NEW CONTRAST MEASURE FOR TRANSFORM BASED IMAGE ENHANCEMENT

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ABSTRACT

The goal of image enhancement is to improve the image quality so that the resultant image is better than the original image for a specific application or set of objectives [7]. Proposed are new contrast measure and novel image enhancement algorithms. The contrast measure is derived from Michelson's law of the human visual system and is used in spatial domain. Proposed algorithms performances are quantitatively compared the one of the best transform based image enhancement algorithm: α – rooting. The fundamental advantages of these algorithms are: a) They perform "better" than modified α –rooting; b) they can be used for enhancement the images in the decompression stage, c) They can be used for automatically choosing the best enhancement method, and the best parameters.

I. INTRODUCTION

Image enhancement algorithms are used to make an image clearer. This may be to aid interpretation by humans or computers. Types of image enhancement include, noise reduction, edge enhancement and contrast enhancement. Enhancement may be used to restore an image that has suffered some kind of deterioration due to the optics, electronics and/or environment or to enhance certain features of an image. Image enhancement improves the quality of the original image such that the resultant image is "better" visually or is improved so that it can be used for other image processing algorithms. Many methods have been proposed to enhance images, in spatial domain, are based on histogram modification [3], [4], while other methods are based on local contrast transformation and edge analysis [5], [6], or the global entropy transform [9]. The transform domain algorithms like unsharp masking, filtering, modified α – rooting, logarithmic technique, and homological technique. Computational complexity of the spatial domain algorithms makes them unsuitable to a lot of applications. Orthogonal transforms are classical examples of the types of transforms used for transform-based algorithms. A typical methodology for transform-based enhancement is:

Step 1: Perform the transform
Step 2: Modify transform coefficients
Step 3: Perform inverse transform

The final step of the generic enhancement algorithm was proposed in [1] for measuring the performance of enhancement. In this paper a new method of enhancement is proposed which enhances the image by modifying the contrast in the transform domain and is compared quantitatively using a new algorithm, as described in the next section, with modified α – rooting.

II. BACKGROUND
A. Modified α – Rooting

Modified α – rooting [1] or root filtering can be described through the following block diagram in Figure 5. The block diagram shows the magnitude of each transformed coefficient is raised to power α, where $0<\alpha<1$ and the sign or phase of the coefficient is unchanged $\hat{X}(n_1,n_2)$ can be written as

$$X(n_1,n_2) = | X(n_1,n_2) |^{\alpha-1} * X(n_1,n_2) \qquad (1)$$

When α is equal to zero, only the phase or the sign of the coefficients is changed. With $0<\alpha<1$, the amplitude of the large transform coefficients is reduced more relative to the small transform coefficients. Since high frequencies are often associated with small transform coefficients the result is edge and details enhancement. The optimal value of α can either be chosen by adjusting interactively or by iterating through a range of values and identifying the optimal α by using mathematical models for image enhancement measure as described in the next section.

III. PROPOSED ALGORITHMS

A. Measure of Enhancement Performance

A crucial step in the direct image enhancement approach is the establishment of a suitable image contrast measure. For

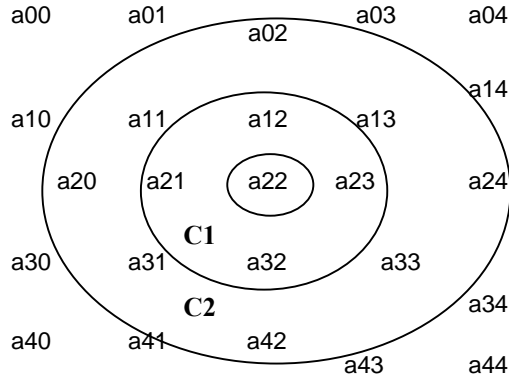**Figure 1:** Bands in Cosine Transform Matrix

