Pixel & Feature Level Multi-Resolution Image Fusion based on Fuzzy Logic

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Abstract: - The motivation behind fusing multi-resolution images is to create a single image with improved interpretability. In algorithm (based on pixel and feature level) presented in this paper, images are first segmented into regions with fuzzy clustering and are then fed into a fusion system, based on fuzzy if-then rules. Fuzzy clustering offers more flexibility over strict clustering; thus allowing more robustness as compared to other segmentation techniques (e.g. K-means clustering algorithm). A recently proposed subjective image fusion performance/quality evaluation measure known as IQI (Image Quality Index) [1] is used to measure the quality of the fused image. Results and conclusion outlined in this paper would help explain how well the proposed algorithm performs.

Key-Words: - Image Fusion, Discrete Wavelet Frame Transform (DWFT), Fuzzy logic, Fuzzy C-mean Clustering, Discrete Wavelet Transform (DWT).

1 Introduction

In the past few years multi-sensor systems utilize sensor and data fusion to get the improved and enhanced version of the acquired data. Modern sensor technology requires the need of processing techniques that uses two or more imaging techniques to provide information in a given diagnostic or research situation. Image fusion, a popular research area in image processing, is a process by which several registered images or some of their features are combined together in such a way that there is no loss of information and introduction of distortion[2]. Fused image produced is thus more suitable and enhanced for human / machine perception. Composite image improves image content and make it easier for detection, recognition and identification of targets and thus increase situational understanding.

It has a number of applications in remote sensing, camera applications, medical imaging, concealed weapon detection and night-time security etc.

Image Fusion is generally performed at three different levels of information representation; these are pixel level, feature level and decision level[2]. Fusing images at pixel level means to perform integration at a level where the pixels are least processed. Each pixel in the fused image is calculated from pixels in input/source images. Fusion at feature level first requires extraction of features from the source images (through e.g. segmentation) first; fusion thus takes place based on features that match some selection criteria. At symbol level/decision level the output from initial object detection and classification from the source image are put as input to fusion algorithm. Every image fusion algorithm is performed at one of these three levels or at the combination of these levels. Our algorithm focuses on a framework which combines the aspects of both pixel and feature level image fusion.

Looking in the literature, we find image fusion techniques which vary from simple pixel averaging to complex methods involving principal component analysis (PCA) [4], pyramid based image fusion [3] and wavelet transform (WT) fusion [5]. Lately methods involving wavelet based fusion have gained much popularity because wavelet transform provides directional information while the pyramid representation doesn't introduce any spatial orientation in the decomposition processes. Liu et al[7] proposed a method in which authors take discrete wavelet frame transform (DWFT) of images because of its shift invariant property which lacks in DWT (discrete wavelet transform). Images are then clustered / segmented into regions using K-Means

Clustering Algorithm and are fed into the fuzzy fusion system.

In this paper we introduce an image fusion algorithm based on fuzzy logic. We perform the segmentation of images with fuzzy c-mean clustering algorithm instead of k-means clustering algorithm because fuzzy clustering not only preserves but also emphasizes the grey level presented.

The subsequent sections of this paper are organized as follows. Section 2 gives a brief review of the related theory, Section 3 explains the proposed scheme of image fusion, then a summary of Image Quality Index, an objective image fusion quality evaluation measure is given followed by experimental results, conclusion, acknowledgements and references.

2 Ingredients of our Scheme.

The key constituents of our scheme are discrete wavelet frame and fuzzy c-mean clustering. Below we have discussed some of the prospects regarding these techniques.

2.1 Why DWFT?

The lack of translation invariance together with rotation invariance is the key drawback of DWT in feature extraction. Due to shift variance the fusion methods using DWT lead to unstable and flickering results. This can be overcome with DWFT by calculating and retaining wavelet coefficients at every possible translation of convolution filters or in other words the redundant transforms. More detail can be found in MATLAB wavelet toolbox, where it is called Discrete Stationary Transform (SWT).

2.2 Fuzzy C-Mean Clustering

Fuzzy c-means is a technique for clustering which allows one data item to belong to more than one cluster, whereas in hard (K-mean) clustering an entity belongs to one and only one cluster. For more information on K-means clustering you may visit http://mathworld.wolfram.com/KmeansClusteringAlgorithm.html.

In fuzzy c-mean clustering algorithm random membership values and cluster centers are assigned. The iterative process continues to calculate the new membership values and cluster centers according to the distance b/w entities and centers. This process comes to stop when a maximum number of iteration is reached or an objective function reaches a required threshold value [6].

3 Image Fusion based on Fuzzy Logic

It is important to know for the readers that the set of images used in this algorithm are registered images. With registration we find correspondence between images. It is necessary because only after it is ensured that spatial correspondence (information from different sensors can be guaranteed to come from identical points on inspected object) is established, fusion makes sense. More detail on image registration can be found in [8], [9].

