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DCT를 사용한 디지털 하프토닝

Digital Halftoning using DCT

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요 약 이 논문에서는 먼저 디지털 하프토닝 영상을 생성하는 기존의 방법들과 DCT 변환에 대해서 설명한다. 그런 후에 DCT 변환에 근간을 둔 새롭고 단순한 하프토닝 알고리즘을 제안한다. 이 논문은 제안한 알고리즘을 검정하기 위해서 실현 가능성 검증을 수행한다. 그래서 DCT 계수의 가중치를 조절하여 생성된 여러 가지 영상들을 평가하였다. 실험을 통해서 단순한 이상적인 계단 함수 형태의 가중치를 사용하는 것보다는 램프 함수 형태의 가중치를 사용하면 더 좋은 결과를 얻었다. 단순한 응용분야로서 MPEG 비디오에 제안한 알고리즘을 적용하여 하프토닝 비디오를 생성할 수 있다.

Abstract In this paper, we discussed the traditional methods of generating digital halftoning image and DCT transform. Then we propose a new and simple halftoning algorithm that is based on DCT transformation. We do the feasibility test to verify the proposed algorithm. So we assessed several images generated by adjusting weights of DCT coefficients. As a result, we got the better result for weights of the ramp function type than for weights of the step function type through experiment. As a simple application, we can apply our algorithm to the MPEG video for generating the halftoning video.

Key Words : Ordered Dither, Error Diffusion, Digital Halftoning, DCT

Ⅰ. Introduction

Digital halftoning is a technique to display an image with only black and white colors. We need this kind of technology when a monochrome or color image is printed by a printer with limited number of ink colors. The history of halftoning technology can be dated back to the last century when physical screens and gauzes were used to generate halftone image[1-4]. These techniques have been translated directly to digital halftoning. Ordered dither is the natural digital solution, where it designed a two-dimensional threshold array and the halftoning process is accomplished by a simple pixel-wise comparison of the grayscale image against this array.

In he better result for weights of the ramp function type than for weights of the step function type through the experiment. Also, we think we need further works for adjusting the coefficients of the DCT transformation.

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The most popular technology of halftoning algorithms is error diffusion that propagates quantization errors to unprocessed neighboring pixels according to some fixed ratios. The error diffusion preserves the average intensity level between the original input images and the binary output image. Furthermore, the error diffusion produces good half tone image despite relatively low cost. However, since ordered dither and error diffusion algorithm may generate worm artifacts especially in the image areas of flat intensity, various modification are proposed [1-8]. Also there are another research area of halftone in the parallel processing[9-10].

In this paper, we will propose the new and simple method that use DCT transformation to get halftoning image. Also we do experiment of the feasibility test using DCT transformation for halftoning. As a result, we can conclude we can use the DCT transformation for digital halftoning.

Ⅱ. Existing methods

This section analyzes two extreme methods of digital halftoning and DCT(Discrete Cosine Transform). Section 2-1 describes ordered method which uses ordered dither array to threshold the value of image. Section 2-2 describes conventional error diffusion which uses a fixed error filter and a quantizer by thresholding. Section 2-3 describes DCT.

2.1 Ordered dither

The OD(Ordered Dither) algorithm generates a binary halftone image by comparing pixels of an original continuous-tone image to the dither array. It is the array of a threshold values which is composed of a deterministic values. The OD algorithm is a point operation, that is, the output depends only on the value of the current pixel and threshold value of OD array [1-4].

The OD array are “ordered” rather than “random”. However, the OD array is not unique. Two classes of OD array are commonly used: dispersed-dot and cluster-dot. In a dispersed-dot OD array, consecutive entries visited are far apart, while in clustered-dot dither, they are adjacent or almost so. Fig. 1 gives four examples of the OD array[5].

0	2
3	1

(a)

0	1
3	2

(b)

0	8	2	10
12	4	14	6
3	11	1	9
15	7	13	5

(c)

6	7	8	9
5	0	1	10
4	3	2	11
15	14	13	12

(d)

1. Ordered Dither 배열의 예들.
Fig. 1. Examples of ordered dither array. (a) dispersed-dot (2x2), (b) clustered-dot (2x2), (c) dispersed-dot (4xx4), (d) clustered-dot (4x4).