Figure 2: Bands in Fourier Transform Matrix

simple patterns, two definitions of contrast measure have been frequently used. One is the Michelson contrast measure [9]; the other is the Weber contrast measure [10]. The Michelson contrast measure is used to measure the contrast of a periodic pattern such as a sinusoidal grating, while the Weber contrast measure assumes a large uniform luminance background with a small test target. Both measures are therefore unsuitable for measuring the contrast in complex images [7]. On the other hand to reduce the subjectivity involved in interpretation of quality of enhancement we need a metric which would possibly simulate the human response to image enhancement. A number of contrast measures were proposed for complex images [1][2][5][5][6][7][10][11]. For example: A local contrast [6], is measured using the mean gray values in two rectangular windows centered on a given pixel, or another contrast measure based on a local analysis of edges is defined in [7] and is derived from the definition in [6]. There is no universal metric, which helps identify the "best" enhancement for complex images. It is natural to modify the Michelson and Weber contrasts in such way that they can be used for suitable for measuring the contrast in complex images. Some modification of the Weber contrast was proposed in [1]. The concept of local intensity measurement is based on Weber law, which argued that the human visual interpretation depends on the ratio of light intensity values f (x, y) and f (x, y) + ∂f (x, y). This quantitative measure is also useful in choosing enhancement methods, parameters in parametric enhancement methods. Let the image be split into $k_1 k_2$ blocks $w_{k,l}$ (i, j). For a given class $\{\phi\}$ of orthogonal transforms, enhancement performance measure (EME) is calculated as follows:

$$EME = \min_{\phi \in \{\phi\}} (EME(\phi))$$

$$= \min_{\phi \in \{\phi\}} \left(\frac{1}{k_1 k_2} \sum \sum 20 \log \frac{I^w_{\max;k,l}(\phi) - I^w_{\min;k,l}(\phi)}{I^w_{\max;k,l}(\phi) + I^w_{\min;k,l}(\phi)} \right) \quad (2)$$

where, $I^w_{\max;k,l}(\phi)$ and $I^w_{\min;k,l}(\phi)$ are respectively maximum and minimum of the image X (n_1, n_2) inside the

block $w_{k,l}$ (i, j), after processing the block by ϕ transform based enhancement algorithm. The block size chosen for this paper is 3 by 3.

B. Transform domain contrast enhancement

The basic idea in this technique is again to enhance the image by manipulating the transform coefficients. The contrast in transform domain is the ratio of high frequency and low frequency content.

Since the energy concentration is region based, majority of the coefficients are zero value based and hence the computational complexity is less. Utilizing the spatial frequency distribution of the orthogonal transform a scan can performed on the transform matrix as shown, for example, in figures 1 and 2 for DCT and Fourier transform matrices. We can then classify the coefficients into bands. The nth band is composed of n = p + s coefficients. For example in DCT, Hartley and Walsh-Hadamard the bands are as shown in figure 1. The bands in Fourier transform case or in the system (3) case as defined as shown in figure 2. As the band number increases, the frequency content of the band increases due to the nature of the transform's spatial frequency distribution. The contrast is measured between adjacent bands as follows:

$$Q_n = \frac{C_n}{\sum_{k=0}^{n-1} C_k} \quad (3)$$

where,

$$C_k = \sum_{p+s} \frac{\Im(|\hat{X}(p,s)|)}{N} \quad (4)$$

And N is the total number of coefficients in the band. $\Im(\hat{X}(p,s))$ is an enhancement function. It operates only on the magnitude of the coefficients, as we do not wish to alter the phase information. We have several possibilities for $\Im(\hat{X}(p,s))$ which offers greater flexibility. The function can be of the forms:

1) $\hat{X}(p,s)^\gamma$ = *Constant*. (When $\gamma = 0$, the enhancement perseveres all constant information)

2) $\hat{X}'(p,s) = \hat{X}(p,s) |\hat{X}(p,s)|^{\alpha-1}$ (Which is called modified α –rooting [8])

3) $\hat{X}'(p,s) = \log^\delta [|\hat{X}(p,s)|^\lambda + 1], 0 \le \delta, 0 < \lambda$

4) For different bands we can use different above-mentioned functions with different parameter values.

