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Proposed Novel Fusion Methods Based on Barycentric and Demosaicing Algorithms

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Abstract: Image fusion is the process of merging information from more than one source in order to produce more informative image by taking any number of different images for different scenes or by taking any number of same images with different focus or accuracy in order to produce enhanced image that take suitable information from one image or ratio among all input images according to some conditions. In this study, new two methods will be proposed to perform fusion operation in adaptive mechanism that change the ratio from each input images depending on pixel environments, barycentric fusion translate RGB colors to forces on a right triangle and assumed that the triangle is balanced and static to calculate the ratio from each image in the specific pixel and repeat this operation for each pixel in the fused space until producing output fused image that contain information from all fused images with unfixed ratio while demosaicing fusion simulate the process of pixels interpolation due to lack of sensors in camera for economic aspects this process decide pixels from each images that entered to construct specific pattern of a Color Filter Array (CFA) then apply any suitable interpolate method to calculate other pixels component.

Key words: Image fusion, barycentric, demosaicing, color filter array, adaptive fusion, specific pixel

INTRODUCTION

Fusion is a method of complement different images information get from many scenes into one, output image either with a good quality that better than input images or with best information which is used for human or agent perception (Stathak, 2008) depending on this definition fusion goals can be summarized as:

- Noise reduction to improve (SNR) by taking the average over input images or by selecting best input one
- Improving the spatial resolution
- Maximizing of the spatial space, e.g., mosaicking
- Visualization of high-dimensional images, e.g.
- Multispectral as false-color images
- Constructing desired fusion output that result in the case of images that generated from various physical principles, e.g., sonar image and X-ray image (Stathak, 2008)

The objectives of fusion process are: to discover and get all the important information from the input images and merging them into specific way that produce better results for many desired aspects as well as for later processes not to provide these information which will make the observer or computer (Bloch, 2008) more reliable and robust against difficult states such as mis-registration (Wang and Chang, 2011) and for helping in establishing the main three operations of object recognition, detect, recognize and identify.

In last years, fusion in images has been getting a great amount of importance in a very wide scale of applications such as medical diagnosis, Concealed Weapon Detection (CWD) defect inspection, remote sensing and military monitoring (Kumar *et al*., 2014). Fusion operation can be divided into the following general methods.

Pixel-level fusion: Pixel-level fusion can be used to combine multiple images into one image by performing operations that deal with the related pixels of input images in each steps (Sinija and Karthik, 2015). The quality enhancement is related with pixel level fusion can most easily be proved. These methods can be classified in three groups: linear such as average, nonlinear such as maximum and minimum and multi-resolution such as wavelet transform methods (Hnatushenko and Vasyliev, 2016).

Feature level fusion: Performed by extracting desired features from related images either by calculating features separately from each image or by simulating process of all images (Alparone *et al*., 2015).

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Region-based image fusion: The basic idea is to construct intermediate fused image by any simple pixel fusion method among source images then segmentation process will be applied for this intermediate fused image (Raol, 2015) and use the results of segmentation as a guide to the fusion process in selecting this region from specific input images by comparing this features such as Row (RF) and Column (CF) frequencies of the specific region (Bloch, 2008).

Decision-level fusion: This level merge decisions from multiple sources such as classifier results or sensors so the output decision represent all input decisions in compatible way and produce a strong decision for all input ones (Alparone *et al*., 2015) this process done by combining decisions of unrelated sensors by applying Boolean operations or by selecting a suitable score. Fusion structures can be mainly classified into three types:

- Hierarchical
- Overall and
- Arbitrary fusion structure

Figure 1 shows the first type (hierarchical) aims to fuse images with predefined scores in a suitable decided order and in each process exactly two images can be merged. This type is accepted in fusion algorithms that are designed to fuse only two source images each time (Stathak, 2008).

For algorithms that need to fuse more than two images in a single operation the second type (overall) structure shown in Fig. 2 is more acceptable by merging all input images in one process to yield one output image. The previous types are generally used together in some predefined fashion in order to produce the output fused image by the third type (arbitrary) (Stathak, 2008) as shown in Fig. 3.

Digital camera, used electronic sensor captured images in a subsampled pattern called Color Filter Array (CFA), one of the most important and widely used CFA is a Bayer pattern (Bp) (Anzagira and Fossum, 2015), a (Bp) is an array of dimensions (8×8) as shown in Table 1 and the other pixels color will be calculated by applying demosaicing operation by one of the interpolate algorithm that can be classified as:

Non adaptive algorithms: In this algorithms a fixed context of processes will be applied in all operations for each pixel location in the colored sub image to calculate the unknown missing color parts (Moses and Selvathi, 2016).