Let (i,j) be the normalized grayscale image defined on domain D, where D has the size of $\times J$. A dither array D is an $m \times n$ array containing all the integers from 0 to $mn-1$. Then threshold values of OD array is given by the following equation:

$$Th(k) = \frac{2k+1}{2mn}, \quad k = 0,1,\cdots,mn-1 \qquad (1)$$

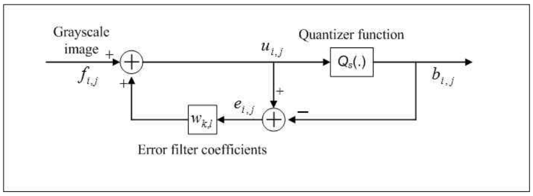
and we can get the output image b of OD halftoning by using the following equation:

$$b(i,j) = \begin{matrix} 1 & \text{if}\, f(i,j) \geq Th(D(i \bmod m, j \bmod n)) \\ 0 & otherwise \end{matrix}$$

Clustered-dot OD method is primarily used for printing devices that have difficulty printing isolated single pixels. Obviously, this congregation of pixels will result in noticeable low-frequency structures in the output image. On the other hand, in Dispersed-dot OD method, halftone dots in a cell are turned on individually without grouping them into clusters. Therefore, sharp edges can be better rendered compared to clustered-dot dither. However, dispersed-dot method is more susceptible to the dot gain problem that is the increase in size of the printed dot relative to its intended size[5].

2.2 Error diffusion

Floyd and Steinberg diffuse the quantization error over the neighboring continuous-tone pixels. They call this error diffusion(ED). This ED method is not a point process but a neighborhood process because the output is determined by the value of current pixel along with values of pixels surrounding it. The block diagram for grayscale ED method is as the following Fig. 2[5-7].



2. ED 알고리즘의 블록 다이어그램.
Fig. 2. The block diagram of ED algorithm.

In this method, the output pixel value (i,j) of binary image is determined in raster(or serpentine) scan order. The value $b(i,j)$ is determined simply by thresholding as follows:

$$b(i,j) = \begin{cases} 1 & \text{if } u(i,j) > 1/2 \\ 0 & \text{if } u(i,j) \le 1/2 \end{cases} \tag{2}$$

Clearly, the quantization error is computed by the following equation:

$$e(i,j) = u(i,j) - b(i,j) \tag{3}$$

Note that the ED algorithm selects the pixel value of the output binary image to minimize the absolute value of error $|e(i,j)|$. Then it distributes the weighted error to the set of unprocessed pixels.

$$f(i+k,j+l) = f(i+k,j+l) + w_{k,l} \bullet e(i,j) \tag{4}$$

Where $w_{k,l}$ are coefficients of the error filter. The commonly used coefficients for error filters are those as following Fig. 3.

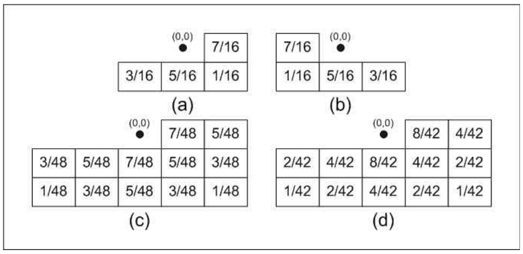


그림 3. ED 기법에서 사용되는 일반적인 오차 필터들.
Fig. 3. Commonly used error filters for ED methods. (a) Floyd-Steinberg (raster), (b) Floyd-Steinberg (serpentine), (c) Javis (raster), and (d) Stucki (raster).

The success of error diffusion lies in the fact that it is a "good blue-noise generator" as pointed out by Ulichney. In the academic literature, the nature of noise is often described by a color name: i.e., white-noise is so named because of its flat power spectrum. On the other hand, blue-noise has most of its energy located at high spatial frequencies with very little low frequency component. Patterns with blue-noise characteristics generally enjoy the benefits of aperiodically uncorrelated dot patterns without low-frequency graininess[6].

2.3 Discrete Cosine Transform

The discrete cosine transform (DCT) helps separate the image into parts (or spectral sub-bands) of differing importance (with respect to the image's visual quality). The DCT is similar to the discrete Fourier transform: it transforms a signal or image from the spatial domain to the frequency domain. You can often recostruct a sequence very accurately from only a few DCT coefficients, a useful property for applications requiring data reduction. The general equation for a 1D (N data items) DCT is defined by the following equation:

$$y(k) = w(k) \sum_{n=1} x(n) \cos\left(\frac{\pi(2n-1)(k-1)}{2}\right) \tag{5}$$

where

$$(k)=\begin{cases} 1 & k=1 \\ \dfrac{2}{N} & 2\le k\le N \end{cases}$$

The definition of the two-dimensional DCT for an input image A and output image B is defined by the following equation:

$$_{q} \quad \alpha_p\beta_p \sum_{m=0}^{-1}\sum_{n=0}^{N-1} A_{mn}\cos \ \frac{\pi \ 2m+1)p}{2M}\Big)\cos\left(\frac{\pi(2n+1)q}{2N}\right) \tag{6}$$

where

$$\alpha_p=\begin{cases} \dfrac{1}{N} & p=0 \\ \dfrac{2}{N} & 1\le p\le M-1 \end{cases} \qquad \beta_q=\begin{cases} \dfrac{1}{\sqrt{N}} & q=0 \\ \sqrt{\dfrac{2}{N}} & 1\le q\le N-1 \end{cases}$$