Q_n is the ratio of the nth band average coefficient to the sum of the averages of all the bands less than n. Q_n when linearly scaled to results in enhanced n^{th} band in the frequency
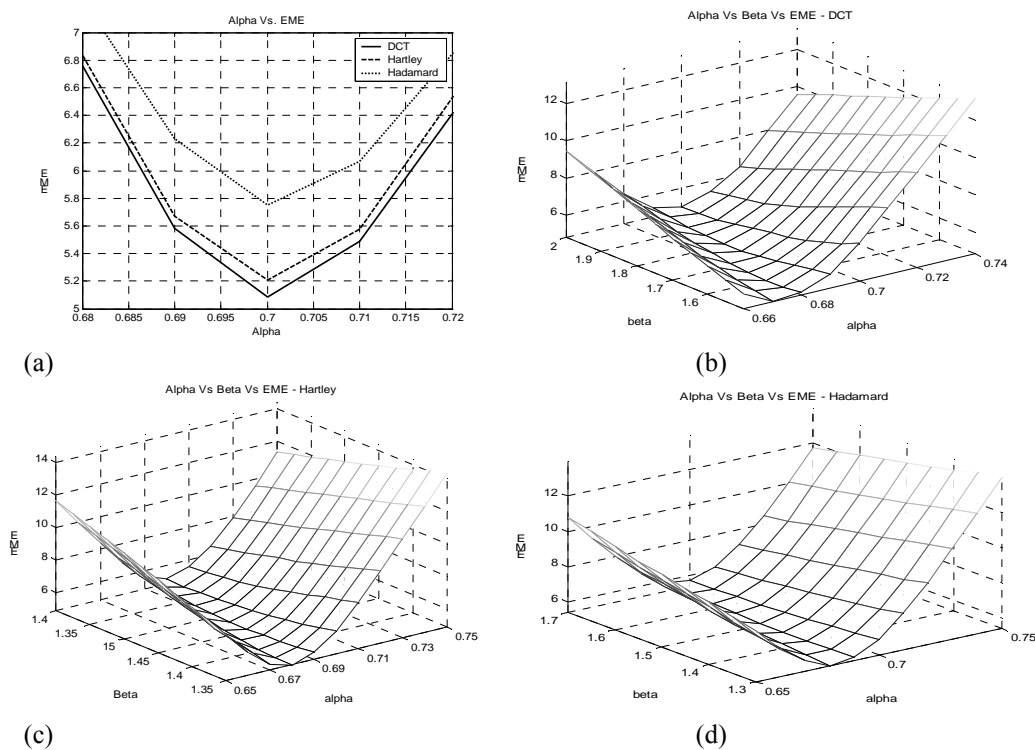
(a)

(b)

(c)

(d)

