Comparison of Image Fusion based on DCT-STD and DWT-STD

Chu-Hui Lee and Zheng-Wei Zhou

Abstract — **With the development and application of digital technologies, the digital camera is more popular than other electronic products for all ages. Now the functions for human could get a photograph in high resolution easily, mostly cameras have preset modes for different applications, such like the applications can adjust the brightness, contrast, camera raw, white balancing, camera modes, and etc. The applications are easily to adjust for anytime, and anywhere you like, make sure that may work and take a photograph nicely. Now all the structure of normal digital cameras have Depth of field (DOF) limit problem, they could only focus with one point or use the built in automatic focus application. For this DOF limit problem, the area within the depth of field appears sharp, while the areas in front of and beyond the depth of field appear blurry. This paper provided two image fusion mechanisms to extend depth of field. The ideas in this paper are fusion image by DCT-STD and DWT-STD auto focus measurement, through the experiment and comparison prove that the method by DWT-STD is superior.**

Index Terms — **Depth of field (DOF), Discrete Cosine Transform(DCT), Discrete Wavelet Transformation (DWT), Image fusion, Multiple focus**

I. INTRODUCTION

Traditional cameras capture light onto photographic film or photographic plate to get the images, the weakness is cannot review the images immediately, on the other hand, how to take a high quality photographs need the pro-photography knowledge so this is a troubles for who doesn't have the pro-photography knowledge [4]. But nowadays as the technology has improved and evolved, people can actually grab the wonderful moment through the digital camera in anytime, and the best way is people can review the images from the screen of digital cameras, even allows store the photographed images digitally in computers. Technology always begins from human, means that technology motivation always from the human demand, although all the cameras having variety applications and personality functions, but nothing is perfect. All the structure of normal digital cameras have Depth of field (DOF) limit problem, they could focus with one point or use the built in automatic focus application to make it. For this DOF limits problem the area within the depth of field appears sharp, while the areas in front of and beyond the depth of field appear blurry.

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The Depth of field (DOF) limits problem of digital camera is an extremely interesting issue with many intellectuals in these few years. Many intellectuals had suggested variety method, for example, Discrete Wavelet Transformation (DWT), Discrete Cosine Transform (DCT), Support Vector Machine (SVM),etc [2]. In this paper, we provided two new novel image fusion mechanisms based on DCT-STD or DWT-STD.

II. RELATED WORKS

In the area of images processing, the images fusion is an interesting issue, the proposed image fusion is according to the Lee' s auto focus measurement, it is through the methods of Discrete Cosine Transformation (DCT) and Standard Deviation (STD) into the processing of images fusion [5]. Besides that, we will replace DCT with DWT to observe the affection for image fusion.

A. Discrete Cosine Transform

Normally the digital images are displaying on a screen immediately after they are captured. There are two represent types for digital image that is spatial domain or frequency domain [9]. Spatial domain image can be realizes through our human eyes, but frequency domain use to analysis of spatial domain. In general, human eyes are more sensitive through the medium and low spatial domain, and the image features with high spatial frequency those could not be realized easily [9]. Discrete Cosine Transformation (DCT) are important to numerous applications in science, engineering and in images compress, like MPGE, JVT, etc [5]. For simplicity, Discrete Cosine Transformation (DCT) can convert the spatial domain image to frequency domain image [8].

Fig. 1 showed that frequency distribution of the image which is converted by Discrete Cosine Transformation (DCT). According to the Fig. 1 showed that images converted can be distributed by 3 parts, the coefficient on the left-top named DC value, others are named AC values. The DC value represents the average illumination and the AC values are coefficients of high frequency. Lee observes that the image has more detail information then some basis in DCT have higher coefficient values. Then it is useful to observe the distribution of AC values by standard deviation [5].

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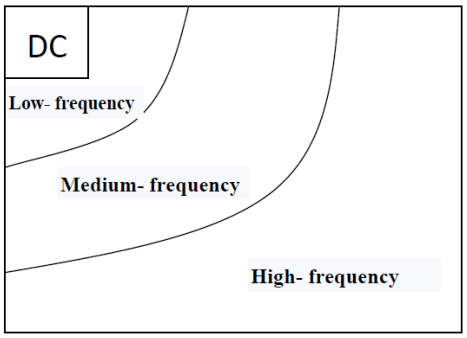

Fig. 1 Frequency distribution of DCT

B. Discrete Wavelet Transformation

The second method of this mechanism uses 2-D Discrete Wavelet Transformation (DWT). DWT also converts the image from the spatial domain to frequency domain. According to the Fig. 2, the image is divided by vertical and horizontal lines and represents the first-order of DWT, and the image can be separated with four parts those are LL1, LH1, HL1 and HH1. In additional, those four parts are represented four frequency areas in the image. For the low-frequency domain LL1 is sensitively with human eyes [7]. In the frequency domains LH1, HL1 and HH1 have more detail information more than frequency domain LL1.

