REVIEW ON IMAGE FUSION ALGORITHMS

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Abstract: Image fusion is a technique that extracts relevant information from two or more source images into single scene. It serve best in wide spectrum of applications i.e. medical diagnosis (Magnetic resonance image (MRI), Computed tomography (CT)), remote sensing, computer vision, robotics, microscopic imaging and to improve Enhanced Fight Vision System (EFVS), so it has been receiving attention of researchers. Image fusion is a new technique which can preserve important information and reduce amount of data for the purpose of human/ machine perception. This paper has been present literature review on various fusion techniques like principal component analysis, Wavelet transform and Laplacian pyramid and comparison of these techniques helps in selecting techniques in future research work.

Keywords: Image Fusion, Image fusion techniques, Wavelet transform.

1. Introduction

An image is an artifact that records two dimensional pictures as well as three dimensional pictures that is usually a physical object such as photograph and statue respectively. They may be captured by any of the optical device and natural phenomenon.

In computer vision, multisensory image fusion is technique to extract relevant information from two or more source images into single image. The resulting image contains great quality feature often means highest spatial or higher spectral resolution as well as more reliable and accurate informative as compared to any of the source image. Mainly image fusion requires better understanding of input data to gain the independent results. The aim of image fusion is to reduce amount of data, retains desirable characteristics and create a new image for the purpose of human/ machine perception. Some generic requirement could be imposed on the image fusion scheme [2]: (a)The image fusion process should preserve all important information contained in the source image. (b)The image fusion process should not introduce any artifacts or inconsistencies which would effects the human observer or following processing stages.(c) Irrelevant features and noise should be suppressed as much as possible.

Generally, Image fusion methods can be classified into three categories depending on the stage at which fusion takes place. It is often divided into three levels, namely: pixel level, feature level and decision level of representation. Pixel fusion is the lowest –level fusion, which analyzes and integrates the information before the original information is estimated and recognized. Feature fusion is done in the middle level, which analyzes and deals with the feature information such as edge, contour, direction obtained by pretreatment and feature extraction. Decision fusion is the highest –level fusion, which points to the actual target. Before fusion, the data should be procured to gain the independent decision result, so the information lose cannot be avoided and at the same time the cost is high [3]-[4]. The objectives of this study are to explain the different image fusion algorithm/techniques for a wide spectrum of application.

Image fusion is necessary techniques in some cases where it is not possible to obtain an image that contain all important objects in focus due to limited focus depth of optical lenses in CCD devices. Consequently, resultant image will not be in focus everywhere. Image fusion process is required to achieve all objects in focus so that all focused objects are selected. In recent years, image fusion has been widely used in many fields and more suitable technique for computer processing application such as feature extraction, object recognition and segmentation as well as for human visual perception. It serve best in medical diagnosis (Magnetic resonance image (MRI), Computed tomography (CT)), remote sensing, computer vision, robotics, microscopic imaging.

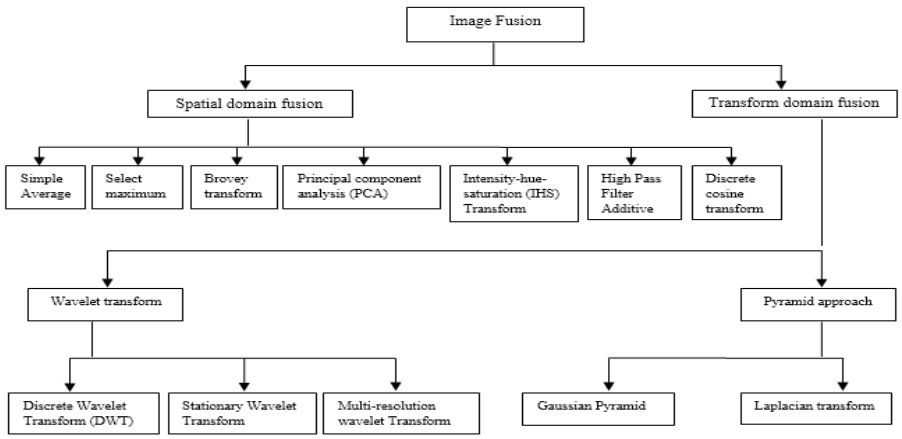

Fig.1 Image fusion techniques

2. Detailed Review of Image Fusion Techniques/Algorithms

Image fusion methods can be broadly classified into two groups-spatial domain fusion and transform domain fusion. In order to achieve optimum fusion result, various fusion techniques had been tested by many researchers. In this review, a few algorithms/ techniques have been discussed:

2.1. Spatial Domain Fusion

In spatial domain fusion, one directly manipulate pixel image to produce desirable result. The fusion method such as averaging, select maximum, brovey transform(BT) method, principal component analysis (PCA) and intensity –hue-saturation (IHS) transform, High pass filter approach, Discrete cosine transform (DCT) based methods discussed below fall under spatial domain approaches. Another important spatial domain method is high pass filtering based techniques .The disadvantage of spatial domain fusion is that it produce spatial distortion in a fused image, i.e. becomes a negative factor while one go for further processing.

2.1.1. Simple Average method: It is a pixel- based method that suppressing any noise in the source image. It is well documented fact in which one takes the pixel by pixel average of the source images. It is one of the simplest image fusion method the major side effect of average is that it reduce contrast. The average is one of simplest method for suppressing any noise in the source image with major side effect of average is that it reduced contrast. Mathematically can be written as:

$$P(i,j) = [X(i,j)Y(i,j)\ ]/2 \quad \text{(I)}$$

Where$X(i,j)$ and $Y(i,j)$ are two source images.

2.1.2. Select Maximum method: This algorithm takes the greatest value of each pixel such as $\mathrm{P(i,j)}$from source images and compare to each others. The greatest pixel value is then assigned to the corresponding pixel of new image. It is one of the straight forward and fastest algorithms but also alter the spectral information of the source image.

$$\mathrm{P(i,j)} = \sum_{i=0}^{l}\sum_{j=0}^{m} \max.\mathrm{X(i,j)Y(i,j)} \quad \text{(II)}$$

2.1.3. Brovey Transform (BT): Brovey transform also known as color normalization transform, is based on the red-green-blue (RGB) color transformation and concept of intensity modulation. Its purpose is to normalize the three multispectral bands for RGB display. The basic procedure of the brovey transform, where the data value of each band of low spatial and high spectral resolution multispectral (MS) band are divided by the sum of the MS bands and combined by the high spatial and low spectral resolution panchromatic (PAN) data set. The resultant image has both high spatial and spectral resolution that is require in many remote sensing application. Thus it is the simplest method that it increases the contrast in the low and high end of the image histogram for combining data from different sensors, with the limitation that only three bands are involved.

2.1.4. Principal Component Analysis (PCA): PCA based image fusion also called as Karhunen – Loeve transform or the Hostelling transform, improve spatial resolution of the image. It is a subspace model in which the principal component is applied to the multispectral bands. The PAN is histogram matched to first PC1.It is then replace the selected component with PAN imagery and the inverse PCA transform takes the fused datasets back into the original multispectral feature space. The first principal component is taken to be along the direction with the maximum variance. The second principal component is constrained to lie in the subspace perpendicular of the first principal component and so on [5]. PCA has major advantage that an arbitrary number of bands can be used with disadvantage that it is sensitive to the area to be sharpen and produce fusion results that may vary depending on the selected image.

The PCA is widely used in image compression, image classification and feature extraction [6]. In PCA based image fusion is taken to obtain the palm print used in access control and forensic applications. Multiple features were extracted from this palm print containing enhanced information. Mohamed R. Metwali [5] employed integrate HPF and PCA technique that extract high frequency component from PAN image to provide fused image with superior spatial resolution and minimum spectral distortion and evaluated that spatial quality of its is higher than HPF fusion method and comparable to the PCA and Gram –Scmidt fusion method.

