Color Image Fusion using Fuzzy Logic

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Abstract - *Image fusion using fuzzy logic gives a new dimension to the multi-sensor image processing task. Using different membership functions and rules it can combine the information from the multiple images of same scene. Many works on image fusion using fuzzy logic are done in gray scale domain which are very useful in medical and satellite imaging purpose. In surveillance systems the images we get sometime taken in extreme lighting condition. Color information of the images are playing a vital role in some cases. This paper proposed a method of doing the fusion using fuzzy logic in red, green and blue domain separately. Experimental results shows that proposed method not only combine the color information of source images but also improve the fusion performance.*

Key Words: multi-sensor, fuzzy logic, membership function, gray scale, image fusion

1. INTRODUCTION

The term fusion means in general approach to extract information acquired in several domains. Image fusion is the process of integrating multiple images of the same scene into a single fused image to reduce uncertainty and minimizing redundancy while extracting all the useful information from the source images. Image fusion applied in every field where images are needed to be analyzed. Image fusion has lot of application medical imaging [9], satellite imaging [7] and surveillance systems [8] to get more information and also to get more accurate view. Image fusion is essential for computer vision and robotics systems in which fusion results can be used to aid further processing steps for a given task. Large amount of attention were recently given in the area of image fusion. There are several image fusion techniques like Principle Component Analysis (PCA) based image fusion [3], discrete Wavelet Transform based image fusion [4], and Contrast Pyramid based image fusion [5].

Fuzzy sets and fuzzy logic proposed by Zadeh [1] is powerful mathematical tools for modeling and controlling uncertain systems in industry, humanity, and nature. Fuzzy logic is the facilitator for approximate reasoning in decision making in the absence of complete and precise information. Fuzzy logic used in a lot of applications to different controllers which improves Human Daily Life [10]. Image fusion algorithm utilizing fuzzy rules to merge two images in terms of gray level values [2] have been studied during last two decade.

Primary requirement of any image fusion process is that it should preserve all the useful edge information from the source images. Objective image fusion performance measure [6] gives the measurement of how much edge information are returned to the fused image from the source images. Different parameters like entropy of the images, standard deviation of images gives the measurement of the quality of output image. So, these parameters are very useful in image fusion performance measure.

Surveillance systems of a restaurant, bar or disco have to deal with the images which are taken in extreme red, green or in any other lights. For this type of images, amount of information stored in red, green, blue domain differs a lot from the amount of information stored in gray scale version of that image. As an example, for an image taken in extreme red light, amount of information in red domain is much more than that of the grey scale domain. So, for this type of case, doing the fusion in grey scale domain is total waste of some vital information. In the present work fusion is done in red, green and blue domain separately which uses the information stored in input images more efficiently. So this process will be very useful keeping some color information. Experimental results also establish the fact that the proposed method improves the fusion performance

2. METHODOLOGY

Input images of the same scene getting from different sensor have been allowed through image registration process first. After images are registered, proper fuzzy inference system is applied to the registered input images to combine the information stored in the inputs and

accordingly the fused image has been obtained. The overall block diagram has been shown in Fig. 1.

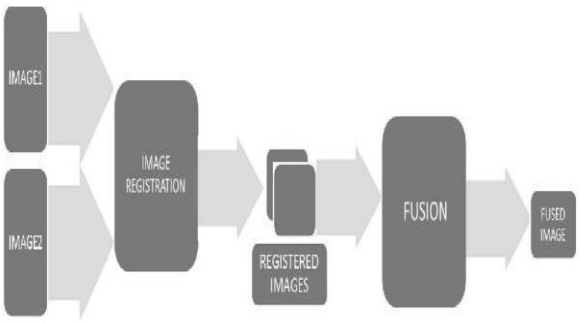


Fig-1: Block diagram of image fusion Process

2.1 Image Registration

Image registration is the process of aligning two or more images of the same scene. Different geometric transformations are applied to an image for aligning the image to another image of same scene. Image registration using template matching is very efficient method and the same has been implemented in the present work.
For template matching two input images has been taken and a particular portion of one source image where fusion is needed has been cropped and then it has been tried to find the area in the other image where cropped portion matches best. The same has been depicted in Fig- 2 where G (i ,j) is the cropped portion from the image 1 (F (i , j)). H(i, j) is image 2 of the same seen taken from different sensor.

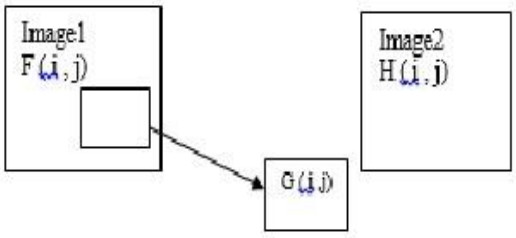


Fig-2: Template matching

From Cauchy-Schwartz inequality, normalized cross-correlation between G(i, j) and H(i, j) value should be maximum in the area where G(i, j) matched to H(i, j). Here is the stepwise algorithm for template matching.

