

Implementation of Image Fusion Algorithms For Clinical Diagnosis

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Abstract

Image Fusion is a process of combining common features of a set of images to get a output image with superior content in terms of subjective as well as objective analysis point of view. Main aim of this work is to present a review on some of the image fusion Techniques. A Comparison of all techniques are done fusing MRI and CT images and analysis is conducted using various quality measures such as entropy, MSE, PSNR, SSIM, and BRISQUE . CT modalities provide information on denser tissues whereas MRI provides information on soft tissues. For medical applications CT and MRI images are fused for diagnostic purposes.

Keywords: Image Fusion, Medical diagnosis, DWT, PCA, IHS, performance evaluation

Introduction

Image Fusion objective is to combine information of no: of images and the resultant image one which is more informative and of better quality.

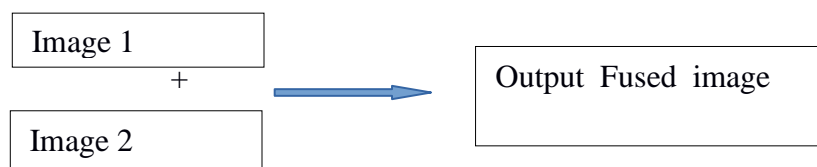


Figure 1: Image Fusion Process

The Fused image is then more suitable for human /machine perception and for further image processing tasks such as segmentation, feature extraction and object recognition[1]

Medical image fusion Techniques has been used to derive useful information from multimodality medical image data. The idea behind this is to improve the image content by fusing images like computer tomography (CT) and magnetic resonance imaging (MRI) images, so as to provide more information to the doctor and clinical treatment planning system[2].

The main principles of image fusion are theredundancy, the complementary, the time-limit and low cost[3].

A. Image fusion types:

1. Multimodal Images: Multimodal fusion is applied to images from different modalities such as the visible and infrared CT,NMR. The main aim is to decrease the amount of data.
2. Multifocus Images: When using digital cameras all subjects at a distance are not sharply focussed.To solve this iamge fusion is done by acquiring series of of images with different focus setting and then fuse them into a single image.
3. Multiview Images: Here a set of iamge are taken by same sensor but at different view points and then fused to get a single image.
4. Multitemporal images: In this iamges are taken at different times inorder to detect changes between images and fuse them to a single image.

B. Image Fusion Classification:

Image fusion can be performed at different levels: signal, pixel, feature and symbol levels. Almost all image fusion algorithms developed to date fall into pixel level.

Pixel level fusion gives a output image in which information content associated with each pixel is determined from a set of pixels in source images. Fusion at this level can be performed either in spatial or in frequency domain. However, pixel level fusion may conduct to contrast reduction.[1]

Feature level fusion requires the extraction of imporatant features which are depending on their environment such as pixel intensities, edges or textures. These similar features from the input images are fused. This fusion level can be used as a means of getting additional composite features. The fused image can also be used for classification or detection.[4]

Decision level is a higher level of fusion. Input images are processed individually for information extraction. The got information is then combined by applying certain decision rules to reinforce common interpretation.[5]

Image Fusion types are broadly classified into 2 groups

1) Spatial Domain:

Spatial domain fusion method is performed directly on the source images. Weighted average is the simplest spatial domain method, which needn't any transformation or decomposition on the original images. The merit of this method is simple and fit for real-time processing, but simple addition will reduce the signal-to-noise of the result image.[6]

2) Transform Domain:

Image is first transformed to frequency domain. In frequency domain methods, the input images are decomposed into multiscale coefficients initially. Various fusion rules are used in the selection or manipulation of these coefficients and synthesized via inverse transforms to form the fused image. This type method can avoid blocking effects. However, many of these approaches, such as discrete wavelet transform(DWT) , wavelet packet transform(WPT) and Curvelet transform are shift-variant.[6]

Implementation of Different Fusion Algorithms

In this work different image fusions such as simple averaging, PCA, IHS, wavelet transform, curvelet transform is implemented .

(a) simple averaging

Image Fusion by Simple Averaging is a basic and straight forward technique and fusion could be achieved by simple averaging corresponding pixels in each input image. The value of pixel $p(i,j)$ of each image is taken and added . This sum is divided by 2 to get the average . This will be repeated for all pixels.