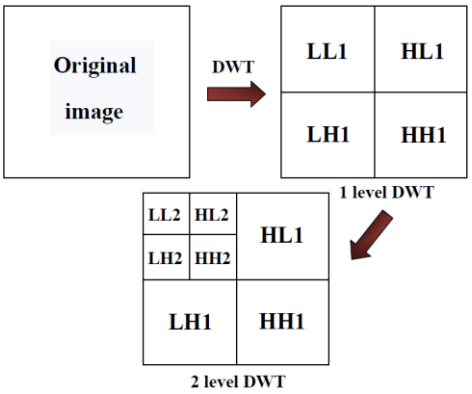

Fig. 2 Frequency distribution of DWT

C. Standard Deviation

The standard deviation (STD) was first used Karl Pearson and it is a widely used measure of statistical dispersion in Statistics. Standard deviation can figure out the population values, for example, a large standard deviation indicates that the data points are far from the mean and a small standard deviation indicates that they are clustered closely around the mean. Calculating the population standard deviation is advantage to figure out the average value and extreme value too [4]. Nowadays, standard deviation is widely used in the stock and the risk of mathematical basis for investment decisions, standard deviation provides a quantified estimate of the uncertainty of future returns in the stock or the net profit of basic for investment. Thus, calculating with standard deviation can figure out the frequency distribution easily [4]. According to Lee's research, it can be realized that standard deviation of AC is larger the image is more clearly [5] and DCT-STD focus measurement was proposed.

D. Image Fusion

Image fusion is the process of combining relevant information from two or more images into a single image [10]. The processing of image fusion is shown in Fig. 3. The original images were analyzed by variety methods [2]. The images were first divided into blocks, next using the method of focus measure to analyze and fusing images by following methods, such as choose max, weighted average, Artificial Neural Networks (ANN), k-nearest neighbor (KNN),etc [2]. In this paper we use Lee's focus measurement DCT-STD into our image fusion process. More even replacing the DCT to DWT, we will compare two transformations affections.

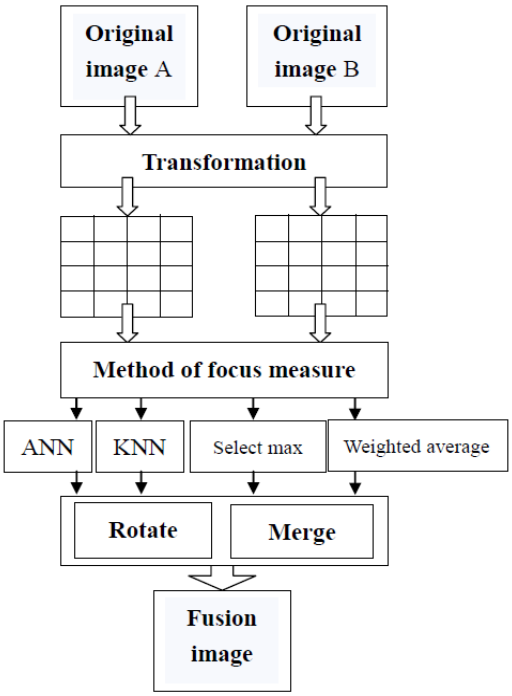

Fig. 3 General process of image fusion

III. FUSION METHOD

In this paper two transformations will be used, which are DCT and DWT. Those transformations analyze the frequency features in the image, and then STD is used to estimate the detail information of image domain. In Lee's discussion, the larger STD value of high frequency means the details in the image domain are richer, on the contrary, the low STD value represents the image has poor detail information [5]. According to the description are mentioned, the method of image fusion compares with high frequency domains of the same region in the two images, the region has the larger STD value of high frequency should be chosen in basically. The processing of this experiment is shown in Fig. 4.

