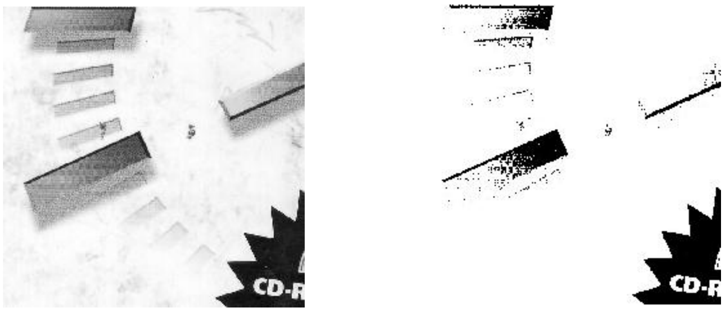
Where
L=255, N,M: is the image damnation
I(X,Y) is the original image
$I'(X,Y)$ is the result image

(a) Text image

(b) Text image

Fig(2)- (a): example of scanned book page containing text, and scanner noise.
(b): enhanced image after apply the algorithm with PSNR=32.1604

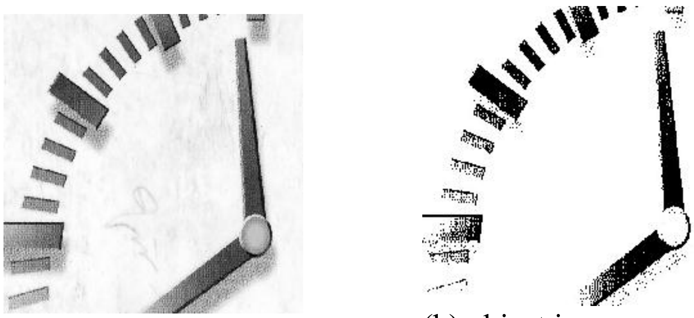
Fig(3) shows the enhancement results in an area with text, white background, and object, the wavelet based enhancement sharpens the text while simultaneously removing scanner noise from the white background and object.



(a) Text and object image (b) Text and object image

Fig(3)- (a): example of scanned book cover containing text, white background, object, and scanner noise. (b): enhanced image after apply the algorithm with PSNR=28.1329

Fig(4) shows the enhancement results in an image contained background and object the wavelet have three level of decomposition .



(a) object image (b) object image

Fig(4)- (a): example of scanned book cover containing object, and scanner noise. (b): enhanced image after apply the algorithm with PSNR=32.0321 .

9. Conclusion

1- The algorithm found that subband adaptive thresholding performs better than a universal thresholding.
2- Most of the parameters used in the algorithm can be precomputed using an appropriate modeling of images and image processing steps in wavelet.
3- For document enhancement the simple translation invariant Haar wavelet system has sufficient smoothness properties. This leads to very simple filtering routines for computing the wavelet coefficients.
4- The image processing steps deblurring and denoising are simple processing steps on wavelet coefficients, namely thresholding and rescaling.

10. References

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