Medicinal Image Fusion Using Stationary Wavelet Transform and Fuzzy Logic

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Abstract— The fusion of images is the process of merging two or more images into a single image preserving significant features from each. Fusion is an important techniques within many different fields such as remote sensing, robotics and medical application. The information extraction process of image. A cost spends on such processing like time and assets is high, mostly for large and complex amount of information. The proposed fusion techniques are based on two process for Stationary Wavelet Transform (SWT) and Fuzzy logic. Stationary Wavelet Transform provide higher level of decomposition for fused image. SWT based image fusion algorithm produce better quality of fused images. Image local features are extracted and combined with fuzzy logic to compute weights for each pixel. Fuzzy logic allows the problems to be solved in linguistic terms at the cost of execution time and number of possible results.

Key words: Image Fusion, Stationary wavelet transform, Pixel level, Fuzzy logic

I. INTRODUCTION

Image fusion methods provide different image’s of the same scene can be combined into a single fused image. It’s to reduce uncertainty and minimize redundancy& maximizing relevance in information in particular application (or) task. Image fusion need for better quality and functionality has lead to seek for new algorithms of enhancement which overcome the technology restrictions. Among such algorithms, image fusion is wide variety of fields such as aerial photos, Medical image, Remote Sensing image, Weapon detection, Weather fore casting and biometric images etc.

Image fusion can reduce the storage memory and accelerate loading processes. By using redundant data, image fusion[1] may improve accuracy and reliability, and by using complementary image fusion may improve interpretability. Objective of image fusion should fulfill several requirements: (1) it should not discard any salient feature, (2) it should not introduce any artifact in detrimental to image interpretability and (3) it should provide robust output against external disruptions as noise or misregistrations.

Image Fusion is a mechanism to develop the quality of information from a set of images. Significant applications of the fusion of images contain medical imaging, tiny imaging, remote sensing, computer vision, and robotics .Use of the Simple ancient method will not recover good fused image in terms of performance parameter like peak signal to noise ratio (PSNR), and Root Mean square error (RMSE).

Fusion techniques: Fusion imagery is usually categorized in three levels of abstraction.
(1). Pixel level
(2). Feature level
(3). Decision level

A. Pixel level:

image fusion the performance of pixel-level image fusion systems Subjective tests that employ samples of the representative are a reliable and straightforward method for performance evaluation. However, this approach is expensive in terms of time, effort, and utility requirement(3). The concept is expanded with the involvement of machine’s (or) Human Visual System modeling within the metric formulation process. Extensive experimentation is conducted for performance measures. A number of such image fusion measures are therefore developed and their characteristics are examined for accurately predicting fusion system performance as compared to that obtained from subjective tests. Extensive experimentation allows for the detailed analysis, optimization, and understanding of the comparative behavior of these image fusion performance measures (6). To overcome the as these have limited directionality. To overcome the drawback of guided filter and related multiresolution representations, transformations live other curve lets and contour lets.

B. Feature level

fusion image fusions require the extraction of different features from the source data before features are merger together. (6)This fusion which operates with attributes such as size, Shape, edge or texture, which involves the use of pattern recognition approaches.

C. Decision level:

Decision level image fusions involves sensor fusion, these fusion combines the clarification of the source images generated after image understanding. The last level of abstraction is called decision level and its deal with symbolic representations of images once each sensor has made a preliminary determination of an entities location, attributes, and identity(6). A wide variety of mathematics tools that perform image fusion has been proposed. This includes gray-value variance, averaging-PCA, neural networks, Bayesian modeling, non-linear filtering, Markov modeling and last but not minimum amount, multi scale or multiresolution (MR)transforms.

Image fusion method can be generally classified into two groups –
(1). Spatial domain fusion
(2). Transform domain fusion

In spatial domain techniques, we strictly deal with the image pixels. The pixel values are manipulate to achieve desired result. In frequency domain methods the image is first transferred into frequency domain. That the Fourier Transform of the image is computed first. All the Fusion operations are perform on the Fourier transform of the image and then the Inverse Fourier transform is performed to get the resultant image. Image Fusion applied in every
field where images are ought to be analyzed. Multimodal image muster is a difficult task, due to the most important intensity variations between the images.

A common approach is to use different similarity measures, such as common information, that are robust to those intensity variations. However, these correspondence measures are computationally exclusive and, also, often fail to capture the geometry and the associated dynamics linked with the image.(7) It’s a medical imaging, fused image’s are obtain by combining information from multiple modalities such as Magnetic Resonance Image(MRI), Computer tomography(CT), Positron Emission Tomography in order to improve diagnosis.

