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Image processing based on the Wavelet Transform

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ABSTRACT. This article presents a method for adjusting the contrast of images, based entirely on the Discrete Wavelet Transform.

1. INTRODUCTION

Reducing and enhancing contrast are two of the most frequently performed operations in image processing. Many of the existing algorithms use a mask to perform those operations. This approach has the disadvantage that it only modifies the raw data. The Discrete Wavelet Transform (DWT) offers more flexibility with the amount of information that has to be enhanced or attenuated at different resolutions.

This article presents the effect of controlling the DWT coefficients in various subbands on the contrast of images and proposes an algorithm for implementing uneven filters that can be drawn as greyscale images.

2. THE CONTRAST ADJUSTING APPLICATION

The application presented in figure 1 was built for controlling the contrast of images:

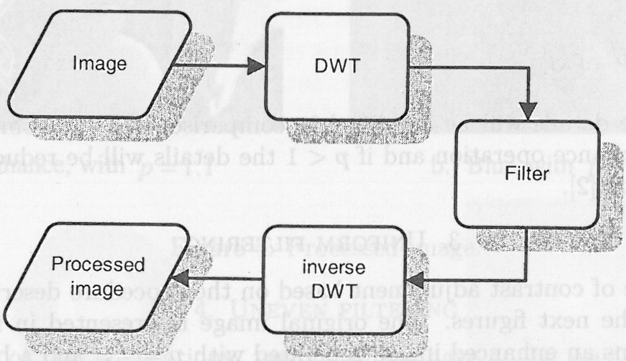


Figure 1: Image processing application

The DWT module decomposes the image in a hierarchy of coefficients, that are arranged according to figure 2 in several subbands [1], [3]. The coefficient placed in the upper-left corner of the array represents the general average of the image, and the other ones are detail coefficients corresponding to various resolutions. Each subband is composed of three groups of coefficients: H_k, V_k and D_k, representing the horizontal, vertical and diagonal oscillations, where k is the number of the subband. The last subband contains the finest details of the image. The Villasenor 18/10 digital filter [4] was used for computing the DWT.

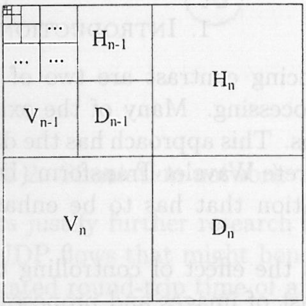


Figure 2: Localization of the subbands

The next module adjusts the contrast of the image, by applying the filter presented in relation (2.1) to the array of DWT coefficients, where $c_{i,j}$ is the coefficient placed on line i and column j of the array, p is a constant that defines the operation, and k is the number of the subband $c_{i,j}$ belongs to.

$$(2.1) \quad c_{i,j} = p^k \cdot c_{i,j}$$

If $p > 1$ the details will be amplified in comparison with the smooth regions, resulting an enhance operation and if $p < 1$ the details will be reduced, resulting a blur operation [2].

3. Uniform filtering

An example of contrast adjustment based on the procedure described above is presented in the next figures. The original image is presented in figure 3, and figure 4 contains an enhanced image generated with $p = 1.1$, and a blurred image obtained with $p = 0.9$.

Figure 3: Original image

a.) Enhance, with $p = 1.1$

b.) Blur, with $p = 0.9$

Figure 4: Processed image.

4. Uneven filtering

For some of the applications, various filters have to be used for processing different regions of the same image. The following algorithm is proposed for implementing an uneven filter suitable for square images of side l.

1. Draw the filter as a l x l pixels grey-level image. The darkness of the filter

2. Compute the filter elements $f_{i,j}$ according to relation (4.2), where $p_{\min}<1$ is the maximum blur coefficient, $p_{\max}>1$ is the maximum enhance coefficient, and max_f is the maximum value that can be represented on the same number of bits as the elements of the filter.

$$(4.2) \qquad f_{i,j} = p_{\min} + \frac{p_{\max} - p_{\min}}{\max_f} f_{i,j}$$

3. $n =$ the number of the last image subband.
$h = l/2$

Repeat the steps 3.1 - 3.3 for all the subbands of the image.

3.1. Half both the horizontal and vertical resolutions of the filter, according to relation (4.3), where $f^n_{i,j}$ are the elements of the filter corresponding to the DWT coefficients $c_{i,j}$ placed at the same position in subband number n and $f^{n+1}_{i,j}$ are the elements of the filter used at the previous step.

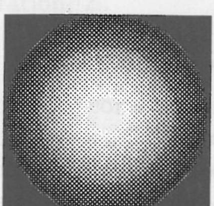
$$(4.3) \qquad f^n_{i+h,j} = f^n_{i,j+h} = f^n_{i+h,j+h} = \frac{f^{n+1}_{2i,2j} + f^{n+1}_{2i+1,2j} + f^{n+1}_{2i,2j+1} + f^{n+1}_{2i+1,2j+1}}{4}$$

3.2. Modify the coefficients in subband n, according to relation (4.4).

$$(4.4) \qquad c_{i,j} = f^n_{i,j} \cdot c_{i,j}$$

3.3. $n = n - 1$
$h = h/2$

In figures 5 and 6 are presented two uneven filter examples, and the results of their application to the image in figure 3. Filter a enhances the middle of the image and blurs the margins. Filter b contains a ring shaped maximum blur region, and in rest the contrast is enhanced at maximum.



Filter *a*

Filter *b*

a.) Effect of filter *a*, with $p_{\min} = 0.7$ and $p_{\max} = 1.15$

b.) Effect of filter *b*, with $p_{\min} = 0.6$ and $p_{\max} = 1.1$

Figure 6: Uneven filtering example

References

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[4] Signal and Image Processing Group, University of Bath, http://dmsun4.bath.ac.uk

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