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Fusion Algorithms for Images Based on Principal Component Analysis and Discrete Wavelet Transform

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Abstract

Extensive research has been done in the field of image fusion. Image fusion is formation of appropriate information from two or more images into a single fused image. As a consequence the final resultant image will carry more information as compared to the input images. Thus purpose of image fusion algorithm is to take redundant and complementary information from the source images and to generate an output image with better visual quality. This paper presents a review on some of the image fusion techniques like Principal component analysis (PCA) based fusion, Discrete wavelet transforms (DWT) and Curvelet transforms.
Keywords: Image Fusion, Principal Component Analysis (PCA), Discrete Wavelet Transform (DWT)

I. INTRODUCTION

Image fusion generates a single image by integrating information from a set of many source images using Pixel level, Feature level or Decision level techniques. The fused image consists of larger information content for the scene than any one of the individual image sources alone. Due to insertion of analogous and interrelating information, the accuracy and overall detail of the image is increased, due to. Images should be registered first before they are fused. The main intention of employing fusion is to produce a resultant fused image that provides the most detailed and valid information.

Image Fusion has lot of advantages on remote sensing, medicine, computer vision, multi focused fusion and identification that it has overcome the blind spot in many fields of science and technical difficulties. Mostly in computer vision, image fusion technology has achieved better accuracy in identification of objects.

II. IMAGE FUSION TECHNIQUES AND ALGORITHMS

Image fusion method can be broadly classified into two groups -

- Spatial domain fusion method
- Transform domain fusion

In spatial domain techniques, image pixels are taken into consideration. Various operations are performing on pixel values to achieve desired result. In frequency domain methods the image is shifted in to frequency domain which indicates that the Fourier Transform of the image is computed first. All the Fusion operations are performed on the Fourier transform of the image and then the Inverse Fourier transform is performed to get the resultant image. Spatial distortion is generated in resultant image which becomes the main disadvantage of spatial domain approaches.

Spectral distortion becomes a negative factor while we go for further processing such as classification problem. Spatial distortion can be very well handled by frequency domain approaches on image fusion. For analyzing remote sensing images, the multi resolution analysis has become a very helpful tool. The discrete wavelet transform has become a very useful tool for fusion. Some other fusion methods are also there such as Laplacian- pyramid based, Curve let transform based etc. These methods show a higher quality performance in spatial and spectral quality of the fused image compared to other spatial methods of fusion.

Different methods have been developed to perform image fusion are listed below -

1) Principal component analysis (PCA) based fusion
2) Intensity-hue-saturation (IHS) transform based fusion
3) Multi scale transform based fusion:-
   a) High-pass filtering method
   b) Pyramid method:-
      - Laplacian pyramid
      - Gaussian pyramid

- Gradient pyramid
- Morphological pyramid
- Ratio of low pass pyramid

c) Wavelet transforms:-
- Discrete wavelet transforms (DWT)
- Stationary wavelet transforms
- Multi-wavelet transforms

d) Curvelet transforms.

A. Principal Component Analysis (PCA):

Principal Component Analysis (PCA) is especially used in image compression and image classification techniques. Principal Component Analysis (PCA) is a vector space transform often used to reduce multidimensional data sets to lower dimensions for analysis in other words PCA transform the number of correlated variables into uncorrelated variables called principal components. The most important advantage of PCA is, when its data size is compressed as well as if dimensions are altered then there is no much loss of information at the output image.

The fusion is accomplished by weighted average of images to be fused. Eigen vector related to the largest Eigen value of the covariance matrices of each source are used to obtain weights for each source image. It computes a compress and best description of the data set. The PCA basis vectors like FFT, DCT and wavelet are changing rapidly and its basis vectors depend on the data set.

The direction of the maximum variance is used to compute the first principal component. The second principal component is forced to be situated in the subspace vertical (perpendicular) of the first. Inside this subspace, this component points the direction of maximum variance. The third principal component is in the maximum variance direction in the Subspace vertical to the first two and so on. PCA is also known as Hotelling Transform or Karhunen-Loeve transforms.

The information flow diagram of PCA-based image fusion algorithm is shown below. The input images (images to be fused) I_1 (x, y) and I_2 (x, y) are arranged in two column vectors and their empirical means are subtracted. The resulting vector has a dimension of n x 2, where n is length of the each image vector. Compute the eigenvector and eigenvalues for this resulting vector are computed and the eigenvectors corresponding to the larger eigenvalue obtained. The normalized components P1 and P2 (i.e., P1 + P2 = 1) are computed from the obtained eigenvector.

