Image fusion of medical images based on Fuzzy set

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ABSTRACT

Image fusion is a technique to improve the image quality. In this paper, a new way is drawn to fuse two images by using max-min operations in Sugeno’s Intuitionistic fuzzy generator. It operates on images with lots of uncertainties. Firstly, input images are reform into Intuitionistic fuzzy images (IFIs) and then evaluate fuzzy rules by using best entropy of input images, and IFIs are constructing based on black-count & white-count. This paper compares the performance of Average, Fuzzy Sets, Intuitionistic Fuzzy Sets and Sugeno’s type Intuitionistic fuzzy (proposed method) in terms of various performance measures.

Keywords

Image fusion, Intuitionistic Fuzzy Generator, Intuitionistic fuzzy.

Fusion methods

Average fusion algorithm

Average fusion is one of the spatial domain fusion techniques, and it is directly averaging pixel value of input images, written as

\[ AVG = \frac{a + b}{2} \]  

(1)

Where \( a \) and \( b \) are the input images and AVG represent the output image (fused image).

Fusion by fuzzy sets

In this technique, initially fuzzifies the input image, then resultant image must be in fuzzified nothing but multi-valued brightness. Fuzzify the brightness of input image why because of the image having uncertain pixel values, that’s why images are transferred to fuzzy domain then it can reduce ambiguity or vagueness of input image. In Fuzzy sets, obtain fused image using membership function, there is no information about non-membership function and hesitation function.

Fusion by Intuitionistic fuzzy sets:

In Intuitionistic fuzzy sets (IFSs), mainly needs membership, non-membership, and hesitation functions to get fused image. Now consider the IFSs from FSs. Consider a fixed length of fuzzy set which is

\[ P = \{ p_1, p_2, p_3, \ldots, p_n \} \]

(2)

Fuzzy set of \( P \) can be written as

\[ F = \{ (p, \mu_F(p)) \mid p \in P \} \]

(3)

Where \( \mu_F(p) \) membership function of fuzzy sets in the range of \([0, 1]\)

And non-membership function \( 1 - \mu_F(p) \) nothing but non belongingness of set \( P \), and Intuitionistic fuzzy sets can be written as

\[ F = \{ (p, \mu_F(p), \nu_F(p)) \mid p \in P \} \]

(4)

Where \( \nu_F(p) \) non-membership function in the range of \([0, 1]\)

And hesitation function obtain due to lack of knowledge, has been introduced by szmidt and kacprzyk. IFSs can be written as

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\[ F = \{(p, \mu_F(p), \nu_F(p), \pi_F(p)) | p \in P\} \]  

Where \( \pi(f) \) is the hesitation function and the above equation should satisfy the given equation,  
\[ \mu_F(p) + \nu_F(p) + \pi_F(p) = 1 \]  

**Sugeno’s Intuitionistic fuzzy sets:**  
Atanassov introduced intuitionistic fuzzy set theory [15], consider the membership function (\( \mu \)), and non-membership function (\( \nu \)) of the elements of set [17]. Proposed method is improved Intuitionistic fuzzy sets, in this method using Sugeno’s type Intuitionistic fuzzy generator [13-14] for finding the membership function, and hesitation function to generate fused image. 

Let as consider an image \( A \) of \( R \times S \) dimension and \( Q \) levels of grayness, fuzzy singletons are related to the values of pixels. Initially fuzzify the input image \( A \) by using given equation  
\[ \mu(A(i,j)) = \frac{a - a_{\min}}{a_{\max} - a_{\min}} \]  

Where \( a_{\min} \) and \( a_{\max} \) are smallest and highest values of the gray levels of the image \( A \). And fuzzified input image is in fuzzy domain and it is converted into Intuitionistic fuzzy domain why because, to find out the fused image using three fuzzy set theory rules which are membership, non-membership, and hesitation rules at best value of \( \gamma \)  

The best value of \( \gamma \) obtained from highest value of I.K.Vlachos & sergiadis’s entropy [11-12]. Written as  
\[ E = \frac{1}{P \times Q} \sum_{i = 0}^{P-1} \sum_{j = 0}^{Q-1} \mu(A(i,j)) \nu_{SIF}(A(i,j)) + \frac{\pi_{SIF}^2(A(i,j))}{\pi_{SIF}(A(i,j))} \]  

\[ \gamma_{\text{best}} = \max(E(SIF; \gamma)) \]  

\[ \nu_{SIF}(A(i,j)) = \frac{1 - \mu(A(i,j))}{1 + \gamma \mu(A(i,j))} \quad ; \gamma \geq 0 \]  

\[ \pi_{SIF}(A(i,j)) = 1 - \mu(A(i,j)) - \frac{1 - \mu(A(i,j))}{1 + \gamma \mu(A(i,j))} \quad ; \gamma \geq 0 \]  

and decompose the image, get the blended image based on black count and white count using max, min operations. Finally Intuitionistic fuzzy image (IFI) is obtained without uncertainty.  

**Proposed method Algorithm:**  
Following steps involve in Sugeno’s Intuitionistic Fuzzy Sets (SIFs)  

**Step 1:** Consider the two source images named as \( A_1 \) and \( A_2 \), respectively, and fuzzify both images by using equation (1)  

**Step 2:** Calculate the \( \gamma_{\text{best}} \) using \( E \) from equation (8) and by using non-membership function and hesitation function from (10) & (11).  