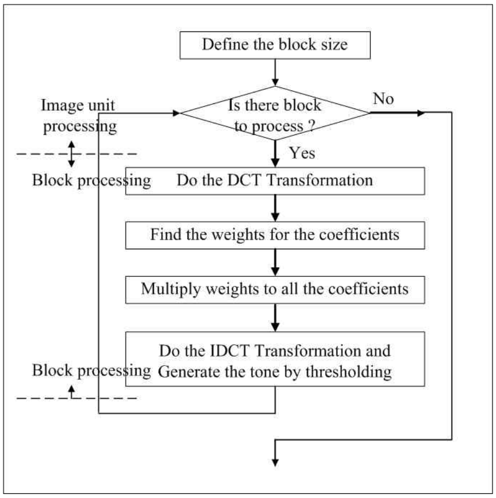
the definition of the two-dimensional inverse DCT is defined by the following equation:

$$A_{mn}=\sum_{p=0}^{M-1}\sum_{q=0}^{N-1}\alpha_p\beta_p B_{pq}\cos\left(\frac{\pi(2m+1)p}{2M}\right)\cos\left(\frac{\pi(2n+1)q}{2N}\right) \tag{7}$$

Ⅲ. The proposed algorithm

In this paper, we present the efficient digital halftone algorithm that is based on the DCT. This algorithm achieves digital halftoning by the block processing that is typically 4x4, or 8x8. At first this algorithm decides the block size and then do the block based processing.

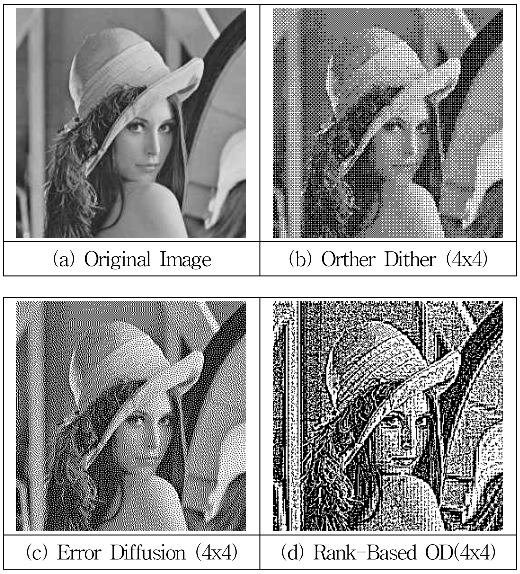
For the each block, this algorithm does the DCT transformation at first and then finds the weights for the each coefficients. After finding the weight for the coefficients, this multiply the weights to all the coefficients. After that, this does the IDCT transformation and generate the halftone for the block by thresholding. The overall flow diagram of the proposed algorithm is appeared in the Fig. 4.



4. 제안한 알고리즘의 전반적인 흐름도.
Fig. 4. The overall flow diagram for the proposed algorithm.

Ⅳ. Experimental results

We did several experiments to verify the our proposed algorithm. At first, we represented the results of the other algorithm. See the Fig. 5.



(a) Original Image	(b) Orther Dither (4x4)
(c) Error Diffusion (4x4)	(d) Rank-Based OD(4x4)

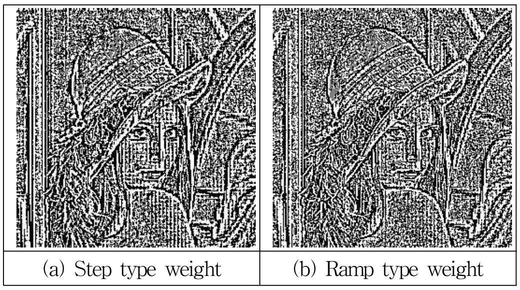
그림 5. 여러 가지 기법들의 하프토닝 영상들.
Fig. 5. The halftoning images of various methods.