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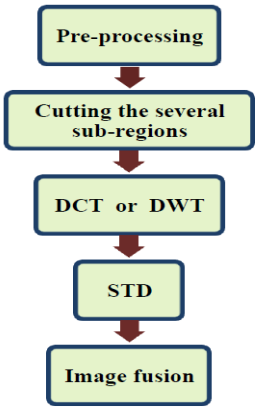

Fig. 4 Research model

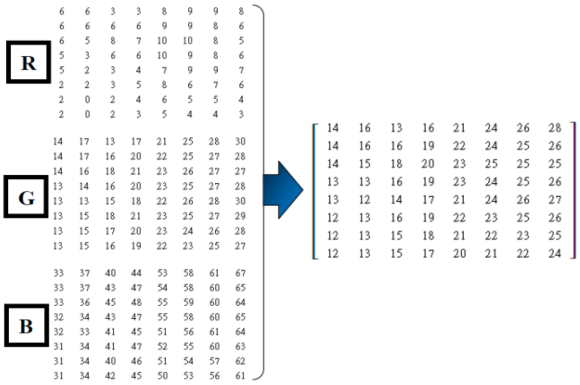

Fig. 6 Color images type to grayscale image type

A. Pre-processing

First, this experiment chooses two images are captured with same objects and background. Each image has a focus object with the proper focusing distance. Suppose that there are A and B objects in the image. The first image has object A in focus and then the second image has object B in focus. This image fusion will generate a proper image that has both objects A and B all in focus. Normally, the image will be divided into blocks, the blocks sizes of image were decided by the experiment with the suitable sizes [6].

B. Discrete Cosine Transformation (DCT)

This experiment tries the method of 2-D Discrete Cosine Transformation (DCT) at first. The image should be grayscale before the DWT starts, After the grayscale transformation is completed, just start the process of 2 dimension Discrete Cosine Transformation (DCT) for each 8*8 blocks. The process of the RGB image transformed to grayscale image is shown in Fig. 5 and Fig. 6.

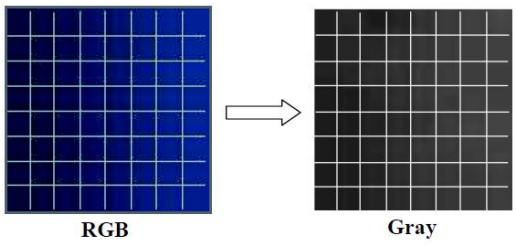

Fig. 5 Color images type to grayscale image type

According to the Fig. 5, the RGB image is divided into blocks with size of 8*8 pixel with blue color in gradient, the gradient scalar field is show the direction from left (deep blue) to right (light blue). After grayscale, the RGB image should be in gray color, the gradient scalar field is show the direction from left (black) to right (grey). Fig. 6 showed the processing of grayscale, the image is grouped by matrices of red, green and blue, and it coverts to one grey matrix. This matrix will be used in next DWT transformation.

After the matrix of grayscale will process the two dimensional Discrete Cosine Transformation (DCT2), the definition two dimensional of Discrete Cosine Transformation (DCT2) is:

$$C(u,v)=\alpha(u)\alpha(v)\sum_{x=0}^{N-1}\sum_{y=0}^{N-1}f_b(x,y)\cos\left[\frac{\pi(2x+1)u}{2N}\right]\cos\left[\frac{\pi(2y+1)v}{2N}\right]$$

The two dimensional Discrete Cosine Transformation (DCT2) is defined that frequency of grayscale blocks convert from spatial domain to frequency domain and gain the result of frequency matrix which is shown in Fig. 7:

$$\begin{bmatrix}
155.8750 & -37.7500 & -1.2785 & 1.6728 & 1.3750 & -1.5279 & -0.1469 & 0.3417\\
5.3945 & -0.3776 & 1.7761 & 1.6692 & -1.0479 & -0.8983 & -0.9005 & -0.7822\\
-2.4730 & 1.8847 & 2.0973 & -0.3121 & -0.3547 & -1.7125 & -1.0455 & -0.9001\\
-0.4420 & -2.9511 & 2.7093 & 0.5616 & 0.2314 & -0.3319 & -0.9536 & -0.3387\\
-2.1250 & -1.8353 & 2.5291 & 1.1301 & 0.3750 & -0.3960 & -0.1005 & 0.1010\\
0.1663 & -0.1310 & -0.5271 & 0.0217 & 0.3672 & -0.4580 & -0.0340 & 0.1399\\
0.8891 & 0.2560 & -0.5455 & -0.2363 & -0.5296 & 0.1396 & 0.1527 & 0.3032\\
-0.3380 & -0.4287 & 1.1169 & 0.8073 & -0.3887 & 0.1389 & 0.3658 & -0.2259
\end{bmatrix}$$

Fig. 7 Matrix of DCT frequency coefficient

Discrete Cosine Transformation (DCT) has the characteristic of energy compact. In the following steps, we will observe the distribution of AC values by STD calculation.

