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A COMPREHENSIVE REVIEW ON DIFFERENT TECHNIQUES OF IMAGE FUSION

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Abstract: ***Image fusion is one of the current areas of research of image processing. Image fusion is the process of combining two or more images or some of their features into a single image retaining the features from each of the original images without the introduction of distortion or loss of information. The fusion of images is often required to integrate complementary multisensor, multitemporal and/or multiview information into one new better quality image. In this paper we will discuss the different levels and techniques of image fusion. This Paper will be helpful for the research in the field of image fusion.***

Keywords: Image fusion, Wavelet Transform, Spatial fusion methods, Transform fusion methods.

1. Introduction

Image fusion is the process in which a single fused image is generated that contains a more accurate description of the scene than multiple images from different sources .Many Fusion techniques have been developed that allow the integration of different information sources in order to create a new image that is more suitable for human visual or machine perception. The major objective here is to extract all the useful information from the source images in such a way that no inconsistencies or artifacts are introduced that distract the human observers. Assessment of the quality of the fused images is an important issue in image fusion. Major applications of image fusion include medical imaging, remote sensing, microscopic imaging, computer vision, and robotics.

2. Basic Levels of Image Fusion

Image fusion can be processed at three levels: Pixel-Level Fusion, Feature-Level Fusion and Decision-level Fusion. [5].

2.1 Pixel level image fusion

Image fusion at pixel-level is the fusion at the lowest processing level referring to the merging of the measured physical parameters and its application is very wide [4]. Pixel-level fusion is operated in the phase of image pre-processing. The purpose is to obtain a further clear image, which provides more information. Pixel-level fusion is divided into two parts, signal-level and image-point fusion. Signal-level_fusion refers to synthesize a group of signals obtained by sensors in order obtain high-quality signals, whose format is consistent with the original image. In the process of image-point fusion, image points of every image are directly synthesized.

2.2 Feature level image fusion

Feature-level fusion is the medium level fusion and prepared for decision-level fusion. Feature-level fusion is done in the course of image feature extraction. In this, features of every image are extracted and same kind of features of different images is organically synthesized. The typical features are edge, shape, profile, angle, texture, similar lighting area and similar depth of focus area. While fusing features, the forms and contents of main features are correlative with the applied Fusion, Feature-Level Fusion and Decision-level Fusion. [5].

2.3 Decision level image fusion

Decision-level fusion is the highest-level fusion. All decision and control are decided according to the results of decision-level fusion.

3. Methods of image fusion

In a broader sense image fusion is done into two methods:
3.1 Spatial Fusion

3.2 Transform Domain Fusion

3.1 Spatial fusion

Some the spatial image fusion methods are:

3.1.1 Average method

It is the simplest method of image fusion. In this, we take the average of the two images pixel by pixel. However, this method usually leads to undesirable side effect such as reduced contrast .More robust algorithm for pixel level fusion is the weighted average approach in which the fused pixel is estimated as the weighted average of the corresponding input pixels. However, the weight estimation usually requires a user-specific threshold.

$$I\,(x,\,y) = \frac{I1\,(x,) + I2\,(x,y)}{2}$$

Where I1 (x, y) & I2 (x, y) are the input images.

It is the simple technique and very easy to implement.

Averaging works well when images to be fused are from same type of sensor and contain additive noise. However, due to addition of some noise into the fused image, the resultant image quality is consequently reduced and leads to some undesirable effects such as reduced contrast.

3.1.2 Intensity-hue-saturation (ihs) method

It is most popular fusion methods used in remote sensing. The fusion is based on the RGB-IHS conversion model. In this method, the principle is based on the fact that the IHS color space is catered to cognitive system of human beings and that the transformation owns the ability to separate the spectral information of an RGB composition in its two components H and S, while isolating most of the spatial information in the I component. . In this method three MS bands R, G and B of low resolution Image are first transformed into the IHS color coordinates, and then the histogram - matched high spatial resolution image substitutes the intensity image which describes the total color brightness and exhibits as the dominant component a strong similarity to the image with higher spatial resolution. Finally, an inverse transformation from IHS space back to the original RGB space yields the fused RGB image, with spatial details of the high resolution image incorporated into it. This method provides a better visual effect and high spatial quality for the fused image. Limitation of this method is that it produces a significant color distortion with respect to the original image.

3.1.3 Principle component analysis

It uses statistical mean method and transforms a number of correlated variables into a small number of uncorrelated linear combinations of variables called principal components. The main advantage of this method is that an arbitrary number of bands can be used (Wang, Ziou and Armenaki, 2005). This technique is easy to understand and implement. The major advantage of this method is that it prevents certain features from dominating the image because of their large digital numbers. However, the disadvantage is that it suffers from spatial degradation.