Figure 3: (a) Modified α – Rooting: α Vs. EME for DCT, Hartley and Walsh Hadamard (b), (c) and (d) – Proposed Algorithm: α Vs. β Vs. EME DCT, Hartley and Walsh-Hadamard respectively
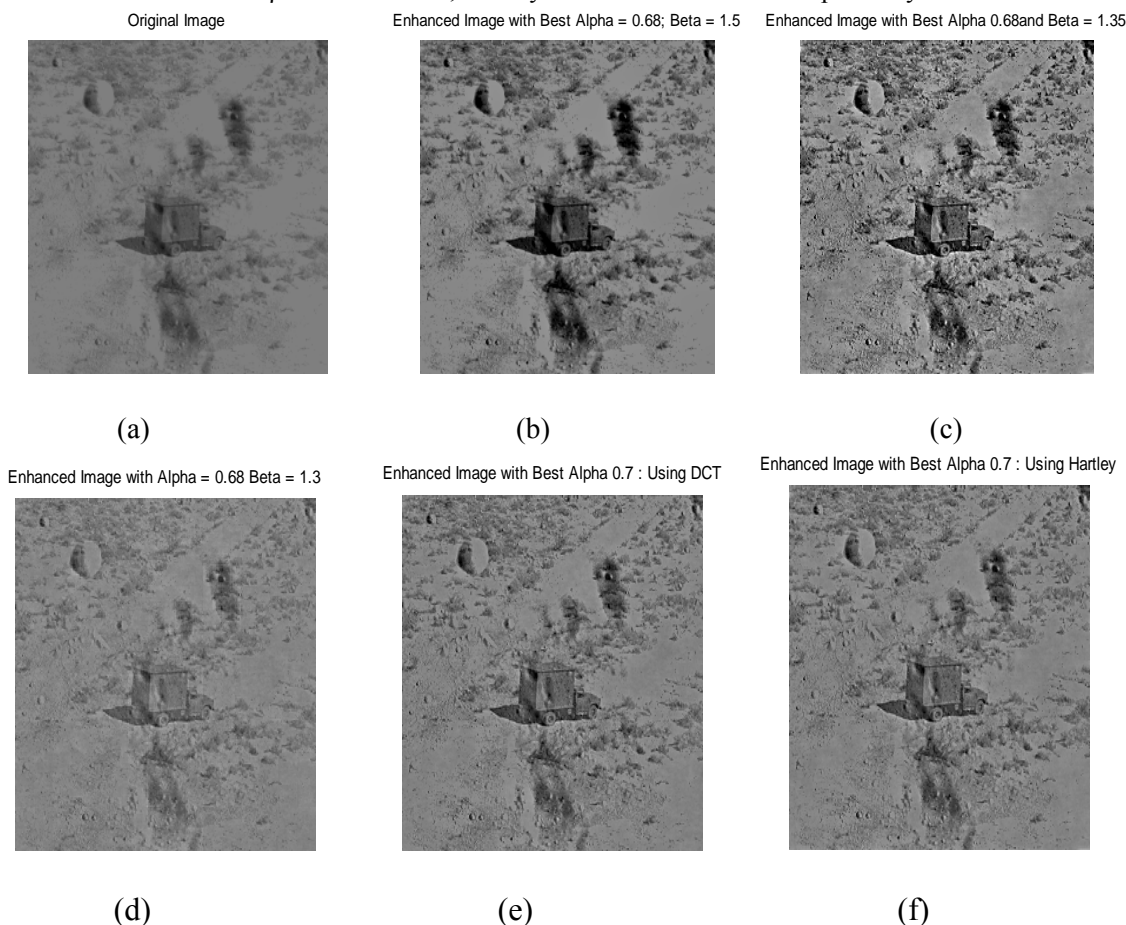

Original Image

Enhanced Image with Best Alpha = 0.68; Beta = 1.5

Enhanced Image with Best Alpha 0.68and Beta = 1.35

(a)

(b)

(c)

Enhanced Image with Alpha = 0.68 Beta = 1.3

Enhanced Image with Best Alpha 0.7 : Using DCT

Enhanced Image with Best Alpha 0.7 : Using Hartley

(d)

(e)

(f)

Figure 4: (a) Original Image, (b), (c), (d) - Enhanced images using proposed algorithm with DCT, Hartley and Walsh-Hadamard respectively, (e) & (f) – Enhanced images using modified α – Rooting with DCT and Hartley
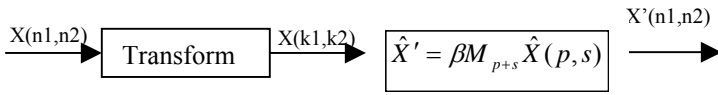
Figure 5: Transform domain contrast enhancement procedure

domain leading to

$$\frac{C'_n}{\sum_{k=0}^{n-1} C'_k} = Q'_n = \beta Q_n = \frac{\beta C_n}{\sum_{k=0}^{n-1} C_k} \qquad (5)$$