II. PROPOSED IMAGE FUSION METHOD
The proposed image fusion algorithm adopts the multimodal analysis with Stationary wavelet transform and Fuzzy logic for two input source image. In this, first process get the two source images such as CT image, MRI images. The second process is to translate source image into low frequency and high frequency in different levels with SWT. The method SWT is performing at each pixel level. the third process can be find the fuzzy membership value for every pixel point. Next process defuzzification. In this process, the multiresolution image archived by fuzzy logic. The final stage is to do Inverse Stationary Wavelet Transform, and the Fusion result is obtained.

A. Stationary wavelet transform
The Discrete Wavelet Transform is not a time invariant transform. The way to re-establish the translation invariance is to average some slightly different DWT, called SWT, to define the stationary wavelet transform (SWT)(8). It does so by suppressing the down-sampling step of the decimated algorithm and instead up-sampling the filters by inserting zeros between the filter coefficients. As with the SWT algorithm, the filters are applied first to the rows and then to the columns. In this case, the four images are produced (one approximation and three detail images) at half the resolution of the original; they are the same size as the original image(10). The approximation images from the SWT algorithm are therefore represented as levels in a parallel piped, with the spatial resolution becoming coarser at each higher level and the size remaining the same. It decomposes a image into low frequency and high frequency in different levels, and it can also be reconstruct at these levels. When images are merged in this method different frequencies are processed differently.

Fig 1: Pixel Based Image Fusion Using Fuzzy Logic
The fusion algorithm is performed at the pixel level. Stationary Wavelet Transform (SWT) is similar to Discrete Wavelet Transform (DWT) but the only process of down-sampling is suppressed that means the SWT is translation-invariant. SWT decomposition scheme and 2D Stationary Wavelet Transform (SWT) is based on the idea of no decimation. It applies the Stationary Wavelet Transform (SWT) and omits both down-sampling in the forward and up-sampling in the contrary transform. More accurately, it applies the transform at each point of the image and saves the detail coefficients and uses the low frequency information at each level. (ISWT) Wavelet based image fusion process the steps generally involved are registering source images, performing Stationary wavelet transform on each input images, generating a fusion decision map based on a defined fusion rule and constructing fused wavelet coefficient map from the wavelet coefficients of the input images according to the Fusion decision map. Finally, transform back (ISWT) to the spatial domain. Stationary Wavelet Transform performs a multilevel 2-D Stationary Wavelet Transform analysis using either a specific orthogonal wavelet or specific orthogonal wavelet decomposition filters. Stationary wavelet decomposition results in estimate and detail coefficients. They are named as; A (contains the coefficient of approximation), H, V and D (contain the coefficient of Horizontal, Vertical and Diagonal details).

Let I1 and I2 be the source images to be used. The given input images are transformed to SWT domain and the activity level measures entropy and energy of the low frequency coefficients are computed.

B. Algorithm for Proposed System
1) Decompose the two source images using SWT at one level resulting in three details sub bands and one approximation sub band (HL, LH, HH and LL bands).
2) Then take the average of approximate parts of images.
3) Take the absolute values of horizontal details of the image and subtract the second part of image from first. D = (abs (H1L2)-abs (H2L2))>=0
4) For fused horizontal part compose element wise multiplication of D and horizontal detail of first image and then subtract another horizontal detail of second image multiplied by logical not of D from first.
5) Find D for vertical and diagonal parts and obtain the fused vertical and details of image.
6) Same process is frequent for fusion at first level.
7) fix on number and type of membership functions for both the input images by tuning the membership functions.
8) Make rules for input images, which resolve the two antecedent to a single number from 0 to 1
9) submit an application fuzzification using the rules developed above on the parallel pixel values of the input images which gives a fuzzy set represent by a membership function and results in output image in column format.
10) Convert the column form into matrix type to get the fused image fI.
11) Fused image is obtained by taking inverse stationary wavelet transform. The same as the number of membership function increases fine details are taken into consideration.

C. Fuzzy Logic
Fuzzy logic derives from the fact that most modes of human reasoning and especially common sense reasoning are estimated in nature. It allows computerized devices to reason more like humans. The fuzzy inference process can put together the mapping from the inputs to the output using the membership functions, fuzzy logic operation and fuzzy control rules (1)(12). Fuzzy set is a class of object grade of membership function. Fuzzy set are represent spatial information in images along with its imprecision. Membership function that represent a graphical method. Membership of each input in the input space. Input spaces refer universe discourse (or) set universal. MF is assigned to each object a grade of membership ranging between (0,1). Fuzzy logic operations are performed in Boolean operation (AND,OR,NOT)(14). Fuzzy control rules are used to IF-then rules. Fuzzy inference process used two main method, Mamdani and Sugeno methods. Mamdani fuzzy inference system requires the output membership functions are fuzzy sets and this requires defuzzification. The sugeno inference system use the output Membership functions that are either constant or linear and this avoids the need for Defuzzification.