3.1 Algorithm

1. Apply DWFT on two registered source images giving detail sub bands and approximation sub band.

2. Fuzzy c-mean clustering algorithm is used to segment the approximations into three regions, important region, sub-important region and background region, named on the basis of grey levels. Each pixel will have a degree of membership for the regions it belongs ranging between 0-1.

3. Segmented/clustered approximations are fed into a fusion system based on Fuzzy if-then rules to get fused approximations. The membership functions, rules and defuzzification function details can be found in[7] (feature level fusion).

4. The details are fused by absolute maximum coefficient selection method (pixel level fusion).

5. Apply morphological filtering Zheng et.al. [4], which use “fill” and “clean” operators to sweep isolated points.

6. With fused approximations and details get fused wavelet frame coefficients map. Take Inverse Discrete Wavelet Frame Transform (IDWFT) and get fused image.

3.2 Flowchart

The general framework of the proposed algorithm can be shown with the help of a flowchart. Step # refers to the steps of the algorithm mentioned above.

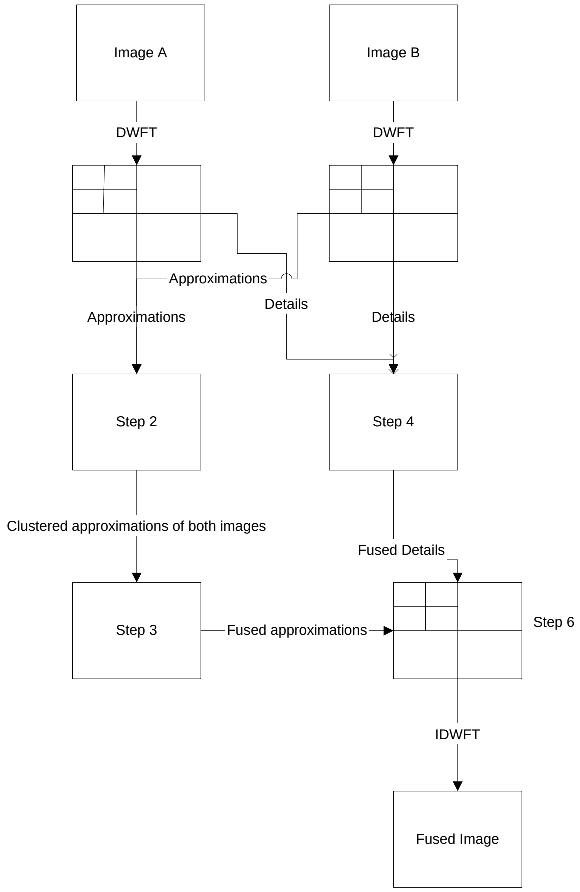

Figure -1 Flowchart of Proposed Algorithm

4 Results & Discussions

Image Quality Index proposed by Piella et al [1] has been used as a subjective image fusion quality evaluation measure because it is easy to calculate and is often used for many image processing applications. The expression of global image quality index is:-

$$Q_o(A,B) = \left(\frac{\delta_{AB}}{\delta_A \delta_B}\right)\left(\frac{2\overline{AB}}{(\overline{A}^2+\overline{B}^2)}\right)\left(\frac{2\delta_A\delta_B}{\delta_A^{\,2}+\delta_B^{\,2}}\right) \qquad (1)$$

where δ_A is variance of A, δ_{AB} is covariance of A and B and $\overline{A}$ is the mean of A. The value of $Q_o \in [0, 1]$, $Q_o = 1$ means A and B are completely identical.

We then compute λ, a local weight giving more importance to one of the two images. The more the value of λ the more weight is being given to that particular image. To compute the value of λ we have:-

$$\lambda = SF(A)/[SF(A)+SF(B)] \qquad (2)$$

In (2), SF is spatial frequency of image and it measures the overall activity level of the image [10].

The quality measure of fused image is thus given by:-

$$Q_F = \lambda Q_o(A,F) + (1-\lambda)Q_o(B,F) \qquad (3)$$

The set of images used for this fusion is large belonging to four major categories naming medical imaging, multi-focus/camera images, night time security and remote sensing. Fusion of images taken from each category is shown in the figures below. All are registered images with 256 grey levels.

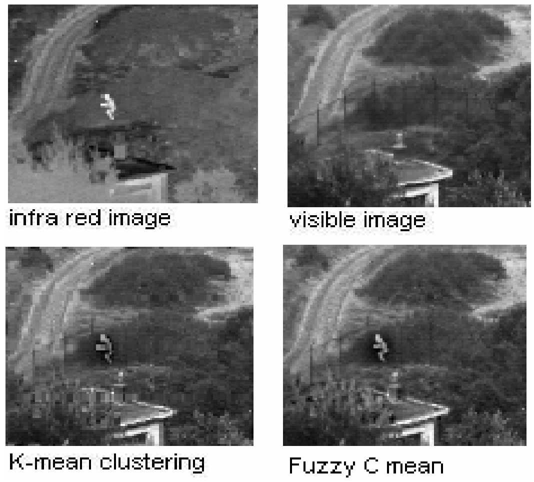

Figure -2 Night Time Security.