$K(i,j) = (X(i,j) + Y(i,j)) /2$ where $X(i,j)$ and $Y(i,j)$ represents the 2 input images.[7]

(b)IHS method:

This method is mainly used for sharpening. In IHS technique the color iamge is conerted to IHS space. In the IHS space spatial information is mostly reflected in hue and stauration. The intensity component of IHS is replaced by high resolution components and then again transformed to RGB. This proves to have better visual effects but also carries distortion.

(c)PCA

Principal component analysis (PCA) is a statistical technique which transforms a number of correlated variables into a number of uncorrelated variables. It computes a compact and optimal description of the data set. 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 .he third principal component is taken in the maximum variance direction in the subspace perpendicular to the first two and so on. The PCA does not have a fixed set of basis vectors like FFT, DCT and wavelet etc. Its basis vectors depend on the data set. 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 $n \times 2$, where n is length of the each image vector. The eigenvector and eigenvalues for this resulting vector are computed and the eigenvectors corresponding to the larger eigenvalue achieved. he normalized components P_1 and P_2 (i.e., $P_1 + P_2 = 1$) are computed from the obtained eigenvector The fusion is achieved by weighted average of images to be fused. The weights for each source image are obtained from the eigen

vector corresponding to the largest eigenvalue of the covariance matrices of each source.[8]

(d) Wavelet transform:

This is common form of transform fusion. The basic idea is to perform decomposition on each input image and getting the low and high frequency components. The level of decomposition is chosen accordingly. At each level 2 sets of coefficients are got. First perform the DWT in the vertical direction, followed by the DWT in the horizontal direction. After the first level of decomposition, there are 4 sub-bands: LL1, LH1, HL1, and HH1. For each successive level of decomposition, the LL sub band of the previous level is used as the input. The approximation and detailed coefficients of both images are combined using fusion rules. The fusion rule used here is simply averages the approximate coefficients and picks detailed coefficients in each subband with the highest magnitude.

(e) Curvelet Transform

Medical images have several objects and curved structures. One good way to enhance spatial resolution is to enhance the edges. It is expected that the curvelet transform would be better in their fusion. Curvelet-based image fusion method provides richer information in the spatial and spectral domains simultaneously.

The curvelet transform is based on the segmentation of the whole image into small overlapping tiles and thereon each tile is subjected to ridgelet transform. The idea of segmentation is to approximate curved lines by straight lines. As with the wavelet transform, the curvelet transform is a multi-resolution transform with frame elements indexed by scale and location parameters. Unlike the wavelet transform, however, the curvelet transform has directional parameters, and the curvelet pyramid contains elements with a high degree of directional specificity. In addition, the curvelet transform is based on a special anisotropic scaling principle that is quite different from the isotropic scaling of wavelets. The elements obey a special scaling law, in which the length of the support of frame elements and the width of the support are linked by the relation $\text{width} = \text{length}^2$. In order to achieve a higher level of efficiency, curvelet transform is usually implemented in the frequency domain. This means that a 2D FFT is applied to the image. For each scale and orientation, a product of U_j, l "wedge" is obtained; the result is then wrapped around the origin, and 2D IFFT is then applied resulting in discrete curvelet coefficients [9].

$$\text{Curvelet transform} = \text{IFFT} \{ \text{FFT} (\text{Curvelet}) \times \text{FFT_Image} \}$$

Results and Discussion

Metric Analysis

Metric analysis includes both reference analysis and non reference analysis. Under reference analysis MSE, PSNR, SSIM were calculated and under non reference analysis Entropy and BRISQUE was evaluated.

Table 1: Parameter Estimation For Different Fusion Methods

		IMAGE SET 1				
		Simple averaging	PCA	IHS	Wavelet transform	Curvelet Transform
ENTROPY		7.4	7.50	7.09	7.28	7.72
MSE	IMAGE1	0.04	0.02	98.50	0.24	0.03
	IMAGE2	0.060	0.04	176.7	0.09	0.12
PSNR	IMAGE 1	13.87	16.68	10.17	18.41	62.22
	IMAGE2	12.17	13.74	6.12	10.62	57.22
SSIM	IMAGE1	0.38	0.38	0.52	0.356	0.262
	IMAGE2	0.18	0.16	0.27	0.109	0.105
BRISQUE		117.5	100.5	114.1	112.01	104.33