Adaptive algorithms: In this algorithms unfixed and intelligent processes will be applied for every pixel location depending on some suitable features or characteristics of the neighboring pixels in order to predict the missing color parts (Serrano, 2016).

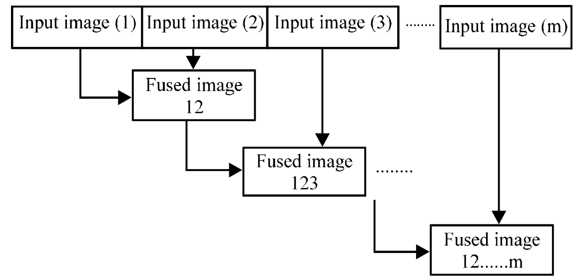


Fig. 1: Hierarchical fusion structure

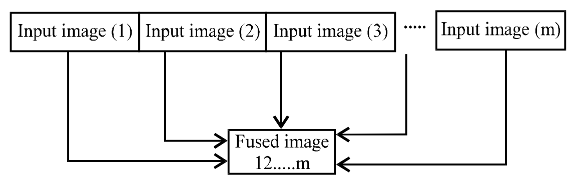


Fig. 2: Overall fusion structure

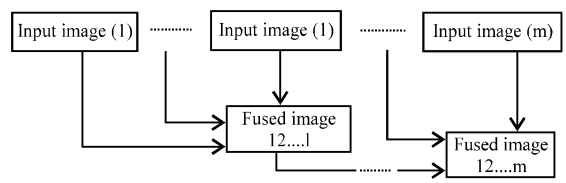


Fig. 3: Arbitrary fusion structure

Table 1: Bayer pattern

1	2	3	4	5	6	7	8
Green	Red	Green	Red	Green	Red	Green	Red
Blue	Green	Blue	Green	Blue	Green	Blue	Green
Green	Red	Green	Red	Green	Red	Green	Red
Blue	Green	Blue	Green	Blue	Green	Blue	Green
Green	Red	Green	Red	Green	Red	Green	Red
Blue	Green	Blue	Green	Blue	Green	Blue	Green
Green	Red	Green	Red	Green	Red	Green	Red
Blue	Green	Blue	Green	Blue	Green	Blue	Green

Literature review: Wang *et al.* (2012) presented a simple and new algorithm for multi-focus image fusion which used Laplacian pyramid method. This algorithm essentially consist of three parts. Initially, the Laplacian pyramids of each input image are decomposed separately then each level of new Laplacian pyramid is fused by taking various fusion techniques and finally the fused image is constructed by applying inverse Laplacian pyramid transform. This method has accepted performance with good quality of the fused image compared to other methods. Ejaily *et al.* (2014) proposed an image fusion method to merge remote sensing satellite images based on complex wavelet transform with dual tree (DT-CWT). The quick bird and worldview satellite data are used for carrying out the experimental work. The objective and visual results show the superiority of the proposed fusion method over that depend on common Discrete Wavelet Transform (DWT) and other methods based on the DT-CWT. Wang *et al*. (2012) proposed a new algorithm for image fusion depending on the Non-Subsampled Contour-let Transform (NSCT) domain and an Accelerated Non negative Matrix Factorization (ANMF). Firstly, the desired input images are deconstructed in various scale and various direction by using the NSCT method. Then, the ANMF algorithm is performed on low-frequency parts of images to calculate the low-pass coefficients and the Neighborhood Homogeneous Measurement (NHM) rule is applied on the high-frequency parts to calculate the band-pass coefficients. Finally, the desired final fused image is constructed by merging all sub-images with the inverse NSCT.

Tico and Pulli (2009) present a method for image enhancement depending on merging the information founded in two images for the same place, exist with different times. The important process is to use the differences between the image that affect the two images where the motion blur is less in the short-exposed image and the noise is less in the long-exposed image.

MATERIALS AND METHODS

Proposed system: The proposed system consist of two adaptive fusion methods.

Barycentric fusion: Barycentric method can be explained as follows.

Forces representation: The red and green components of pixels that must be fused will be represented as forces effected on distance points of right triangle as shown in Fig. 4.