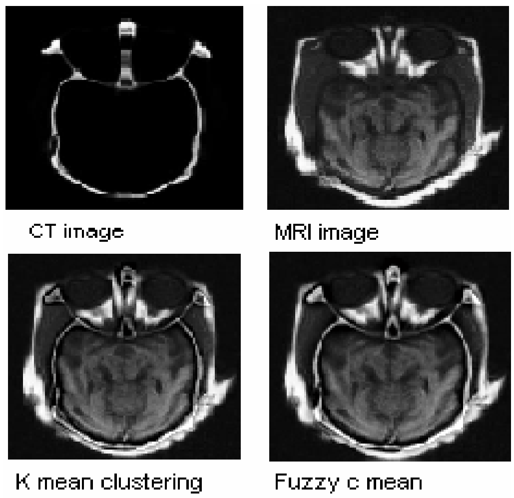

Figure - 3 Medical Images.

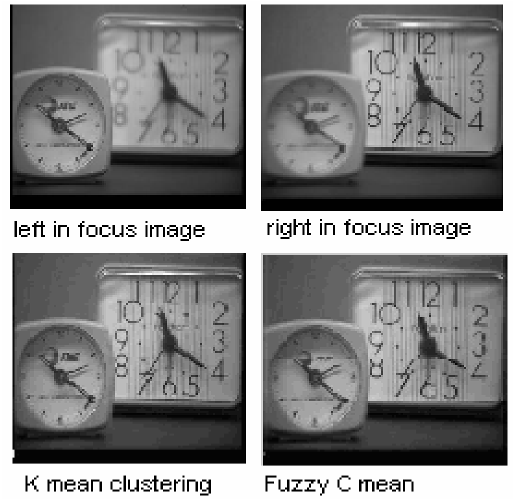

Figure -4 Multi-focus Images.

Figures 3-5 show subjective fusion quality measures where figure-6 demonstrates quantitative and objective measure for quality measurement of fused image.

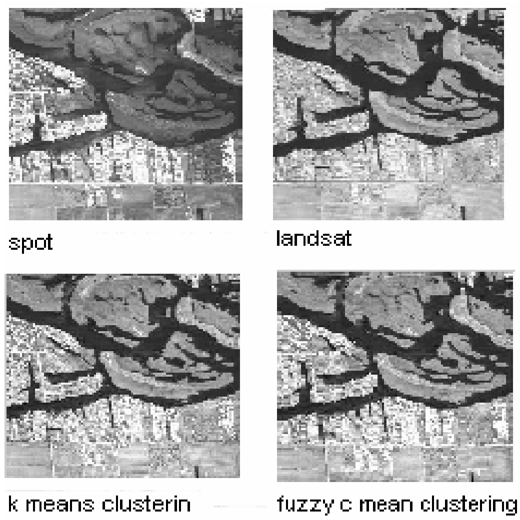

Figure - 5 Remote Sensing.

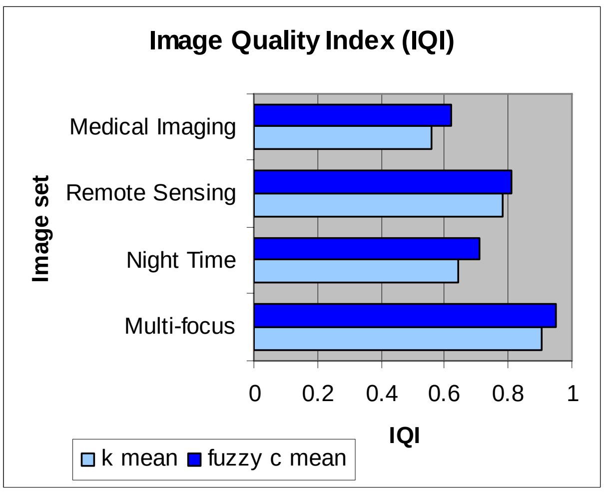

Figure -6 IQI

5 Conclusion

We proposed an image fusion algorithm in this paper, based on fuzzy clustering and discrete wavelet frame transform. With experimental discussion we conclude that our algorithm improves quality of fused image as compared to fusion algorithm based on k-means clustering algorithm.

Our proposed algorithm has one drawback when it comes to computational time. Due to discrete wavelet frame the physical computations required are more and hence the time.

Our future work includes the computationally fast image fusion scheme, which efficiently gives good results.

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