The fused image is: $\mathbf{I_f (x, y) = P_1 I_1 (x, y) + P_2 I_2 (x, y)}$

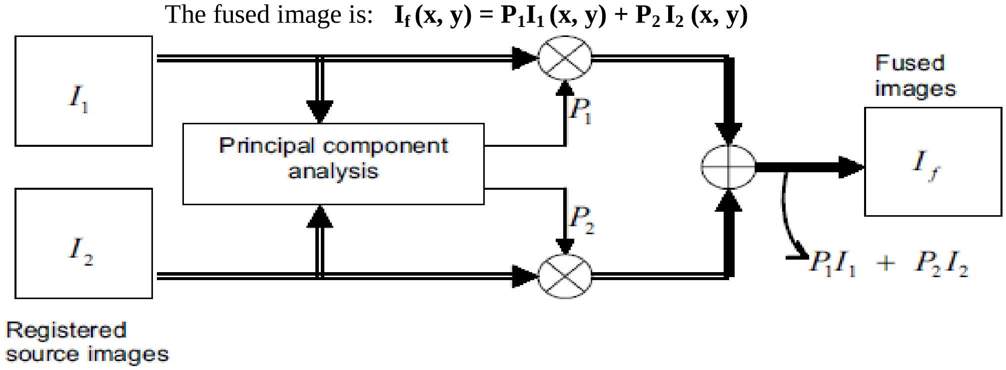

Fig. 1: Image Fusion by PCA

B. Discrete Wavelet Transform (DWT):

Wavelet theory is an extension of Fourier theory in many aspects and it is introduced as an alternative to the short-time Fourier transform (STFT). In Fourier theory, the signal is decomposed into sines and cosines but in wavelets the signal is projected on a set of wavelet functions. Fourier transforms gives good resolution in frequency domain whereas wavelet provides good resolution in both time and frequency domains. It has been extensively used in image processing that provides a multi-resolution decomposition of an image in a orthogonal basis and results in a non-redundant image representation. Wavelets are called basis and these are functions generated by translation and dilation of mother wavelet [4].

In Fourier analysis the signal is divided into sine waves of different frequencies. In wavelet analysis the signal is divided into scaled (dilated or expanded) and shifted (translated) versions of the chosen mother wavelet or function. A wavelet as name itself implies is a small wave that grows and decays essentially in a limited time period.

The main idea of discrete wavelet transform (DWT) in image process is to multi differentiate decompose the image into sub-image of different spatial domain and independent frequency district .After that transform the coefficient of sub-image and when the original image has been DWT transformed, it is decomposed into four different frequency bands, one corresponding to the low pass band (LL), and three other corresponding to horizontal (HL), vertical (LH), and diagonal (HH) high pass bands.

- 1, 2, 3 - Decomposition levels
- H - High frequency bands
- L - Low frequency bands

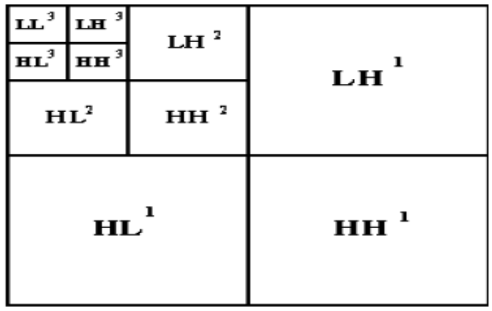

Fig. 2: Wavelet decomposition

Wavelet separately filters and down samples the 2-D data (image) in the vertical and horizontal directions (separable filter bank). The input (source) image is I (x, y) filtered by low pass filter L and high pass filter H in horizontal direction and then down sampled by a factor of two (keeping the alternative sample) to create the coefficient matrices $I_L(x, y)$ and $I_H(x, y)$.

The coefficient matrices $I_L(x, y)$ and $I_H(x, y)$ are both low pass and high pass filtered in vertical direction and down sampled by a factor of two to create sub bands (sub images) $I_{LL}(x, y)$, $I_{LH}(x, y)$, $I_{HL}(x, y)$, $I_{HH}(x, y)$.

The $I_{LL}(x, y)$ contains the average image information corresponding to low frequency band of multi scale decomposition which is considered as smoothed and sub sampled version of the source image I (x, y). It represents the approximation of source image ,I(x, y) , $I_{LH}(x, y)$, $I_{HL}(x, y)$ and $I_{HH}(x, y)$, are detailed sub images which contain directional (horizontal, vertical and diagonal) information of the source image I (x, y) , due to spatial orientation. From the previous decomposition, multi-resolution can be achieved by recursively applying the same algorithm to low pass coefficients [4].

C. Notations:

↓C – Keep 1 column out of 2 (down samplings in columns)
↓R - Keep 1 row out of 2 (down samplings in rows)
X – Convolve with x, where x indicates block name

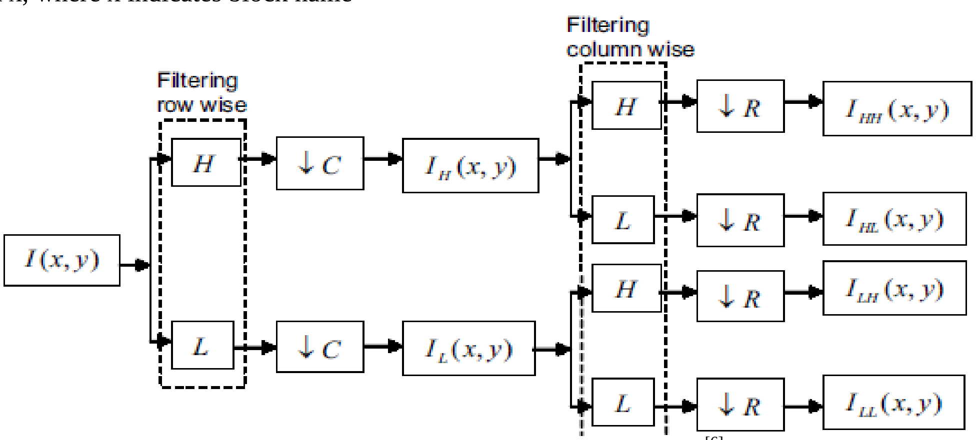

Fig. 3: Image Fusion using Wavelet transform [6]

III. Conclusion

Principal Component Analysis (PCA) considered as most widely used method for dimensionality reduction and feature extraction. The discrete wavelet transform has become a very important tool for fusion. The application of the Wavelet transform in image fusion would result in better fusion results than that obtained using Principal Component Analysis (PCA).

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