2.1.5. Intensity-hue-saturation (IHS) Transform: It is most popular fusion technique used in commercial image processing systems and based on the RGB color space. It preserve more spatial feature and more required functional information with no color distortion. It is become a standard procedure in image analysis for color enhancement, feature enhancement; improvement of spatial resolution and the fusion of disparate data sets [4].In this technique the following step are performed:

(a) Perform image registration (IR) to low resolution MS to high resolution PAN and resampled to same resolution as the PAN image and transform three resample band of the MS from RGB space into IHS components.

(b) The PAN histogram is matched to the histogram of the 'I' component and replace the I component with histogram matched PAN image.

(c) Compute the IHS to RGB transforms to obtain the RGB of new fused MS.

Firouz Abdullah et al [4] employ IHS transformation based image fusion to explore different IHS transformation formulas and show comparison in term of various indices. This paper reported that analytical technique of deviation index (DI) is more useful for measuring the spectral distortion than Root mean square error (RMSE).

2.2. Transform Domain Fusion

In transform image fusion, spatial domain components are transferred into frequency domain using Fourier transformation because spatial distortion can be well handled by frequency domain approaches on image fusion. The fusion methods such as wavelet transform, Laplacian pyramid based methods discussed below fall under this approaches. The methods show a high performance in spatial and spectral quality of the fused image and have been achieving attention of researcher in wide spectrum of application.

2.2.1. Wavelet Transform**:** Wavelet theory is essentially extension of the Fourier theory, thus it provides good resolution in both time and frequency. Wavelet transform is a powerful mathematical tool that has been extensively used in image processing. It is a famous technique in analyzing signals. When decomposition is performed, the approximation and detail component can be separated 2-D Discrete Wavelet Transformation (DWT) converts the image from the spatial domain to frequency domain [1]. Wavelet can be combined with portion of known signal using dilation, contractions (scaling), translational (shifts) or integration techniques called convolution to extract information from an unknown signal. Wavelet transform can broadly classify into discrete, stationary and multi – resolution based.

Discrete Wavelet Transform has a wide number of application in image processing (such as in image segmentation, Image fusion), biomedical etc. The step involved in fusion of image using DWT as shown in are given below:

(a) Considered the wavelet transform "w" and the "n" registered source image$\mathrm{I_i}(x, y)$; i=1, 2…….n.
(b) Decompose each source image with four parts those are$\mathrm{I_{LH}}(\mathrm{x}, \mathrm{y})$,$\mathrm{I_{HL}}(\mathrm{x}, \mathrm{y})$,$\mathrm{I_{HH}}(\mathrm{x}, \mathrm{y})$and $\mathrm{I_{LL}}(\mathrm{x}, \mathrm{y})$which contain directional horizontal, vertical and diagonal) information of the source images$\mathrm{I_i}(\mathrm{x}. \mathrm{y})$.
(c) The final step that performs inverse wavelet transforms w^{-1} to reconstruct the fused image.

Stationary Wavelet Transform is a translation –invariant that is similar to the DWT but removing the down sampler and up sampler as on DWT.A few application of SWT are Pattern recognition, de-noising etc.SWT is applied to the source image to get edge image information and fused to achieve complete edge information using spatial frequency measurement that is compared with a simple fusion method.

Multi-resolution wavelet Transform is alternative approach to the short time Fourier transforms to overcome the resolution problem. It is well suited to manage image at different frequencies with different resolution that means good time resolution and poor frequency resolution at higher frequencies and vice versa.

Gang Li et al [8] employed improved image fusion algorithm based on wavelet transform in EEVS to enhance the real-time of wavelet transform image fusion algorithm by using matrix Doolittle decomposition and showed that the algorithm can get better fusion effect while ensuring a better real-time. Richa Gupta et al [9] presented wave packet image fusion that will provide better result using Discrete Wave Packet decomposition (DWPT) and optimize result using genetic algorithm (GA) which act as a optimizing problem solver and compared the result with Intensity hue saturation method. Kusum Rani et al [10] presented Image fusion using discrete wavelet and multi wavelet. In this paper we study about discrete wavelet and Discrete Multi wavelet and there use in image fusion. Discrete wavelet transform (DWT) technique is used for multi Resolution fusion. Multi wavelet analysis can provide a more absolute image analysis than wavelet multi resolution analysis. In this paper DWT and DMWT are qualitatively compared with each other.