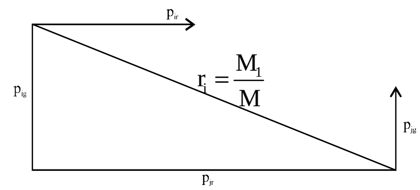
Calculate moments: The moments in points i and j will be calculated as follow:

$$M_t = p_{tg} \times p_{ir} \quad (1)$$

$$M_j = p_{jg} \times p_{jr} \quad (2)$$

Then the moment in the point (k) is:

$$M = p_{ig} \times p_{ir} + p_{jg} \times p_{jr} \quad (3)$$



$$r_1 = \frac{M_1}{M} \quad (4)$$

Fig. 4: Forces representation

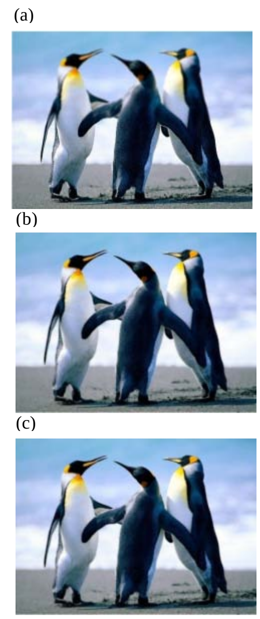


Fig. 5: Barycentric fusion for the same scene: a) Input image; b) Input image and c) Output fused image

Calculate the ratio for pixels: The ratio from each fused pixel will be calculated by applying the following functions:

$$r_2 = \frac{M_2}{M} \quad (5)$$

Calculate the value of the fused pixel: In this step the fused pixel will be calculated and output fused image by applying the following Eq. 6-8:

$$Pr_{new} = r_1 \times p1_r + r_2 \times p2_r \quad (6)$$

$$P_{gnew} = r_1 \times p1_g + r_2 \times p2_g \quad (7)$$

$$P_{bnew} = r_1 \times p1_b + r_2 \times p2_b \quad (8)$$

When the proposed system will be applied on two images with different clarity for the same scene the output fused image reduce the blurring compared to each one of the input images as shown in Fig. 5.

Fig. 6: Barycentric fusion for different scenes: a) Input image; b) Input image and c) Output fused image

While when the proposed system applied on two images with different scene then the output fused image has more information compared to each one of the input images as shown in Fig. 6.

RESULTS AND DISCUSSION

Demosaicing fusion: This method can be summarized by the following steps: translating RGB images into YCbCr images the input RGB images firstly converted to YCbCr images by applying the following Eq. 9 Fig. 7:

$$\begin{bmatrix} Y \\ C_b \\ C_r \end{bmatrix} = \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} + \frac{1}{156}\begin{bmatrix} 65.738\,129.057\,25.064 \\ -37.945 - 74.494\,112.439 \\ 112.439 - 94.154 - 18.285 \end{bmatrix} \bullet \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (9)$$

Constructing CFA: This step the CFA as illustrated in Table 2 will be constructed from input images. The value in cell (1, 1) is Y component from input image while The value in cell (2, 2) is Y component from input image and so on, constructing YCbCr image; by applying simple average interpolation between nearest cells to construct three complete arrays, one for each band (Y, Cb and Cr) as illustrated in Fig. 8, repeating steps (b and c) after replacing input images, this mean that previous image become image and previous image become image, reconstructing CFA for this new state and finally reconstructing YCbCr image as shown in Fig. 9, applying average fusion between output images from steps (c) and (d) as illustrated in Fig. 10, returning image result from step e into RGB space by applying the following equation as illustrated in Fig. 11.

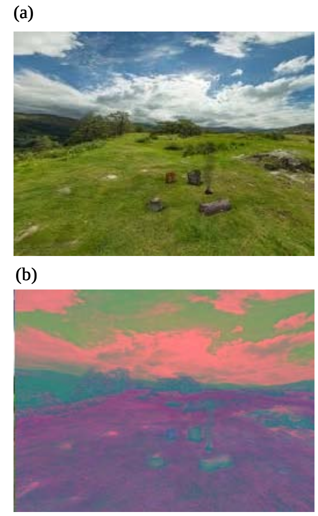


Fig. 7: Translating RGB images into YCbCr images: a) RGB image and b) YCbCr image