C. Discrete Wavelet Transformation(DWT)

Before process of Discrete Wavelet Transformation (DWT), the original image should be converted into the grayscale first similarly. After Discrete Wavelet Transform (DWT) transformation we get four sub bands, that is LL, LH, HL and HH. From the fig. 8, the original image shows in 4*4 blocks and the processing and converting are shown in Fig. 8.

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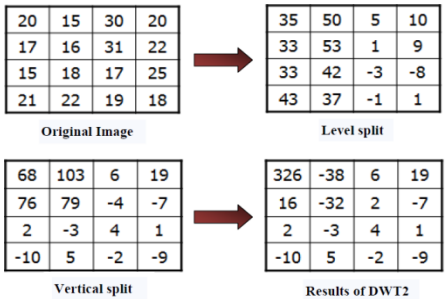

Fig. 8 Conversion Process of DWT2

After the DWT, the standard deviation of frequencies in LH, HL and HH will be calculated in the following steps.

D. Standard Deviation (STD)

In general, images with more detail information will cluster on some base frequency. Values of high frequency after DCT or DWT will concentrate on some basic frequencies. Therefore, we will use standard deviation to observe the distribution of high frequency value of images.

The high frequency AC values in DCT and LH, HL, and HH in DWT contain data with details. Larger AC values and these three sub-band values mean more detail are contained. We filtered out the DC value and LL, the remaining AC values and LH, HL, HH sub bands are calculated with standard deviation, respectively. When the standard deviation value is larger, it means some basic frequency has larger value, which also means the image is clearer. After DCT and DWT, amount of details are determined with standard deviation features. We directly take LH, HL, HH values to calculation, assuming there are m values $X_1, X_2, \cdots, X_m$ as data input , then under DCT the n AC values $X_1, X_2, \cdots, X_n$ are followed by substitution into Eq. (3) and (4), presenting in DCT as example.

The average formula is [5]:

$$\overline{X} = \frac{1}{n-1}\sum_{i=2}^{n} x_i$$

The standard deviation:

$$f_b^{\sigma} = \sqrt{\frac{1}{n-2}\sum_{i=2}^{n}\left(x_i - \overline{x}\right)^2}$$

The blocks will apply DCT transformation or DWT transformation and then STD standard deviation calculation, denoted as DCT-STD or DWT-STD auto focus measurement. Higher value in both measurement is more in-focus. DCT-STD is a robust auto-focus measurement and the experimental result presents the larger standard deviation value more detail information in the block [4].

E. Image Fusion

Fig. 9 shows the processing of image fusion. For each block of the same position, DCT-STD or DWT-STD is used to select the suit blocks. The block with larger DCT-STD (or DWT-STD) value is selected to constitute the new image.

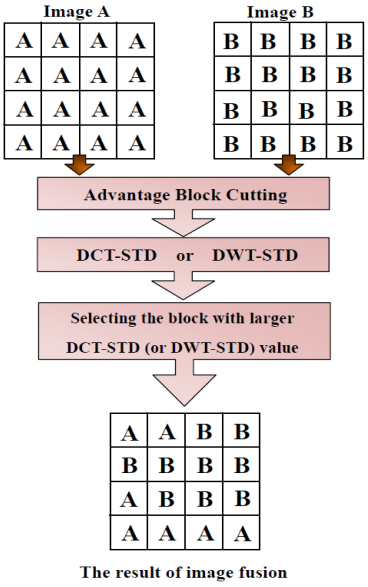

Fig. 9 The process of image fusion

IV. EXPERIMENTAL RESULTS

There are two image sets in our experiment. One is capture by Cannon EOS 5D Mark II and the resolution is 2784 x 1856. The second is capture by NIKON p300 and the resolution is 2592 x 1944. Two major objects are distributed to right and left hand side in the image. The object in left-side is closer camera than object in right-side. The images are divided into different sizes blocks and then the blocks are calculated with DCT-STD or DWT-STD to select the blocks with more detail information. Those steps should be applied on the two original images and fusion a new image. The variety block sizes conduct in different fusion results. In this experiment, there are 10*10, 20*20, …, 200*200, totally are 20 cases with variety sizes to make image fusion, and 70*70 is the most suitable for both two image sets.