where β is a linear scaling factor. Thus from equations 3, 4 and 5 we can simplify

$$C'_n = \beta M_n C_n \qquad (6)$$

IV. EXPERIMENTAL RESULTS

The objective of the experiments was to establish the optimal algorithm for image enhancement. The images considered were (1) a linear combination of moon image and truck image, (2) a linear combination of moon and clock image, and (3) pentagon image and enhancement was performed on the resultant images. The un-enhanced image is shown in figures 4 (a), 6(a) and 6(e). The results of enhancements using the proposed algorithms were compared to α–rooting $\Im(\hat{X}(p,s))$ using DCT, Hartley and Walsh-Hadamard transforms. The enhanced images shown in figure 4 (b) – (d) were obtained iteratively for the best enhancement measure as described in section III part A and enhancement using algorithm described in section III part B. They have been compared to α – rooting enhancement using the same $\Im(\hat{X}(p,s))$. Figure 3 shows the EME variation with respect to α and β changes. Tables 1 and 2 show the experimental data for enhancement. As it can be clearly seen Hartley transform based proposed algorithm using α – rooting as $\Im(\hat{X}(p,s))$ gives the best results because not only does it have the lowest EME values but visually, which is a highly subjective assessment, the enhanced images look "better".

Transform Type	A	β	Min. EME
DCT	0.67	1.55	4.89
Hartley	0.68	1.35	4.74
Hadamard	0.68	1.3	5.4

Table 1: Proposed algorithm results (truck + moon)

Transform Type	A	β	Min. EME
DCT	0.68	1.5	5.8
Hartley	0.68	1.1	5.50
Hadamard	0.67	1.7	6.43

Table 2: Proposed algorithm results (clock + moon)

Transform Type	A	B	Min. EME
DCT	0.8	1.3	2.19
Hartley	0.78	1.1	2.10
Hadamard	0.82	1.65	2.32

Table 3: Proposed algorithm results pentagon)

Transform Type	A	Min. EME
DCT	0.7	5.08
Hartley	0.7	5.20
Hadamard	0.7	5.74

Table 4: Modified α –rooting results

V. CONCLUSION

In this paper, contrast enhancement in transform domain based image enhancement algorithm, a new measure for measuring the contrast in complex images, is presented. The performance of these algorithms is compared to modified α – rooting image enhancement technique. A measure of image enhancement quality is used to measure, quantitatively, the enhancement quality for both algorithms. Although being image dependant, for some transforms the proposed algorithm performs "better" than modified α–rooting. The performance also can be visually verified. The function to enhance contrast in the transform domain works better with modified α –rooting than logarithmic function. Also the algorithm provides three parameters to adjust as opposed to only one parameter in modified α –rooting thus provide more versatility to the user. The proposed algorithms perform "better" than modified α –rooting. Another advantages of these algorithms that they can be used for enhancement the images in the decompression stage. The proposed algorithm is applicable to any image compression standard, such as JPEG, MPEG 2 and H. 261.

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Original Image

Enhanced Image with DCT: Alpha 0.68and Beta = 1.5

Enhanced Image with Hartley:Alpha 0.68and Beta = 1.1

(a)

(b)

(c)

Enhanced Image withHadamard: Alpha 0.67and Beta = 1.7

Original Image

Enhanced Image with Hartley: Alpha 0.78and Beta = 1.1

(d)

(e)

(f)

