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Multi-Focus Image Fusion Using Improved Nonlinear Intensity Hue Saturation Transform and Dct

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Abstract— Image fusion is the process of combining the relevant information from a set of multiple images into a single image, where the resultant fused image will be more informative and complete than any of the input images. Image fusion is one of the important techniques to enhance image information. A novel fusion framework is proposed for Multi-focus images coded in Joint Photographic Experts Group (JPEG) based on Discrete Cosine Transform (DCT) and Improved Nonlinear Intensity Hue Saturation (iNIHS) transform. The multi-focus source images are first transformed by Improved Nonlinear Intensity-Hue-Saturation (iNIHS) followed by Discrete cosine transform (DCT). Multi-focus image fusion using improved Nonlinear IHS (intensity, hue, saturation) and DCT, avoids the problem of achieving out of gamut color without appealing to color clipping, avoids color distortion. The proposed method is compared with DCT and iNIHS individually and its performance is evaluated on the basis of parameters such as PSNR (Peak Square Noise Ratio), Correlation, Entropy, MSE (Mean square error), etc. Thus the proposed methodology is superior to the existing DCT based technique, iNIHS and improves the quality of the output image visually for human and machine perception.

Keywords— Image fusion, Improved Nonlinear IHS Transform(iNIHS), Discrete Cosine Transform.

I. INTRODUCTION

Image fusion can be used in different applications for fusion of different images like multi-focus images, complementary images, multisensory images, satellite imaging etc [2]. The limited depth of optical lenses does not describe the complex situation with a single image accurately [1]. Intensity-Hue-Saturation, defines colors mathematically, using cylindrical or spherical coordinates. Hue component refers to the dominant wavelength 0 and 360º. Intensity refers to the total brightness or dullness of a color. Saturation refers to the purity of the color. Both the intensity and saturation component ranges between 0 and 1.

Image fusion using linear IHS transform and nonlinear IHS transform produces gamut problem. Linear IHS color space is said to be in a cube model. After the image fusion, the resulting color point will not be the same as which is present inside RGB cube. It is said to be a gamut problem. Usually gamut problem is resolved by using either one of three types of clipping techniques as discussed in [3]. The nonlinear IHS color space is said to be in cylindrical model with collapsed top, if the color point of the image after backward nonlinear transformation falls into the collapsed portion causes gamut problem. It can be solved by clipping method. But when the collapsed top of the nonlinear cylinder is repaired to a complete cylinder, it is possible to avoid the gamut problem without going for clipping method [3]. Image fusion using nonlinear HIS transform resolve the gamut problem and uses discrete cosine transform based image fusion to overcome the spectral distortion. To completely overcome the high spectral distortion in the resultant fused image, Improved Nonlinear Intensity-Hue-Saturation transform (iNIHS) and Discrete Cosine Transform (DCT) is proposed to remove high spectral distortion in the resultant image and to increase the spatial and spectral resolutions of the fused image.

In the remainder of this paper, Nonlinear IHS color space used in image fusion is presented in Section II. The proposed method of Improved Nonlinear IHS color space using High Pass Filter fusion rule is presented in Section III. Experimental results in Section IV, followed by the conclusion in Section V.

II. PROPOSED METHOD

The Improved Nonlinear Intensity-Hue-Saturation (iNIHS) transform along with Discrete Cosine Transform (DCT) avoid gamut problem, color distortion and improves spatial content respectively. A gamut problem is said to be a subset of color. Certain colors which cannot be expressed within a given color space is said to be gamut problem. The input Multi-focus image undergoes Improved Nonlinear IHS transform (iNIHS), which calculates intensity, hue and saturation value of each pixel to detect the pixel is in RGB color space or CMY color space and then Discrete Cosine Transform (DCT) is used to divide an image into blocks of 8x8 pixels to extract Discrete Cosine Transform (DCT) coefficient which has high spatial contents.