1. 그림 5의 PSNR과 WSNR.
Table 1. PSNR and WSNR of Fig. 5

Methods	PSNR(dB)	WSNR(dB)
Ordered Dither	5.718	0.259
Error Diffusion(4x4)	6.753	30.110
Rank Based Order(4x4)	7.167	13.751

In Fig. 5, the (a) is the original Lenna image that is used in our experiment. And the (b) is the result of ordered dither (OD) method and the (c) is the result of error diffusion (ED) method by Floyed-Steinberg. The (d) is the result of Rank-Based Ordered Dither(RBOD) method[7]. We get the assessment as Table 1 for the Fig. 5. In this paper, we use PSNR and WSNR for assesment[9-10].

At first, we did the experiment to show the effect of weights for the coefficients and got the result as Fig. 6 and Table 2. In the Fig., the (a) is the result of setting the value of DC coefficient to value 0(zero) simply and IDCT transformation and thresholding. In this case it corresponds to the ideal HPF(High Pass Filter) of step function type. The (b) is the result of setting (a) step and multiplying 1/2 to the (1, 2) and (2, 1) coefficient of DCT, and IDCT transformation and thresholding. In this case it corresponds to the ideal HPF of ramp function type. And we used the threshold value as 0(zero) during experiment. We get the assessment as Table 2 for the Fig. 6.



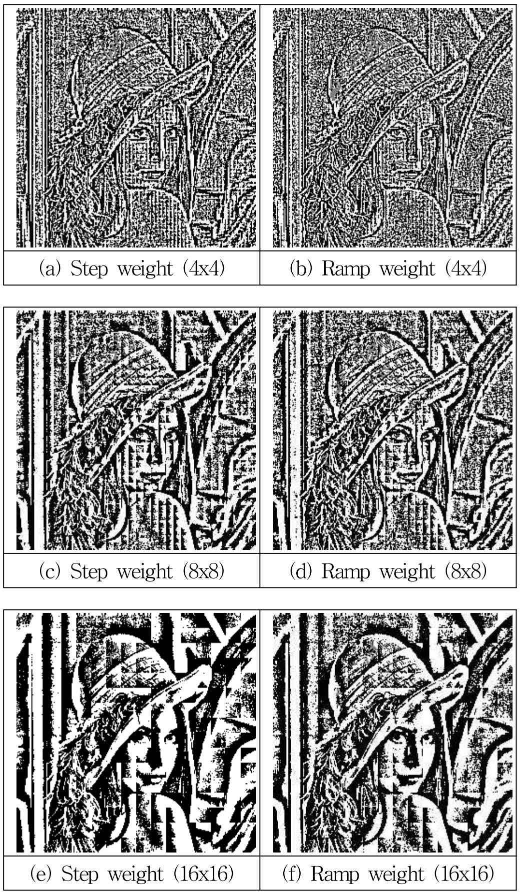
(a) Step type weight (b) Ramp type weight

그림 6. 가중치를 다르게 한 하프토닝 영상들.
Fig. 6. The halftoning images by using different weights.

표 2. 그림 6의 PSNR과 WSNR.
Table 2. PSNR and WSNR of Fig. 6

Methods (block : 4x4)	PSNR(dB)	WSNR(dB)
Step type weight	6.281	9.274
Ramp type weight	6.239	9.754

We also did the experiment to show the effect of block size and got the result as Fig. 7 and Table 3. As you can see from the result image and assessment, we got the better result for weights of the ramp function type than for weights of the step function type. But this time, we do not know how much and how we have to multiply the weight to get the result as error diffusion.



(a) Step weight (4x4) (b) Ramp weight (4x4)
(c) Step weight (8x8) (d) Ramp weight (8x8)
(e) Step weight (16x16) (f) Ramp weight (16x16)

그림 7. 여러 가지 블록 크기에 대한 하프토닝 영상들.
Fig. 7. The halftoning images of various block size.

3. 그림 7의 PSNR과 WSNR.
Table 3. PSNR and WSNR of Fig. 7

Methods	PSNR(dB)	WSNR(dB)
Step type weight (4x4)	6.281	9.274
Ramp type weight (4x4)	6.239	9.754
Step type weight (8x8)	6.769	6.191
Ramp type weight (8x8)	6.672	7.371
Step type weight (16x16)	7.310	4.657
Ramp type weight (16x16)	7.190	5.364

Ⅴ. Conclusion

In this paper, we did the feasibility test of generated halftoning image by using DCT transformation. we can get the better result for weights of the ramp function type than for weights of the step function type through the experiment. As a simple application, we can apply our algorithm to the MPEG video for generating the halftoning video. Also, we think we need further works for adjusting the coefficients of the DCT transformation.

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