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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 image with lot 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 reconstructing 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.

Introduction

In image analysis and computer vision, Image fusion plays significant role, for more details see [1-6]. Different types of image sensors are being used these days in medical imaging but, data obtained from these sensors are redundant and incompatible. Soft tissue details in an image can be obtained by magnetic resonance image and details of bone & blood vessels in an image can be obtained by computed tomography. But in some cases to get an image that simultaneously both the soft tissue and other parts like fat, bone for assisting human visually to detect the irregularities. In this paper, various medical images such as magnetic resonance image (MRI), computed tomography (CT), PET, and SPECT image and so on are consider for fusion.

Image fusion is differentiated into two major techniques those are transform domain fusion and spatial domain fusion. In transform domain fusion, fusion techniques applied on frequency domain of input image and to get fused image again using the inverse Fourier transform. In spatial domain fusion, fuse the two or more input images .based on pixel value of images, based on various techniques like select maximum, select minimum, averaging, principle component analysis (PCA) [7], etc. In average fusion technique have degradation problem, more uncertainties. To overcome this drawback fuzzy sets are applied to image fusion.

The fuzzy set (FS) theory was introduced by zadeh in 1965 [8], it is widely used in various fields to reduce uncertainty of digital image. In fuzzy sets (FSs) consider membership function to get the fused image and there is lack of non-membership and hesitation function information. To get the fused image in the combination of membership, non-membership, and hesitation functions are introduced by Atanassov named as Intuitionistic fuzzy sets (IFSs) [9-10], and in this paper proposed an improved method is nothing but Sugeno's Intuitionistic fuzzy sets [11].

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

$$AVG = \frac{a+b}{2} \quad (1)$$

Where a, b are the input images and AVG represent 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

$$P = \{p_1, p_2, p_3, \ldots, p_n\} \quad (2)$$

Fuzzy set of P can be written as

$$F = \{(p, \mu_F(p)) \mid p \in P\} \quad (3)$$

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

$$F = \{(p, \mu_F(p), v_F(p)) \mid p \in P\} \quad (4)$$

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

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

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$$F=\{(p,\mu_F(p),\nu_F(p),\pi_F(p))|p\in P\} \quad (5)$$

Where $\pi(p)$ hesitation function and the above equation should satisfies the given equation,

$$\mu_F(p)+\nu_F(p)+\pi_F(p)=1 \quad (6)$$

Sugeno's Intuitionistic fuzzy sets:

Atanassov introduced intuitionistic fuzzy set theory [15], consider the membership function (μ), and non-membership function (v) 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

$$\mu(A(i,j))=\frac{a-a_{min}}{a_{max}-a_{min}} \quad (7)$$

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 γ

The best value of γ obtained from highest value of I.K.Vlachos & sergiadis's entropy [11-12]. Written as

$$E=\frac{1}{P\times Q}\sum_{i=0}^{P-1}\sum_{j=0}^{Q-1}\frac{2\,\mu(A(i,j))\,\nu_{SIF}(A(i,j))+\pi_{SIF}^{2}(A(i,j))}{\mu^{2}(A(i,j))+\nu_{SIF}^{2}(A(i,j))+\pi_{SIF}^{2}(A(i,j))} \quad (8)$$

$$\gamma_{best}=max(E(SIF;\gamma)) \quad (9)$$

The IF image obtained from combination of fuzzy rules, written as

$$\nu_{SIF}(A(i,j);\gamma)=\frac{(1-\mu(A(i,j)))}{(1+\gamma\mu(A(i,j)))}\quad ;\gamma\ge 0 \quad (10)$$

$$\pi_{SIF}(A(i,j);\gamma)=1-\mu(A(i,j))-\frac{(1-\mu(A(i,j)))}{(1+\gamma\mu(A(i,j)))}\ ;\gamma\ge 0 \quad (11)$$

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:

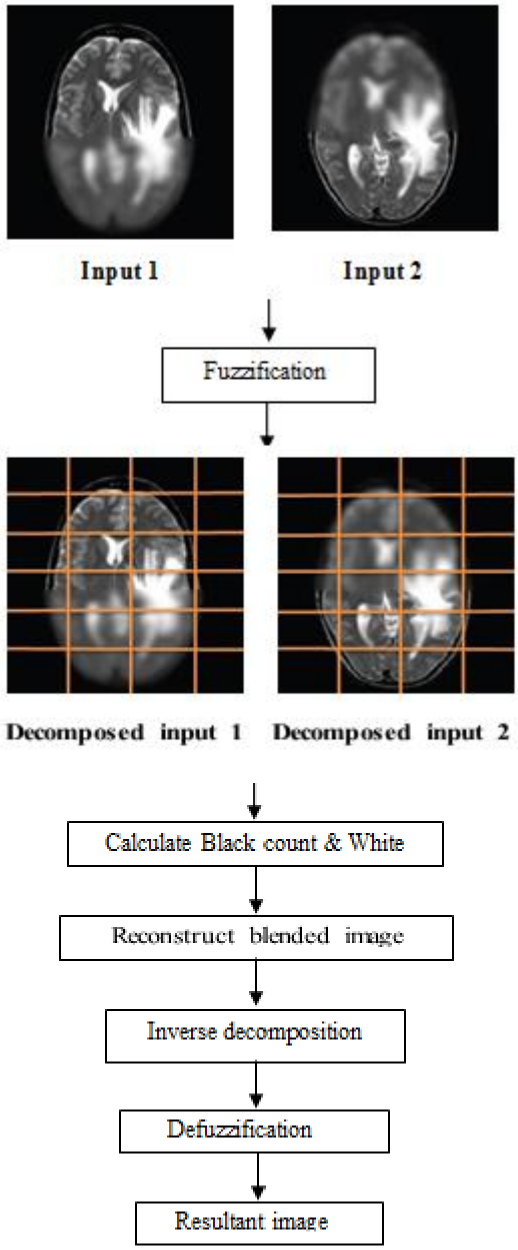
Following steps involve in Sugeno's Intuitionistic Fuzzy Sets (SIFSs),

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 γ_{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 γ_{best}, and output images are named as A_{F1} and A_{F2}

Step 4: Decompose the images obtained from above step into [p q] blocks and denote the kth 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 obtained blended image by using max, min operations shown below,

$$A_{FK}(i,j)=\begin{cases} min\{A_{F1K}(i,j),A_{F2K}(i,j)\}, black\ count > white\ count \\ max\{A_{F1K}(i,j),A_{F2K}(i,j)\}, black\ count < white\ count \\ \frac{A_{F1K}+A_{F2K}}{2} \quad ,otherwise \end{cases} \quad (12)$$

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

$$A'(i,j) = (a_{max} - a_{min}) * \mu \ (A(i,j)) + a_{min} \tag{13}$$

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].

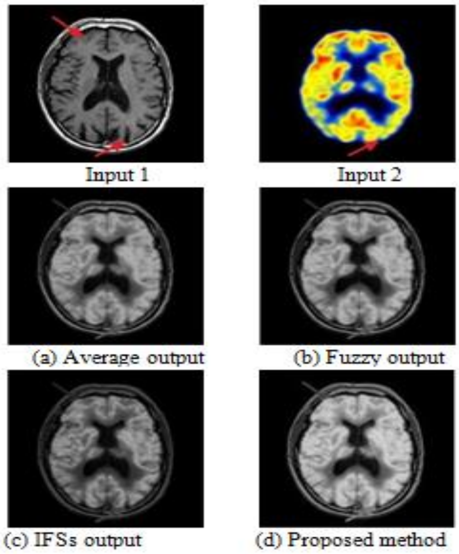


Fig 1. MRI-PET Image.