2.2.2. Image Pyramid approach: Pyramid is a filter based representation to decompose image to information into different scales to extract feature/structure of interest. Typically, in an image pyramid each layer is a factor two smaller as its lower layer except for the base which is the original image. In Gaussian Pyramid original image is convoluted with a Gaussian level as resulting image is low pass version of original image. The laplacian pyramid decomposition is similar to the Gaussian pyramid but uses Laplacian transform instead of a Gaussian. The Laplacian is computed as the difference between original image and low pass filter image.

This process shown in fig. 2 is continued to obtain a set of band pass filtered images as described below:

(a) A Gaussian pyramid on original image I(x,y) is defined as

$$G_0(x,y) = I(x,y) \quad \text{(III)}$$

$$G_{i+1}(x,y) = \text{REDUCE}(G_i(x,y)) \quad \text{(IV)}$$

$$G_{i+1}(x,y) = \sum_{l=-2}^{+2} \sum_{m=-2}^{+2} w(l,m)\, G_i(2x+l, 2y+m) \quad \text{(V)}$$

Where $G_0, G_1, \ldots\ldots\ldots\ldots\ldots G_i$ are the levels of the Gaussian pyramid as G_0 is the bottom of the pyramid and w ( ) is the weighting function.

The reduce operation is carried out by convolving the image with Gaussian low pass filter. The filter mask is designed such that the central pixel gets more weight than the neighborhood ones.

(b) Predict level G_i from level G_{i+1} by expanding G_{i+1} to G_i'.

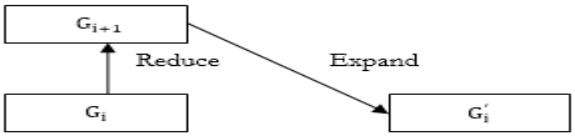

Fig. 2 Process of Laplacian Pyramid

Thus the prediction error is denoted as:

$L_1 = G_i - G_i'$, whereL_0,L_1,……L_i are the levels of the Laplacian pyramid.

(c) Reconstruct the original image from the Laplacian pyramid.

$$G_i = L_i + G_i' \quad \text{(VI)}$$

Pyramid approach eliminates blocking artifact of image at low frequencies with simple reconstruction and coding of source image and also extract feature of interest of images.

Wencheng Wang [3] employed image fusion based on Laplacian Pyramid. This paper show that Laplacian pyramid show better performance also good quality fused image both visually and quantitatively in term of standard deviation (SD) as compared it with other fusion approaches. Akanksha Sahu et al [7] introduced DCT employed Laplicain pyramid as fusion rule. Fused image provide sharp edge and high information content than Daubechies complex wavelet transform.

3. Conclusion

In this paper various image fusion techniques has been discussed like DWT, PCA, Average method, select maximum, select minimum etc. and it found that Simple average is the simplest method but does not give guarantee to have a clear objects from the set of images. Pixel level methods are affected by blurring effect which directly effect on the contrast of the image. PCA is a spatial domain based that may produce spectral degradation. The DWT fusion method may outperform fusion method in terms of minimizing the spectral distortion and provide better signal to noise ratio than pixel based approach. In this method final fused image have a less spatial resolution. Laplacian pyramid based on Laplacian transform shows better performance also good quality fused image both visually and quantitatively. Discrete wavelet transformation leads to some problems like shift variant and not properly preserve the edges of the object in the image. Combine DWT, PCA Transform Multi level fusion where the image undergoes fusion twice using efficient fusion technique provide improved result. This method is complex and required good fusion technique for better result. So there is a need to use the algorithm to overcome these problem and smoothens the image after fusion.

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