		IMAGE SET 2				
		Simple averaging	PCA	IHS	Wavelet transform	Curvelet Transform
ENTROPY		7.19	7.50	7.56	7.6	7.31
MSE	IMAGE1	0.02	0.44	98.06	0.02	0.05
	IMAGE2	0.03	0.05	244.1	0.14	0.20
PSNR	IMAGE1	15.59	13.49	7.19	16.39	60.63
	IMAGE2	14.68	12.48	4.86	8.47	55.01
SSIM	IMAGE1	0.362	0.389	0.47	0.40	0.26
	IMAGE2	0.169	0.18	0.03	0.13	0.113
BRISQUE		101.9	117.26	113.4	113.21	122.65

		IMAGE SET 3				
		Simple averaging	PCA	IHS	Wavelet transform	Curvelet Transform
ENTROPY		7.43	7.50	7.44	7.50	7.53
MSE	IMAGE1	0.04	0.03	254.7	0.04	0.07
	IMAGE2	0.04	0.04	250.5	0.07	0.11
PSNR	IMAGE1	13.8	14.03	6.834	13.6	59.48
	IMAGE2	13.6	13.5	5.57	11.07	57.54
SSIM	IMAGE1	0.29	0.30	0.007	0.30	0.21
	IMAGE2	0.37	0.37	0.005	0.29	0.25
BRISQUE		107.2	107.87	114.6	100.59	123.80

		IMAGE SET 4				
		Simple averaging	PCA	IHS	Wavelet transform	Curvelet Transform
ENTROPY		7.65	7.5	7.4	7.5	7.16
MSE	IMAGE1	0.03	0.03	147.9	0.44	0.02
	IMAGE2	0.04	0.04	252.8	0.20	0.17
PSNR	IMAGE1	14.23	14.3	6.97	18.6	63.37
	IMAGE2	13.24	13.2	3.52	8.94	55.64
SSIM	IMAGE1	0.48	0.48	0.28	0.47	0.39
	IMAGE2	0.23	0.23	0.04	0.75	0.14
BRISQUE		100.8	100.4	112.0	106.17	114.47

Visual Analysis

For visual evaluation following criterion was considered such as appearance, brightness, contrast and enhancement.




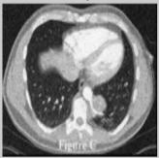



IMAGE SET 1	Input image 1	Input image 2
		
Simple avg. fusion		
PCA fusion		
IHS fusion		
Wavelet fusion		
Curvelet fusion		

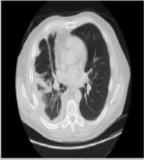
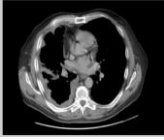

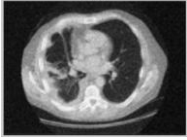
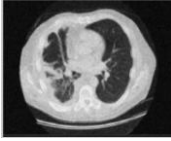

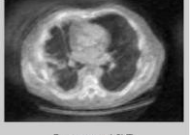
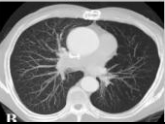
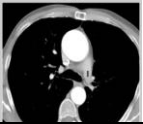
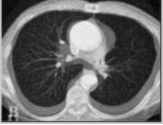

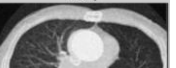
IMAGE SET 2	Input image 1	Input image 2
		
Simple avg. fusion		
PCA fusion		
IHS fusion		
Wavelet fusion		
Curvelet fusion		

IMAGE SET 3	Input image 1	Input image 2
		
Simple avg. fusion		
PCA fusion		
		



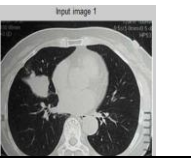
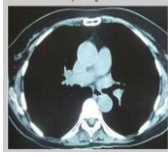
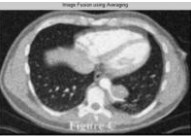




Wavelet fusion	
Curvelet fusion	

IMAGE SET 4	Input image 1	Input image 2
		
Simple avg. fusion		
PCA fusion		
IHS fusion		
Wavelet fusion		
Curvelet fusion		

Conclusions

The simulation results show the superiority of the curvelet transform to the wavelet transform in the fusion of CT and MR images from both the visual quality and the quantitative analysis points of view.

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