Improved Nonlinear Intensity-Hue-Saturation transform (iNIHS) is applied to the color image. And Discrete Cosine Transform (DCT) is applied to the gray scale image, because Discrete Cosine Transform (DCT) is said to be a 1-Dimensional and 2-Dimensional transform. So, only gray scale image can apply to Discrete Cosine Transform (DCT)

Mostly, 2-Dimensional Discrete Cosine Transform is used in digital image processing.

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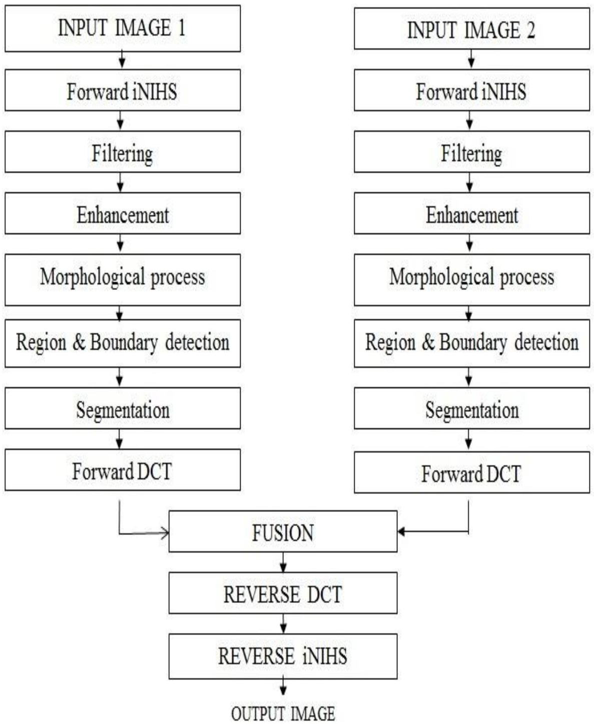

Fig.1 Block diagram for the proposed method.

A. Improved nonlinear intensity-hue-saturation transform

Intensity-Hue-Saturation, defines colors mathematically, using cylindrical or spherical coordinates. Hue component refers to the dominant wavelength 0 and 360º. Intensity refers to the total brightness or dullness of a color. Saturation refers to purity of color. Both saturation and Hue ranges between 0 and 1.

Image fusion using linear IHS transform and nonlinear IHS transform produces gamut problem. Linear IHS color space is said to be in a cube model. After the image fusion, the resulting color point will not be the same as which is present inside RGB cube. It is said to be a gamut problem. Usually gamut problem is resolved by using either one of three types of clipping techniques.

The nonlinear IHS color space is said to be in cylindrical model with collapsed top, if the color point of the image after backward nonlinear transformation falls into the collapsed portion causes gamut problem. It can be by clipping method. But when the collapsed top of the nonlinear cylinder is repaired to a complete cylinder, it is possible to avoid the gamut problem without going for clipping method. To completely overcome the high spectral distortion in the resultant fused image, Improved Nonlinear Intensity-Hue-Saturation transform (iNIHS) is proposed with the Discrete Cosine Transform. Figure 4.2 shows the improved nonlinear Intensity- hue-saturation color model.