1. Pad the image all side with zero. Size of the pad will be so that template can be placed in every portion of the image.
2. Move the mask over entire image and simultaneously calculate the value of summation of template padded image under the template and store it in a array.
3. Calculate the values of padded image under the template's square and sum all he values. Take the square root of obtained values and store it in a array.
4. Divide the result of step 2 by step 3 and store it.
5. Find the position where maximum value in above result obtained.
6. Recover the template from original image using the above co-ordinate obtained.

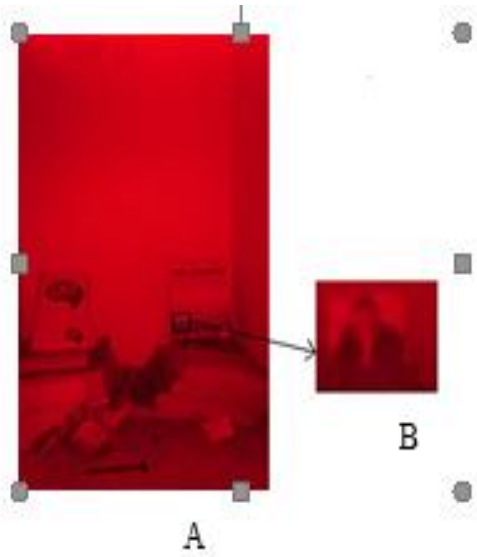


Fig-3: Cropping the portion where fusion needed

Fig-3A is one of the input images to be fused. Fig-3B is the cropped portion where fusion needed

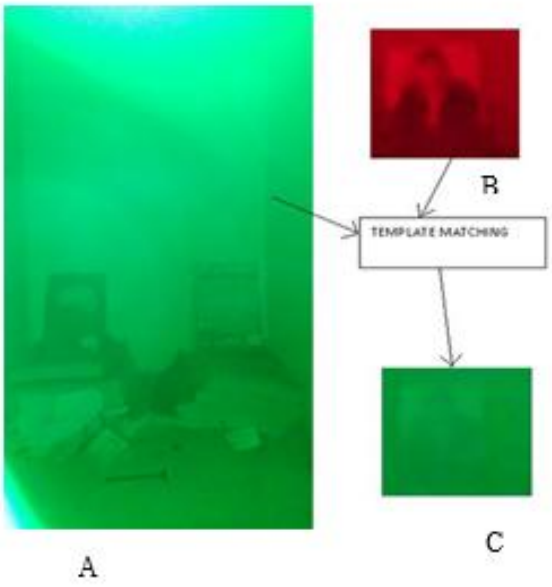


Fig-4: Template matching

Fig. 4A is the second input image and Fig. 4B is the cropped portion of first input. Template matching operation gives the template as shown in Fig. 4C which matches to Fig. 4B.

2.2 Stepwise Algorithm for Fusion Process

1. Read the both template in the variable X and Y.
2. Extract the red and green, blue matrix of X and store in the variable R1, G1 and B1.
3. Extract the red and green, blue matrix of Y and store in the variable R2, G2 and B2.
4. Create a fuzzy inference system using appropriate membership function and proper rule.
5. Fuse R1 with R2, G1 with G2 and B1 with B2 separately and store these results in three different variable called R, G, B.
6. Result stored in the variables R,G,B are in string form so convert all three result in matrix form using proper loop.
7. Create fused color image using these three matrixes.

2.3 FUZZY INFERENCE SYSTEM

In the present work Sugeno type of fuzzy inference system with two input, one output and 25 rules have been used to combine the information in the input images. The basic block diagram is shown in the Fig-4.

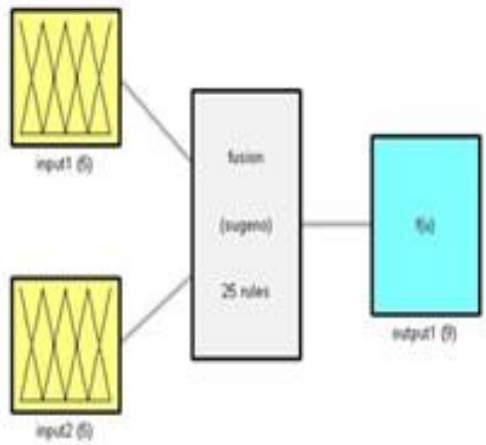


Fig-4: System fusion: 2 inputs, 1 output, 25 rules

2.3.1 Membership Function

In this work triangular membership function are used for the representation of inputs. 5 membership functions are used to represent intensity of two input image. As sugeno type of fuzzy logic is used so linear and constant membership functions are available for use. 9 Constant membership function are used to represent intensity of output image. In the membership function above, input and output variables are all as follow : { NB (negative big) ; NSM (negative small middle) ; NBM (negative big middle) ; NS (negative small) ; ZO (zero) ; PS (positive small) ; PSM (positive small middle) ; PBM (positive big middle) ; PB (positive big) }