**Step 3:** And calculate the non-membership function, hesitation function at \( \gamma_{\text{best}} \), and output images are named as \( A_{F1K} \) and \( A_{F2K} \).  

**Step 4:** Decompose the images obtained from above step into \([p q]\) blocks and denote the \( k \)th image block of decomposed images named as \( A_{F1K} \) & \( A_{F2K} \).  

**Step 5:** Calculate the black count and white count of each block of image.  

**Step 6:** To obtain blended image by using max, min operations shown below,  
\[ A_{F1K}(i,j) = \begin{cases} 
\min[A_{F1K}(i,j), A_{F2K}(i,j)], & \text{black count > white count} \\
\max[A_{F1K}(i,j), A_{F2K}(i,j)], & \text{black count < white count} \\
\frac{A_{F1K} + A_{F2K}}{2}, & \text{otherwise} 
\end{cases} \]  

**Step 7:** Reconstruct the fused image from above step which is SIF image without uncertainty.  

**Step 8:** SIF image obtained from above equation is defuzzified to get a fuzzy image, Defuzzification function is
\[ A(i,j) = (a_{\text{max}} - a_{\text{min}}) \cdot \mu(A(i,j)) + a_{\text{min}} \] 

(13)

Experimental results:

Experimental results are considering different types of medical images like combination of MRI-PET image, multi-focused medical image, and MR-MRA image [16-18].

![Fig 1. MRI-PET Image.](image1)

![Fig 2. Multi focused medical image](image2)

![Fig 3. MR-MRA Image.](image3)

Conclusion

This paper gives a new approach to fuse two medical images better than intuitionistic fuzzy sets. This new approach is improved intuitionistic fuzzy sets by using Sugeno’s intuitionistic fuzzy generator; it is simple and can be apply to real time medical images to reduce the uncertainties present in a digital image. Comparison with existing methods, proposed method gives better results in terms of subjectively and objectively. For better fusion results future research will be done by using neuro fuzzy logic.

Table 1. Performance evaluation of proposed method of MRI-PET image with different fusion techniques (with and without reference image), for Fig.1

<table>
<thead>
<tr>
<th>Fusion Method</th>
<th>SF</th>
<th>E</th>
<th>MI</th>
<th>FS</th>
<th>GalaF</th>
<th>MEAN</th>
<th>SD</th>
<th>AG</th>
<th>PSNR</th>
<th>MSE</th>
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<tbody>
<tr>
<td>AVG</td>
<td>7.7649</td>
<td>5.4805</td>
<td>0.4538</td>
<td>1.5002</td>
<td>0.4352</td>
<td>0.1870</td>
<td>0.2310</td>
<td>0.0473</td>
<td>66.0157</td>
<td>0.0103</td>
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<tr>
<td>FUZZY</td>
<td>8.0328</td>
<td>5.5381</td>
<td>0.5108</td>
<td>1.5010</td>
<td>0.4581</td>
<td>0.1977</td>
<td>0.2462</td>
<td>0.0488</td>
<td>67.9993</td>
<td>0.0103</td>
</tr>
<tr>
<td>IFSs</td>
<td>6.2508</td>
<td>5.2631</td>
<td>0.2096</td>
<td>1.5007</td>
<td>0.2650</td>
<td>0.1511</td>
<td>0.1928</td>
<td>0.0377</td>
<td>66.3286</td>
<td>0.0151</td>
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<tr>
<td>Proposed</td>
<td>8.9693</td>
<td>5.7231</td>
<td>0.5164</td>
<td>1.5145</td>
<td>0.4902</td>
<td>0.2399</td>
<td>0.2853</td>
<td>0.0544</td>
<td>66.4966</td>
<td>0.0146</td>
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Table 2. Performance evaluation of proposed method of multi focused medical image with different fusion techniques (with and without reference image), for Fig.2.

<table>
<thead>
<tr>
<th>Fusion Method</th>
<th>SF</th>
<th>E</th>
<th>MI</th>
<th>FS</th>
<th>GalaF</th>
<th>MEAN</th>
<th>SD</th>
<th>AG</th>
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<th>MSE</th>
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<tbody>
<tr>
<td>AVG</td>
<td>4.2861</td>
<td>4.8797</td>
<td>0.7322</td>
<td>1.9888</td>
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<td>FUZZY</td>
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<td>0.199</td>
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</table>

Where SF=Spatial Frequency, E=Entropy, MI=Mutual Information, FS=Fusion Symmetry, GalaF = Edge strength, SD= Standard Deviation, AG= Average Gradient, PSNR=Peak Signal to Noise Ratio, MSE= Mean Square Error.
Table 3: Performance evaluation of proposed method of MR-MRA image with different fusion techniques (with and without reference image), for Fig. 3.

<table>
<thead>
<tr>
<th>Fusion Method</th>
<th>SF</th>
<th>E</th>
<th>MI</th>
<th>FS</th>
<th>qabf</th>
<th>MEAN</th>
<th>SD</th>
<th>AG</th>
<th>PSNR</th>
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<td>0.1687</td>
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<td>0.0269</td>
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<td>FUZZY</td>
<td>5.3293</td>
<td>4.4933</td>
<td>0.0028</td>
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<td>0.3488</td>
<td>0.1011</td>
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<td>0.3124</td>
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<td>0.4517</td>
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<tr>
<td>Proposed</td>
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<td>5.8704</td>
<td>0.5116</td>
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<td>66.1810</td>
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References