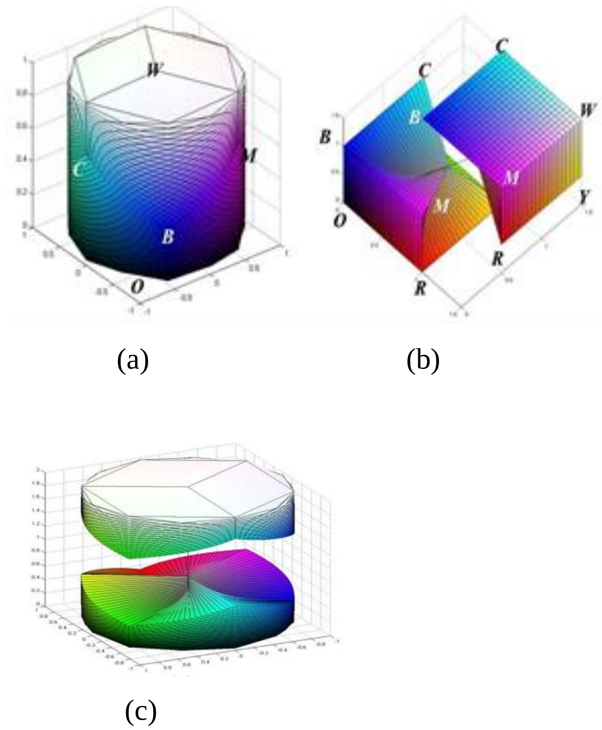

Fig. 2. (a) iNIHS color model. (b) iNIHS color model divided into two parts. (c) The upright portion of iNIHS color model.

The operation of the iNIHS is as follows:

1. iNIHS color space is divided into upper and lower portions such as H_{upper} and H_{lower} (H_{upper} is said to be a CMY color space, whereas H_{lower} is a RGB color space).

2. To decide pixel is in RGB color space or CMY color space, calculate intensity, Hue and Saturation value of each pixel by using the following equation.

$$I = \{R/3 + G/3 + B/3\} \quad (1)$$
$$H = R\text{-mean}(R+G+B) \times \text{std}(I) + \text{mean}(I) \quad (2)$$
$$S = RGB - H - I \quad (3)$$
$$H\text{normalised} = \max(IHS) \text{ or } \min(IHS) \quad (4)$$

The intensity, hue and saturation values of each in image one is added to the each pixel in image 2. Hence the resultant fused image is obtained.

B. Filtering

A filter is a process that is used to remove some unwanted component such as noise or feature from a signal. Different types of filter are used in image processing such as wiener filter, Gaussian filter, etc.

C. Enhancement

Enhancement is said to be a processing of image to bring out specific features of an image. Highlight certain characteristics of an image. The aim of image enhancement is to improve the information in images for human views, or to provide better input for image processing.

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D.Morphological process

Morphological image processing is a collection of non-linear operations related to the shape or morphology of features in an image. Morphological operations rely only on the relative ordering of pixel values, not on their numerical values, and therefore are especially suited to the processing of binary images.

E. Boundary and Region detection

Boundaries traces the exterior outline of the object as well as holes inside the object. Region computes all the shape measurement.

Region features are often projections of general high-contrast closed-boundary regions of appropriate size represented by their center of gravity and their recognition is invariant with respect to rotation, scaling, skewing.

F. Image segmentation

Image segmentation is the process of partitioning a digital image into multiple segments. The goal of segmentation is to simplify the representation of an image. Segmentation is typically used to locate objects and boundaries (lines, curves, etc.)

G.Discrete cosine transform

It is most of the spatial domain image fusion methods are complex and time consuming which are hard to be performed on real-time applications. Moreover, when the source images are coded in Joint Photographic Experts Group (JPEG) standard or when the fused image will be saved or transmitted in JPEG format, the fusion approaches which are applied in DCT domain will be very efficient. To perform the JPEG coding, an image (in color or grey scales) is first subdivided into blocks of 8x8 pixels. The Discrete Cosine Transform (DCT) is then performed on each block. This generates 64 coefficients which are then quantized to reduce their magnitude.

The coefficients are then reordered into a one-dimensional array in a zigzag manner before further entropy encoding. The compression is achieved in two stages: the first is during quantization and the second during the entropy coding process. JPEG decoding is the reverse process of coding.

We denote A and B as the output images of two cameras that have been compressed in JPEG coding standard in the sensor agent and further transmitted to fusion agent of VSN. In the case of using spatial domain method these images must be decoded and transferred to spatial domain. Then after applying fusion procedure, the fused image must be coded again in order to be stored or transmitted to an upper node.

In order to reduce the complication for the real-time applications and also enhance the quality of the output image, an image fusion technique in DCT domain. Here, the variance of 8×8 blocks calculated from DCT coefficients is used as a contrast criterion for the activity measure. Then, a consistency verification (CV) stage increases the quality of output image.