3.1.4 Brovey transform

It is a simle method based on the chromaticity transform and on the concept of intensity modulation. It merges data from different sensors, which can preserve the relative spectral contributions of each pixel but replace its overall brightness with the high spatial resolution image [6]. It provides superior visual and high resolution multispectral image. This method is very useful for visual interpretation and provides high spatial quality of fused images.

3.2 Transform domain fusion

The multi resolution techniques involve two kinds, one is pyramid transform; another is wavelet transform.

3.2.1 Pyramid method

In this method the input images are first transformed into their multi resolution pyramid representations. The fusion process then creates a new fused pyramid from the input image pyramids in a certain fusion rule. The fused image is finally reconstructed by performing an inverse multi resolution transform .Some major advantages of pyramid transform: a) it can provide information on the sharp contrast changes to which human visual system is especially sensitive. It can provide both spatial and frequency domain localization. However, because the pyramid method fails to introduce any spatial orientation selectivity in the decomposition process, this method often causes blocking effects in the fusion results.

3.1.5 Wavelet based method

The transformation of a signal is just another form of representing the signal. It does not change the information content present in the signal. The Wavelet Transform provides a time-frequency representation of the signal. A wavelet is a small wave with finite energy, with its energy concentrated in time or space area to give ability for the analysis of time-varying phenomenon. In wavelet analysis, the signal to be analyzed is multiplied with a wavelet function and then the transform is computed for each segment generated. In this, the width of the wavelet function changes with each spectral component. The Wavelet Transform gives good time resolution and poor frequency resolution at high frequencies whereas it gives good frequency resolution and poor time resolution at low frequencies. This method usually uses the discrete wavelet transform (DWT) for fusion

4. Discrete Wavelet Transformation

The Discrete Wavelet Transform (DWT) is found to yield a fast computation of Wavelet Transform. It is easy to implement and reduces the computation time and resources required. Wavelet transform decomposes a signal into a set of basis functions, called as wavelets. Wavelets are obtained from a single prototype wavelet called mother wavelet by dilations and shifting. Discrete wavelet transforms a discrete time signal into a discrete wavelet representation. . In the case of DWT, there is a time-scale representation of the digital signal which is obtained using digital filtering techniques. The signal to be analyzed here is passed through filters with different cutoff frequencies at different scales. Since the DWT of image signals produces a non redundant image representation, it can provide better spatial and spectral localization of image information as compared to other multi resolution representations. The research results reveal that DWT schemes have some advantages over pyramid schemes such as increased directional information, no blocking artifacts that often occur in pyramid fused images; better signal-to-noise ratios. Therefore, the wavelet-based method has been popular widely used for image fusion. [3].

4.1 RDWT

The redundant discrete wavelet transform (RDWT) is specific redundant frame expansion which is essentially an undecimated version of the discrete wavelet transform (DWT).With redundancy, greater functionality often becomes possible. For instance, redundant transforms provide greater robustness to added noise and quantization as well as increased numerical stability. in the RDWT domain, we can determine exactly the variance (i.e.,expected distortion energy per sample) in the original signal domain of noise added in the RDWT domain. In addition, the redundancy can produce shift invariance, which can facilitate, among other tasks, feature detection and motion estimation.

4.2 Wavelet families

There are various basis functions that can be used as the mother wavelet for Wavelet Transformation. Since the mother wavelet produces all wavelet functions used in the transformation through translation and scaling, it determines the characteristics of the resulting Wavelet Transform. Therefore, the details of the particular application are taken into account while selecting the appropriate mother wavelet in order to obtain the Wavelet Transform effectively.

4.2.1Haar wavelet

The Haar wavelet is the simplest orthogonal wavelet. In mathematical terms, the Haar wavelet is described as a certain sequence of rescaled "square-shaped" functions which together form a wavelet family or basis. The disadvantage of the Haar wavelet is that it is not differentiable as it is not continuous. But this property can be an advantage for the analysis of signals with sudden transitions, such as monitoring of tool failure in machines.

4.2.2 Fast haar wavelet

Fast haar wavelet involves the process of addition, subtraction and division by 2 in order to reduce the calculation work and make the process faster in comparison to haar transform. In this process we first apply FHT to each row of pixel values of the input image matrix in order to decompose the image. After that , we apply FHT to each column in a similar manner. The resultant values are all detail coefficients of the transformed image.

