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Image Fusion using Biorthogonal Wavelet Transform

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Abstract: *Image Fusion is a technique that integrates complementary information from multiple images such that the fused image is more suitable for processing tasks. This paper presents three image fusion techniques. Principal Component analysis is a well known scheme for feature extraction and dimension reduction and is used for image fusion. The discrete cosine transform (DCT) based methods of image fusion are more suitable and time saving in real time systems using DCT based standards of still image or video. The third method used is BWT. Wavelet coefficients at different decomposition levels are fused using absolute maximum fusion rule. Two important properties wavelet symmetry and linear phase are present in BWT. These are able to preserve edge information and hence reduce the distortion in the fused image.*
Keywords: *BWT, Aperture, fusion algorithms, multifocus.*

I. Introduction

The term fusion means in general is an approach to extraction of information acquired in several domain. The actual goal of image fusion is to integrate complementary multisensor, multitemporal or multiview information into a new image[1]. Image fusion is the procedure of merging two or more images into a single image. The quality of image so generated will be more informative and cannot be obtained otherwise. The best information from respective input images is taken and the improved version of the image is hence retrieved. Before images are fused they are to be registered[2]. Image registration is a process of transforming different sets of data into same co-ordinate system.

The next step after registration is image fusion which is categorized into spatial and transform domain methods to improve multiresolution image sharpening and spectral and spatial image content[3]. Spatial-domain methods enchance the spectral domain but suffer from spatial distortion in the fused image. Transform-domain methods show a performance in spatial and spectral quality.

Image fusion has been used in many application areas. In astronomy and in remote sensing, multisensory fusion is used to achieve high spatial resolutions by combining images from two sensors, one of which has high spatial resolution and the other one high spectral resolution. Also in medical imaging like simultaneous evaluation of CT, MRI and PET images[4]. Use of mutlisensor fusion of visible and infrared images have appeared in military, security and surveillance areas.


(a) (b)

(c)

Figure 1: (a) Input image I, **(b)** Input image II
(c) Fused Image

In the given figure 1, the first image is blurred from left side. The second image is blurred from right side. After using any fusion algorithm the resultant image is obtained and it has more information than the input images.

The images that are fused usually they consist of same scene but the only difference is that the information present in each image is different. These images may be named as multifocus and multiresolution images. The low depth-of-field is one of the optic systems fundamental limitations; it is often difficult to obtain good focus for all objects in the picture because certain objects at particular distance are focused while other objects are blurred to a degree depending on their distances from the camera[5]. This problem which is called multi focus is encountered in photography and of the microscopy. Image fusion is one of the approach that solve the problem of multi focus.

II. Depth of field

Depth of field refers to the region of proper focus that is available in any photographic image. When the camera is focused, it is not possible to get a paper-thin region of proper focus in an image, instead there's some distance in front and behind the subject that will also be in focus. This entire region of sharp focus is called the depth of field, or sometimes the depth of focus. The region that is out of depth of field will be blurry. There are three factors determining the depth of field[6]:

- **Aperture** which means the size of lens opening that determines how much light reaches camera's imaging sensor.
- **Focal length** is the second factor which means a measure of the len's ability to magnify a scene.
- **Subject distance** is the distance from the subject determines how much depth of field can be obtained in the scene.

Depth of field can be increased to make the entire image from foreground to background as sharp as possible.

III. Multifocus images

Multifocus image fusion is a process of combining information of two or more images of a scene and as a result has 'all-in-focus' image. When one scene contains objects in different distance, the camera can be focused on each object one after the other, creating set of pictures[7]. Then, using image fusion techniques, an image with better focus across all area can be generated.

Figure 2: Multifocused images

IV. Fusion Techniques

Many different and image fusion techniques have been developed in recent past. When using ihe image fusion techniques,some general requirements must be considered[8-9]:

- The fusion algorithm should not discard any information contained in the source images.
- The fusion algorithm should not introduce any artifacts or in consistencies that can distract or mislead a human observer or any subsequent image processing steps.
- The fusion algorithm must be reliable, robust and have, as much as possible, the capability to tolerate imperfections such as nosie or misregistrations.

Some commonly applied image fusion techniques are:

(i) Principal Component Analysis

Principal component analysis is a mathematical tool which transforms a number of correlated variables into a several uncorrelated variables[10]. PCA is widely used in image classification. The fusion using PCA is achieved by weighted sum of source images. The number of principal components is less than or equal to the number of original variables.