2.3.2 Decision Maker Rule Base

Table-1: Rules for the system

Intensity of output image	Intensity of input image1 →				
Intensity of Input image2 ↓	NB	NS	ZO	PS	PB
NB	NB	NSM	NBM	NS	ZO
NS	NSM	NBM	NS	ZO	PS
ZO	NBM	NS	ZO	PS	PSM
PS	NS	ZO	PS	PSM	PBM
PB	ZO	PS	PSM	PBM	PB

Table 1 represents the rules of this fuzzy inference system. Here every connection is 'or' and same weight is given to every rule. Fig.5 gives the surface view of the system.

2.3.3 Surface View of Rule Base

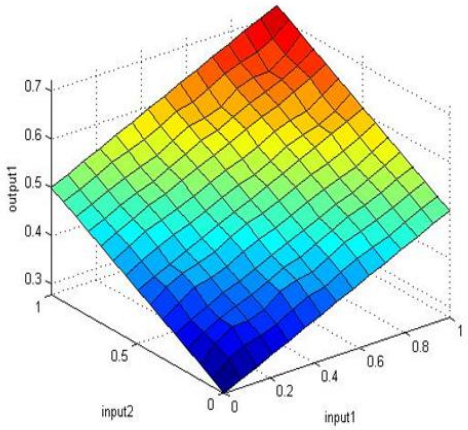


Fig-5: Surface view of fuzzy inference system

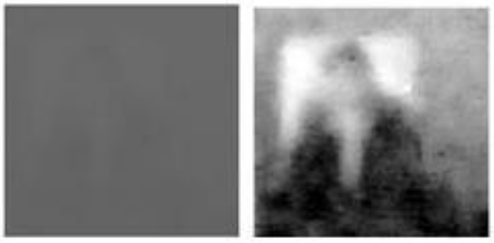
3. RESULT AND DISCUSSION

3.1 Experiment No-1

Fig. 5A and Fig. 5B are two input image to be fused. Fig.6A and Fig. 6B are the fused image and enhanced fused image done by gray scale fusion. Fig. 7A and Fig. 7B are the fused image and enhanced fused image done by color fusion.

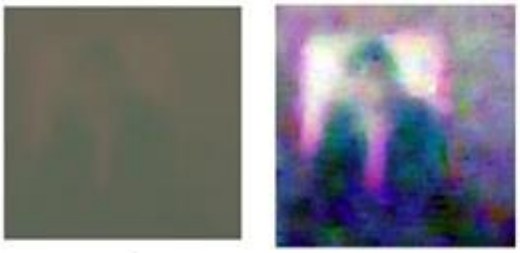
A B

Fig-6: input images



A B

Fig-7: Fused image, enhanced fused image (gray scale fusion)



A B

Fig-7: Fused image, enhanced fused image (color fusion)

3.1.1 Image Fusion Performance (Gray Scale Fusion vs Color Fusion)

Table-2: performance of gray scale fusion

Gray scale fusion			
Parameter	Input1(gray scale)	Input2(gray scale)	Output(gray scale)
Entropy	4.9797	4.2309	3.1288
Standard deviation	9.7122	5.0288	2.5394
Objective image fusion performance Xydeas & Petrovic ($Q^{AB/F}$) = 0.7240			

Table-3: performance of color fusion

Color fusion			
Input1 (color)			
Parameter	Red	Green	Blue
Entropy	6.6301	0.0527	3.9965
Standard deviation	31.1245	0.1281	4.0113
Input2 (color)			
Parameter	Red	Green	Blue
Entropy	0.03	4.8425	4.7654
Standard deviation	0.1	7.5431	6.7169
Output (color)			
Parameter	Red	Green	Blue
Entropy	3.2925	1.7097	2.7766
Standard deviation	6.9129	1.6820	1.7096
Objective image fusion performance Xydeas & Petrovic ($Q^{AB/F}$)=0.7247(gray scale) ,0.7007(Red), 0.6967(Green), 0.7112(Blue)			