Fuzzy process involves 3 main steps:

1. **Fuzzification**: The procedure that converts crisp numerical input values into linguistic variables is referred to as Fuzzification.

2. **Rules**: if-then rules
   Rule : (IF H1 is Low and E1 is low and H2 is high and E2 is High THEN W1 is Low)

3. **Defuzzification**: This process of producing a crisp output from the fuzzy response, the Defuzzifier is the aggregate output fuzzy set that covers a set of output values (15).

III. PERFORMANCE EVALUATION METRICS

A. **Entropy (H)**
Entropy E is a scalar value in place of the entropy of grey scale image. Entropy is a numerical measure of randomness that can be used to explain the quality of the input image. Entropy is defined as:

\[ E = \sum (p \log_2(p)) \]

Where, \( p \) contains the histogram count arrival from the Matlab function ‘imhist’. Image with high entropy value is taken as good quality image.

B. **Root Mean Square Error (RMSE)**
The root mean square error (RMSE) procedures the amount of change per pixel due to the processing. The RMSE between a mention image and the fused image is given by:

\[ RMSE = \sqrt{\frac{1}{mn} \sum_{i=1}^{m} \sum_{j=1}^{n} (I(i,j) - \hat{I}(i,j))^2} \]

Where \( I(i,j) \) and \( \hat{I}(i,j) \) are the grey value of fused image and reference image respectively at index \( (i,j) \). For better quality images, the root mean square error must be less.

C. **Peak Signal to Noise Ratio (PSNR)**
Peak signal to noise ratio (PSNR) rate will be high when the fused and the ground truth images are equivalent. Higher rate implies better fusion. PSNR can be measured as:

\[ PSNR = 20 \log_{10} \left( \frac{L^2}{\text{RMSE}} \right) \]

Where, \( \text{RMSE} \) is the root means square error and \( L \) is the number of grey levels in the image.

D. **Standard Deviation (SD)**
Standard deviation reflect discrete case of the image grey intensity qualified to the average. The standard deviation represent the difference of an image. If the standard deviation is large, then the image grey scale is more scattered and contrast is more sharp. Standard Deviation is given by:

\[ SD = \sqrt{\frac{1}{mn} \sum_{i=1}^{m} \sum_{j=1}^{n} (I(i,j) - m)^2} \]

Where \( m \) is the mean pixel values of the fused image.

IV. EXPERIMENTAL RESULT
Image fusion algorithms are (SWT and Fuzzy Logic) described in section II are implement on Matlab and tested on a set of images using various fusion quality evaluation metrics (explained in section III). For testing of , Medical images have been taken as two Input (source) images, which are to be fused image dimension ( \( I1 \) and \( I2 \) ) 256x256 are obtained by vague impression the true image as shown in Fig.4.
Medicinal Image Fusion Using Stationary Wavelet Transform and Fuzzy Logic
(IJSRD/Vol. 3/Issue 03/2015/384)

In Fig 4.1.3 CT Image As An Input We Perform Horizontal, Vertical And Diagonal Operations.

Compressed CT Image Using SWT

In Fig 4.1.4 MRI Image As An Input We Perform Horizontal, Vertical And Diagonal Operations.

Compressed MRI Image Using SWT

Expected Result

In Fig 4.1.5 represents, QY denotes the Structural Similarity of image for fusion assessment, QC denotes covariance matrix, it refer universal image quality index, QG denotes gradient based index. It evaluates the success of edge information transformed from source images to the fused image.

V. CONCLUSION

Image fusion algorithms base on SWT and fuzzy logic were developed and confirmed. It was observed that fusion using SWT with higher levels of decomposition provides better results. Fuzzy image fusion with more number of membership functions provides better results. A novel image fusion algorithm had been developed by combining the features of SWT and fuzzy logic. pixel level image fusion methods like traditional Stationary wavelet transform and fuzzy logic to fuse them so that fused image will be more informative than the individual image for medical purpose. Results of Stationary Wavelet Transform are superior than the wavelet transform method in terms of PSNR, RMSE, Entropy, Standard Deviation and image quality.

REFERENCE


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