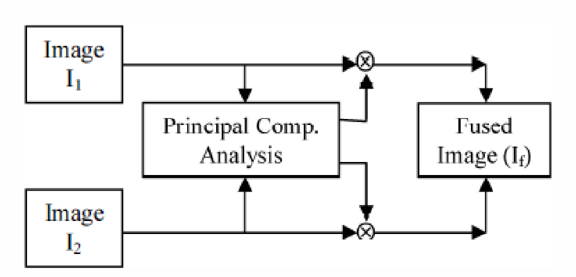
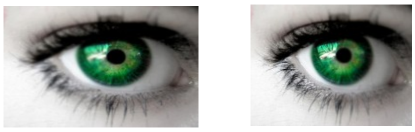
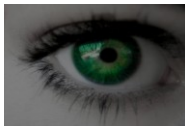


Figure 3: Image Fusion using PCA



(a) (b)



(c)

Figure4: (a) and **(b)** input images and **(c)** fused image using PCA

Image no.	API	SD	AG	Entropy
1	56.8233	30.3756	1.5591	6.5605
2	86.4317	39.8867	4.4170	4.5623
3	69.3018	30.2154	2.0101	5.8165
4	50.3765	35.8011	2.3351	5.5101
5	85.6530	33.5788	2.5011	5.331

Table1. Performance measure using PCA

(ii) Discrete Cosine Transform

A DCT is used tp put across a sequence of finite data points indicated by a sum of cosine functions alternating at different frequencies. Discrete cosine transform widely used in digital image processing.

Image no.	API	SD	AG	Entropy
1	110.4911	59.8812	4.5949	6.5015
2	170.3534	85.6512	15.658	5.3171
3	138.6555	64.3214	4.9121	6.5112
4	100.3911	72.6518	5.1824	6.6546
5	175.4911	65.2026	7.5621	7.0130

Table 2. Performance measure using DCT

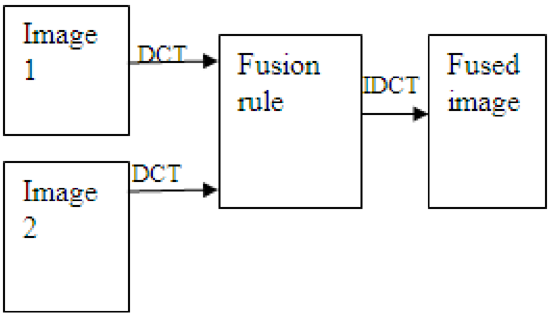


Figure 5: Image fusion using DCT

(a) (b)

(c)

Figure 6: (a) and **(b)** are input images **(c)** fused image using DCT

V. Biorthogonal wavelet transform

Biorthogonal Wavelets are families of compactly supported symmetric wavelets. These are different from orthogonal wavelets as these orthogonal wavelets doesnot provide the symmetry property and hence leda to edge distortion in the fused image[11]. The symmetry of the filter coefficients is often desirable since it results in linear phase of the transfer function. In the biorthogonal case,rather than having one scaling function,there are two scaling and wavelet function, there are two scaling functions that may generate different multiresolution analysis, and accordingly two different wavelet functions.

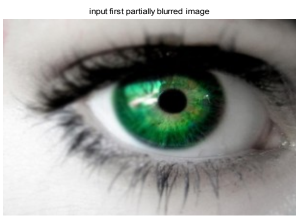
Firstly source images of same scene that can have different focusing and modality, are decomposed using biorthogonal wavelet transform. Secondly, coefficients obtained are merged using absolute maximum selection rule. Wavelet and scaling functions are used in BWT for decomposition of source images. The choice of proper wavelet for decomposition differ from application to application. No general selection criteria for wavelet and scaling function is existing[12]. Although vanishing moment and regularity or smoothness of wavelet can be considered to decide wavelet function. For image fusion application, selection of wavelet with adequate vanishing moment is preferred. The coefficients obtained by decomposition of source images are fused using absolute maximum fusion rule.

The dual scaling and wavelet functions have the following properties:

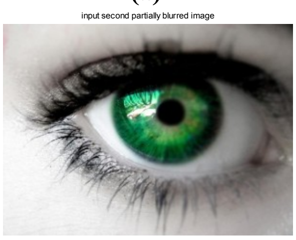
- They are zero outside of a segment.
- The calculation algorithms are maintained, and thus very simple.
- The associated filters are symmetrical.
- The functions used in the calculations are easier to build numerically.

Selection fusion rule used to combine wavelet coefficients is as given below

$$W(m,n)=\begin{cases} W_1(m,n), \text{if} |W_1(m,n)| \geq |W_2(m,n)| \\ W_2(m,n), \text{if} |W_2(m,n) \geq |W_1(m,n)| \end{cases}$$



(a)



(b)

(c)

Figure 7: (a) and **(b)** are input images and **(c)** fused image using BWT

Image no	API	SD	AG	Entropy
1	90.2314	40.2156	1.5478	3.4517
2	105.2369	34.3698	4.3698	2.5136
3	100.2364	34.3697	1.5987	3.0569
4	80.2146	45.1598	2.1456	4.0236
5	110.2784	30.2571	1.5698	1.5698

Table 3. Performance measure using BWT

VI. Conculsion

The image fusion is a method in which different images are combined together and a new improved image is generated. This new image is more informative and useful. The different techniques used for image fusion i.e. principal component analysis, discrete cosine transform and biorthogonal wavelet transform generate a new image. Out of these techniques the BWT is more efficient as it has linearity phase and symmetry property.

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