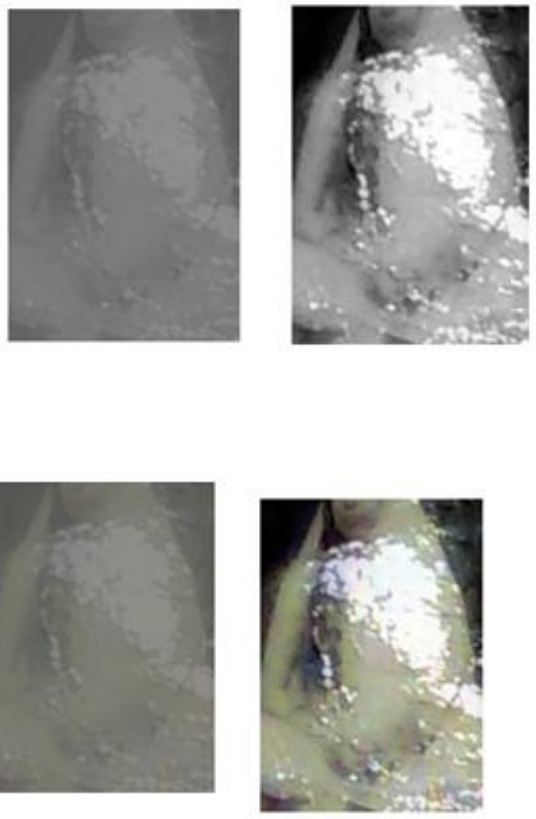


Fig-10: fused image, enhanced fused image (color fusion)

Table 2 and Table 3 gives fusion performance analysis of gray scale and color fusion of experiment no 1.

Table-4: performance of gray scale fusion

Gray scale fusion			
Parameter	Input1(gray scale)	Input2(gray scale)	Output(gray scale)
Entropy	7.1599	5.7083	5.4875
Standard deviation	51.4737	16.4505	13.7139
Objective image fusion performance Xydeas & Petrovic ($Q^{AB/F}$) =0.5433			

3.2 Experiment No-2

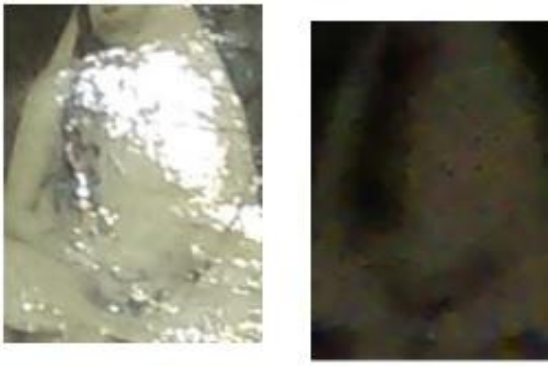


Fig-8: input images

Table-5: performance of color fusion

Color fusion			
Input1 (color)			
Parameter	Red	Green	Blue
Entropy	7.0719	7.1335	7.2513
Standard deviation	51.133	54.3568	54.1871
Input2 (color)			
Parameter	Red	Green	Blue
Entropy	6.0019	5.7607	5.6219
Standard deviation	18.4282	16.6549	13.4271
Output (color)			
Parameter	Red	Green	Blue
Entropy	5.5676	5.4875	5.5772
Standard deviation	13.9792	13.7079	13.5319
Objective image fusion performance Xydeas & Petrovic ($Q^{AB/F}$) = 0.5435(gray scale), 0.6504(Red), 0.6632(Green), 0.6801(Blue)			

Table 2 and Table 3 gives fusion performance analysis of gray scale and color fusion of experiment no 1.

Two different pairs of color image are fused using fuzzy logic. First experiment shows that color fusion can extract some important color information like the color of the blazer of the person in the image where two input images has little clue about that. Fusion performance Analyses shows that the measure of objective fusion performance taking gray scale version of color input and output images of color fusion process is better than that of the gray scale fusion process. Also the quality of the gray scale version of the output of color fusion process is better than the output image quality of gray scale fusion. So, if there is not much of color information like second experiment or if there is a need of a gray scale image at the output still we can go for color fusion. Here we also analyzed the fusion performance and image quality parameters in red, green, blue domain separately.

4. CONCLUSION

Gray scale fusion can fuse the images to get more accurate view. But if there is a need for some color information then gray scale fusion is not a solution. Color image fusion is necessary where there is a need for combination of the color information of the input images. From the experiment it is very much clear that the images taken in extreme red, green, blue light or any other light image fusion in color domain is more useful. For this type of images color fusion use the information stored in input images more effectively than that of gray scale fusion. Not only that, it can be useful everywhere because of its better performance. Most importantly color image fusion gives flexibility to the process. This process allow to use different fuzzy logic in red, green, blue domain according to the need of the application.

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BIOGRAPHIES

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