The results of these experiments are good and effectively as shown in Fig. 10. There are two groups of images. Each group includes two original images. The fusion of two original images is proposed by DCT-STD or DWT-STD as previous descriptions. In group A, the medicine bottle on the table being the main object in the image, they are focused in different point, for example, the Fig. 10(a) is focusing on the medicine bottle circled by yellow stroke, thus the details of bottle is clear and the right bottle is far away from the zone focusing so blurry; In group B, the Yakult bottle being the main object in the image, the yellow box presents it is the best zone focusing in the image, and the Fig. 11(a) and Fig. 11(b) represents two different zone focusing of original images.

According to the Fig. 10(c), 10(d), 11(c) and 11(d) shows that either DCT-STD or DWT-STD methods to result a good quality images. Next to comparing which is better method, thus we use Evaluation of Image Resolution (EIR) software for two transformations. The EIR software is including the variety parameters for evaluating high resolution, such as TenenGrad, Brenner, Vollath, Square-Gradient, Variance and entropy,etc [11]. The parameters of EIR can be chosen by the user decision. We

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compare DWT-STD or DCT-STD through the EIR software, and the results are shown in the TABLE I and TABLE II. The ratios of the parameters in EIR are set as 20% for TenenGrad, Brenner, Square-Gradient, Variance and entropy equally. The more high evaluation value means more clarity in image. Both results of two image sets showed the DWT-STD is better than DCT-STD method a little in TABLE I. However, in spending time comparison, the DCT-STD is better than DWT-STD method as shown in TABLE III and TABLE IV.

Experiment A

Fig.10(a) Original image1

Fig.10(b) Original image2

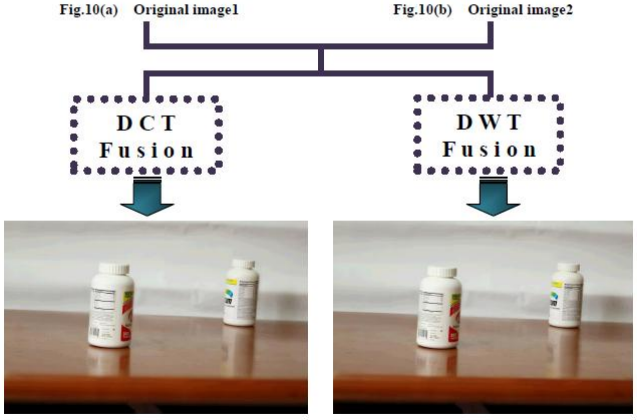

Fig.10(c) The fusion image by DCT

Fig.10(d) The fusion image by DWT

Experiment B

Fig.11(a) Original image1

Fig.11(b) Original image2

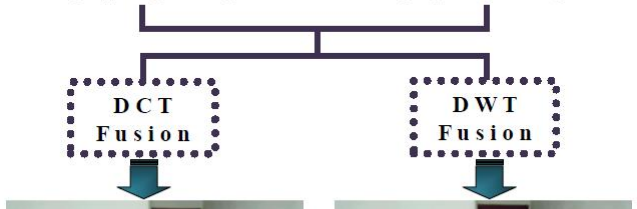

Fig.11(c) The fusion image by DCT

Fig.11(d) The fusion image by DWT

TABLE I USE EIR TO EVALUATE THE DCT AND DWT FUSION

	TenenGrad	Brenner	Variance	Square-Gradient	Entropy	Comprehensive evaluate
10(c)	95.2840	88.3009	99.5174	100.00	100.00	96.6205
10(d)	100.00	100.00	100.00	99.8742	99.3799	99.8454

TABLE II USE EIR TO EVALUATE THE DCT AND DWT FUSION

	TenenGrad	Brenner	Variance	Square-Gradient	Entropy	Comprehensive evaluate
11(c)	91.4949	91.0448	99.4895	91.9848	100.00	94.8028
11(d)	100.00	100.00	100.00	100.00	97.6331	99.5266

TABLE III COMPARE TO DCT AND DWT FUSION BY EXPERIMENT A OF TIME SPENT

	Experiment A combine with function of DCT	Experiment A combine with function of DWT
Spent time	5.973742(s)	7.520257(s)

TABLE IV COMPARE TO DCT AND DWT FUSION BY EXPERIMENT B OF TIME SPENT

	Experiment B combine with function of DCT	Experiment B combine with function of DWT
Spent time	5.825325 (s)	7.464657 (s)

V. CONCLUSION

In this paper, we proposed two image fusion methods. According to the experimental result, these two methods of image fusion have good quality both. By the EIR software comparison of two methods showed the fusion by DWT-STD is better than DCT-STD a little in fusion quality. However, the DWT-STD need more processing time. In the future, we will apply those methods to the issues of composite of depth of field.

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