Enhanced Image with DCT: Alpha 0.8and Beta = 1.3

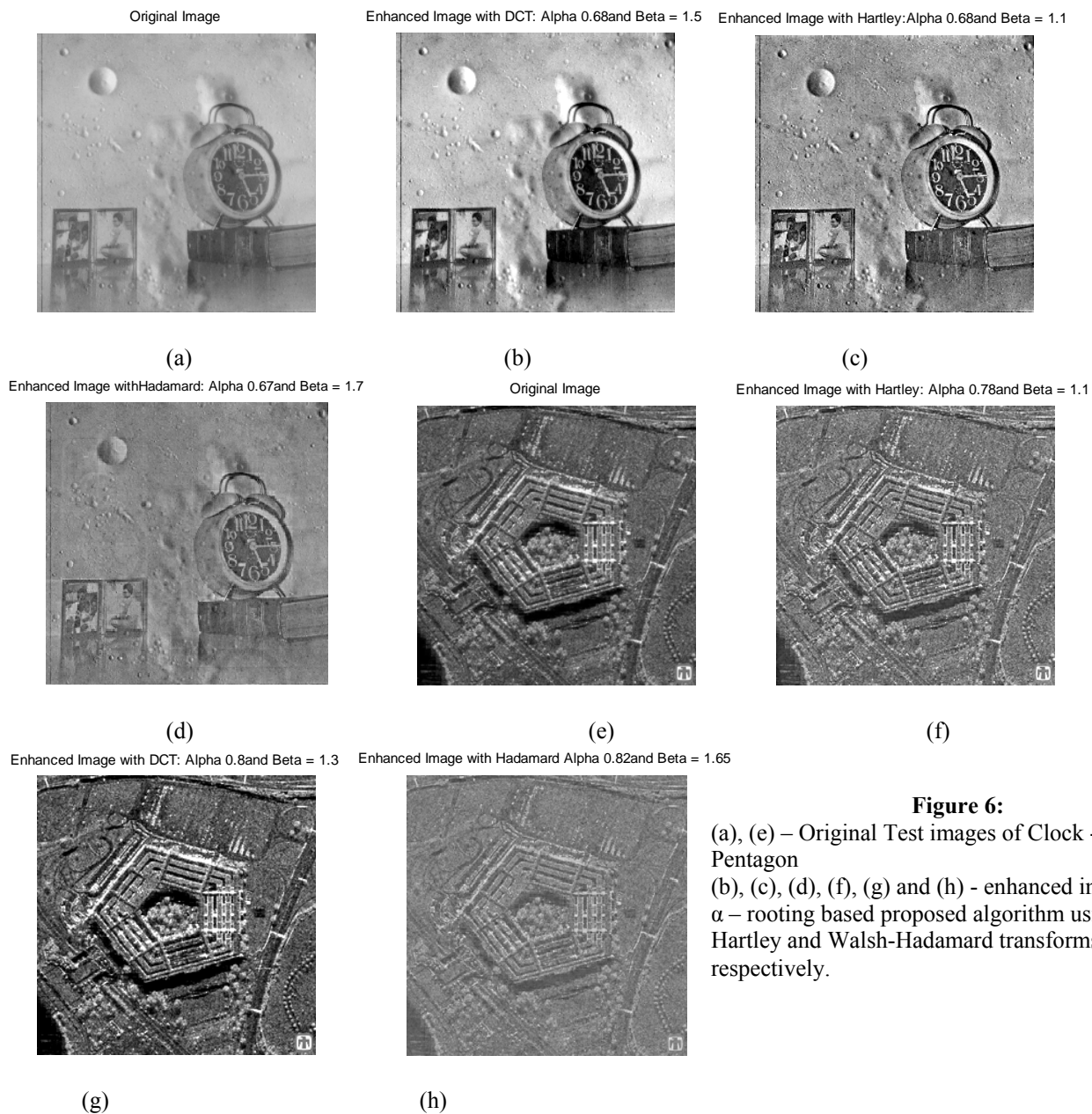Enhanced Image with Hadamard Alpha 0.82and Beta = 1.65

Figure 6:
(a), (e) – Original Test images of Clock - Moon and Pentagon
(b), (c), (d), (f), (g) and (h) - enhanced images using α – rooting based proposed algorithm using DCT, Hartley and Walsh-Hadamard transforms respectively.

(g)

(h)

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