The discrete cosine transform (DCT) is one of the most widely used transform in image compression applications. Several commercial standards widely used such as JPEG still image coding standard, Motion-JPEG, MPEG are based on DCT. Using vector processing, the output matrix of a two-dimensional DCT for an input matrix is given by:

$$F = C.f.C^t \tag{5}$$

where C is an orthogonal matrix consisting of the cosine coefficients and C^t are the transpose coefficients

$$C^{-1} = C^t \tag{6}$$

The inverse DCT (IDCT) is also defined as:

$$f = C^t.F.C \tag{7}$$

The total spatial frequency (SF) of a block in the spatial domain is calculated as:

$$SF^2 = RF^2 + SF^2 \tag{8}$$

The row frequency (RF) and column frequency (CF) of an 8x8 image block are given by

$$RF^2 = \frac{1}{8\times 8}\sum_{x=0}^{7}\sum_{y=1}^{7}(f(x,y) - f(x,y-1))^2 \tag{9}$$

$$CF^2 = \frac{1}{8\times 8}\sum_{x=1}^{7}\sum_{y=0}^{7}(f(x,y) - f(x-1,y))^2 \tag{10}$$

DCT Encoding

The general equation for a 1D (N data items) DCT is defined by the following equation:

$$F(u) = \left(\frac{2}{N}\right)^{\frac{1}{2}} \sum_{i=0}^{N-1} \Lambda(i).cos\left[\frac{\pi.u}{2.N}(2i+1)\right] f(i) \tag{11}$$

And the corresponding inverse 1D DCT transform is simple as $F^{-1}(u)$.

The general equation for a 2D (N by M image) DCT is defined by the following equation:

$$F(u,v) = \left(\frac{2}{N}\right)^{\frac{1}{2}} \left(\frac{2}{M}\right)^{\frac{1}{2}} \sum_{i=0}^{N-1}\sum_{j=0}^{M-1} \Lambda(i).\Lambda(j).cos\left[\frac{\pi.u}{2.N}(2i+1)\right] cos\left[\frac{\pi.v}{2.M}(2j+1)\right].f(i,j) \tag{12}$$

and the corresponding inverse 2D DCT transform is simple as $F^{-1}(u,v)$.

III. EXPERIMENTAL RESULTS AND ANALYSIS

To verify the effectiveness and the validity of the proposed method, experimental results were conducted for the pairs of blurred images of same size and same scene which is focused either at the right side or left side of the scene captured. The resources used for simulation is a sets of non-referenced multi-focus images from the online resources [5]. The proposed method is compared with DCT and iNIHS individually and its performance is evaluated on the basis of PSNR, MSE, Entropy and correlation, etc.

(a)

(b)

(c) (d)

Fig. 3. Images used for simulations. (a) Source image focused at the left side. (b) Source image focused at the right side. (c) Another set of source image focused at the left side. (d) Another set of source image focused at the right side.

By carefully observing the fusion results, we can clearly see that the method DCT and Improved nonlinear Intensity-hue-saturation (iNIHS) suffers undesirable blurring effects and artifacts.

TABLE I. PERFORMANCE ANALYSIS OF IMAGE FUSION

Parameter	Types of Fusion Method		
	DCT	*iNIHS*	*DCT+iNIHS*
PSNR	22.9207	66.0318	66.1032
MSE	331.9037	0.0162	0.0165
Entropy	7.6234	0.8200	0.83362
Correlation	0.9409	0.8396	0.9612

The performance analysis of well-known images such as “Drinks” and “Leg” are shown in Table I. It is observed from the Table I, the performance of proposed method is superior and out performs the traditional image fusion approaches in terms of subjective and objective analysis in terms of above metrics.

IV. CONCLUSION

Experimental results show the proposed iNIHS and DCT based image fusion technique is superior to the existing techniques and avoids gamut problem, color distortion, preserves high spatial and spectral resolution. The quality of different information of different image synthesized and displayed in one picture is highly improved for human and visual perception.

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