4.2.3 Modified fast haar wavelet transform

In MFHWT, first average sub signal (a' =a1,a2, a3… an/2), at one level for a signal of length N i.e. f =(f1, f2,f3,f4…fn) is

$$a_m = \frac{f_{4m-3} + f_{4m-2} + f_{4m-1} + f_{4m}}{4}, \quad m = 1, 2, 3, \ldots, N/4,$$

[17]

and first detail sub-signal(d'= d1,d2,d3….dn), is given as(at the same level):

$$d_m = \begin{cases} \dfrac{(f_{4m-3} + f_{4m-2}) - (f_{4m-1} + f_{4m})}{4}, & m = 1, 2, 3, \ldots, N/4, \\ 0 & , \quad m = N/2, \ldots, N. \end{cases}$$

[17]

In this four nodes are considered two nodes as in HT and FHT. The MFHWT is faster in comparison to FHT and reduces the calculation work. In MFHWT, we get the values of approximation and detail coefficients one level ahead than the FHT and HT .

4.2.4Symlet wavelet

Symlets are "symmetrical wavelets". The Symlets were proposed as modifications to the db family. Properties of the two wavelet families are similar with the difference that whereas the Daubechies wavelets have maximal phase, the Symlets have minimal phase. The Symlets are designed so that they have the least asymmetry and maximum number of vanishing moments for a given compact support. There are 7 different Symlets functions from sym2 to sym8.

4.2.5 Daubechies wavelets

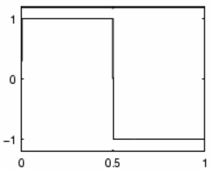
The Daubechies wavelets are a family of orthogonal wavelets defining a discrete wavelet transform and characterized by a maximal number of vanishing moments for some given support. In this , for the wavelet function with P vanishing moments, the minimum filter size is 2p. With each wavelet type of this class, there is a scaling function (called the *father wavelet*) which generates an orthogonal multiresolution analysis.

4.2.6 Coifman wavelet

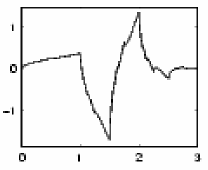
Coiflets are discrete wavelets having scaling functions with vanishing moments. Their wavelet functions have N/3 vanishing moments and scaling functions have N/3-1 vanishing moments. One of the relevant characteristics of Coifman wavelets is that the scaling function (t) is symmetric and vanishes fast as't'goes to infinity.

4.2.7 Biorthogonal wavelet

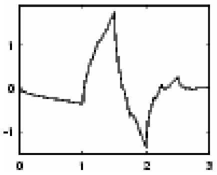
Biorthogonal wavelets provide a pair of scaling functions and associated scaling filters ,one for analysis and one for synthesis. Similarly, there is also a pair of wavelets and associated wavelet filters one for analysis and one for synthesis. This family of wavelets exhibits the property of linear phase, which is needed for signal and image reconstruction. There are different numbers of vanishing moments and regularity properties for the analysis and synthesis wavelets. In this ,we can use the wavelet with the greater number of vanishing moments for analysis while the smoother wavelet for reconstruction. Therefore, here we can use two wavelets, one for decomposition (on the left side) and the other for reconstruction (on the right side) instead of the same single one.



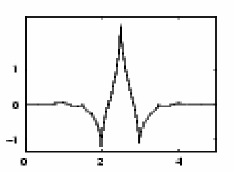
(a)



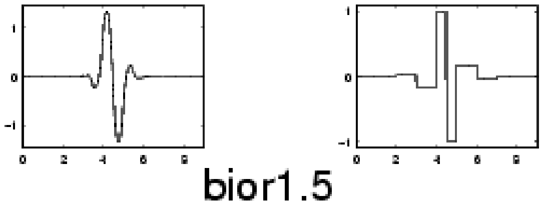
(b)



(c)



(d)



(e)

Figure1: Wavelet families (a)Haar (b)Symlet2 (c) Daubechies4 (d) Coiflet1 (e) bior1.5. [2, 7]

Figure1 describes some of the commonly used wavelet functions. We can select one or hybrid of wavelets depending upon the application.

5. Conclusion and future work

Image fusion therefore is used for combining two or more images or some of their features into a single image retaining the features from each of the original images without the introduction of distortion or loss of information. In this paper, we have discussed the different techniques for image fusion which covers the spatial and frequency transform. We have also described here the wavelet based fusion of images. In future, the different wavelet based techniques can be merged to form a hybrid fusion technique and the results can be compared.

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