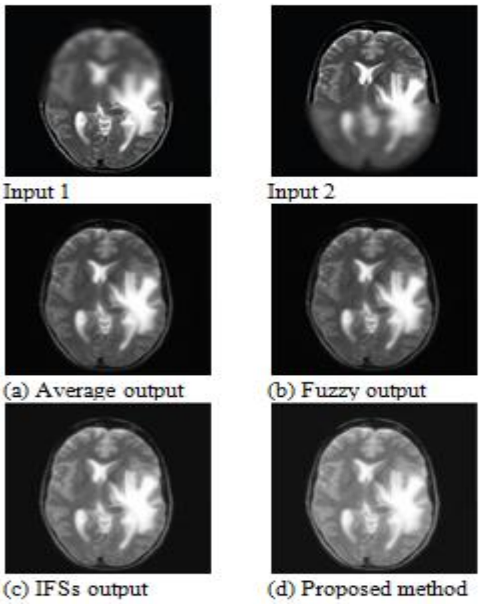


Fig 2. Multi focused medical image

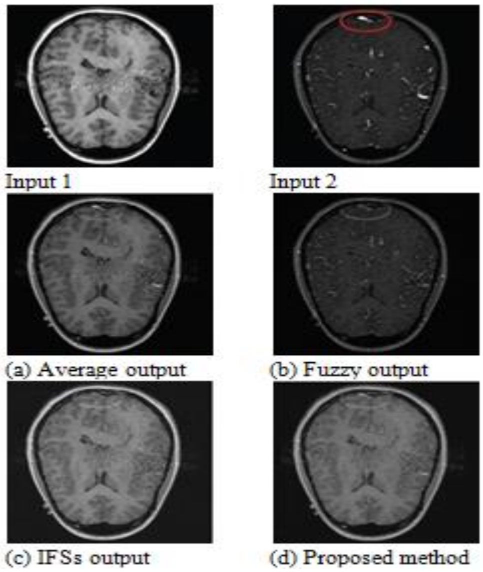


Fig 3. MR-MRA Image.

Conclusion

This paper gives a new approach to fuse two medical images better then 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

Fusion Method	SF	E	MI	FS	Q^{abf}	MEAN	SD	AG	PSNR	MSE
AVG	7.7649	5.4805	0.4538	1.5002	0.4352	0.1870	0.2310	0.0473	66.0157	0.0103
FUZZY	8.0328	5.5381	0.5108	1.5010	0.4581	0.1977	0.2462	0.0488	67.9993	0.0103
IFSs	6.2508	5.2631	0.2096	1.5007	0.2650	0.1511	0.1928	0.0377	66.3286	0.0151
Proposed	8.9693	5.7231	0.5164	1.5145	0.4902	0.2399	0.2853	0.0544	66.4966	0.0146

Where SF=Spatial Frequency, E=Entropy, MI=Mutual Information, FS=Fusion Symmetry, Q^{abf} = Edge strength, SD= Standard Deviation, AG= Average Gradient, PSNR=Peak Signal to Noise Ratio, MSE= Mean Square Error**.**

Table 2.Performance evaluation of proposed method of multi focused medical image with different fusion techniques (with and without reference image), for Fig.2.

Fusion Method	SF	E	MI	FS	Q^{abf}	MEAN	SD	AG	PSNR	MSE
AVG	4.2861	4.8797	0.7322	1.9888	0.5767	0.1916	0.2355	0.0176	69.9484	0.0066
FUZZY	4.2880	4.8590	0.7318	1.9891	0.5791	0.1912	0.2356	0.0176	69.9472	0.0066
IFSs	4.5296	5.1504	0.5823	1.9697	0.5785	0.2566	0.2587	0.0187	67.4091	0.0118
Proposed	4.8006	5.1520	0.4522	1.9761	0.5622	0.2718	0.2812	0.199	65.6774	0.0176

Table 3.Performance evaluation of proposed method of MR-MRA image with different fusion techniques (with and without reference image), for Fig.3.

Fusion Method	SF	E	MI	FS	Q^{abf}	MEAN	SD	AG	PSNR	MSE
AVG	6.9905	5.3531	0.0657	1.5504	0.4574	0.1845	0.1687	0.0252	63.8395	0.0269
FUZZY	5.3293	4.4933	0.0028	1.7017	0.3488	0.1011	0.0854	0.0192	59.7511	0.0689
IFSs	8.1241	5.4373	0.3124	1.5001	0.4517	0.2786	0.1915	0.0292	66.0360	0.0162
Proposed	8.8889	5.8704	0.5116	1.5104	0.4579	0.3021	0.2384	0.0320	66.1810	0.0157

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