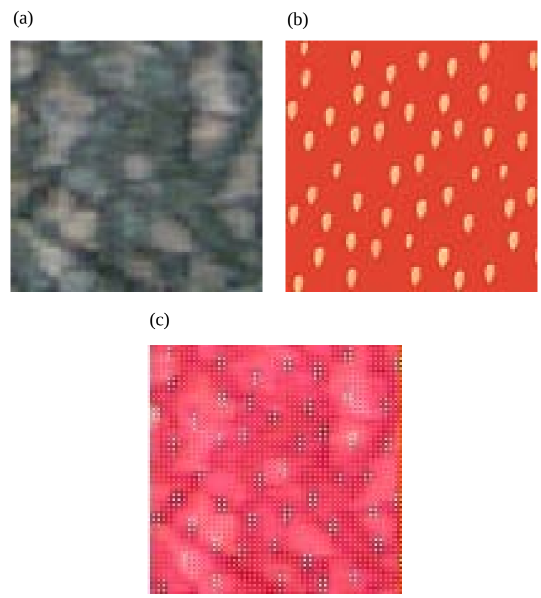


Fig. 8: Constructing first YCbCr image: a) Input image; b) Input image and c) Output YCbCr image

Table 2: Constructing of CFA

1	2	3	4	5	6	7	8
PY_1	PC_{r1}	PY_1	PC_{r1}	PY_1	PC_{r1}	PY_1	Pc_{r1}
PC_{b2}	PY_2	PC_{b2}	PY_2	PC_{b2}	PY_2	Pc_{b2}	PY_2
PY_1	PC_{r1}	PY_1	PC_{r1}	PY_1	PC_{r1}	PY_1	Pc_{r1}
PC_{b2}	PY_2	PC_{b2}	PY_2	PC_{b2}	PY_2	Pc_{b2}	PY_2
PY_1	PC_{r1}	PY_1	PC_{r1}	PY_1	PC_{r1}	PY_1	Pc_{r1}
PC_{b2}	PY_2	PC_{b2}	PY_2	PC_{b2}	PY_2	Pc_{b2}	PY_2
PY_1	PC_{r1}	PY_1	PC_{r1}	PY_1	PC_{r1}	PY_1	Pc_{r1}
PC_{b2}	PY_2	PC_{b2}	PY_2	PC_{b2}	PY_2	Pc_{b2}	PY_2

When we applying the proposed two methods on suitable selected images, the following results can be founded (Table 3 and Fig. 12-14).

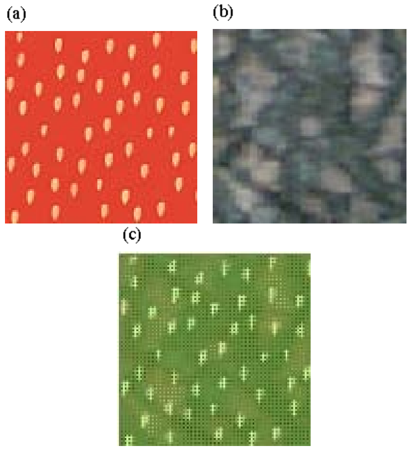


Fig. 9: Constructing second YCbCr image: a) Input image; b) Input image and c) Output YCbCr image

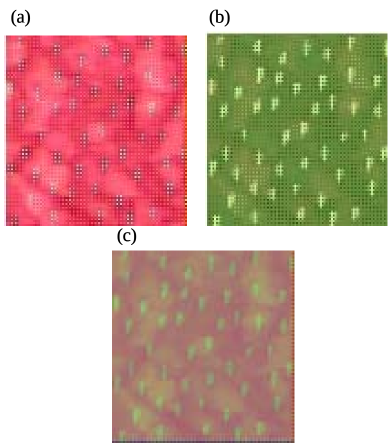


Fig. 10: Constructing fused YCbCr image: a) YCbCr image; b) YCbCr image and c) Fused YCbCr image

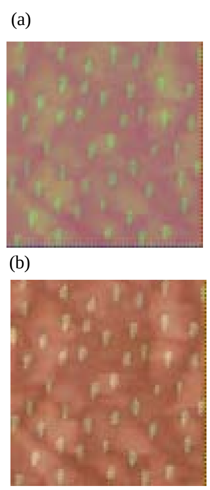


Fig. 13: Example (2) results: a) Image; b) Image; c) Fused image; d) Fused image and e) Average fusion

Fig. 11: Final fused image: a) Fused YCbCr image and b) Fused RGB image

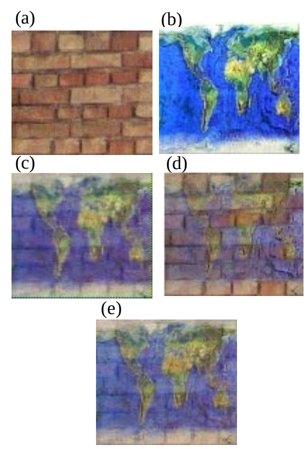


Fig. 12: Example (1) results: a) Image; b) Image; c) Fused image by method; d) Fused image by method; e) Fused image by average method and f) Original image

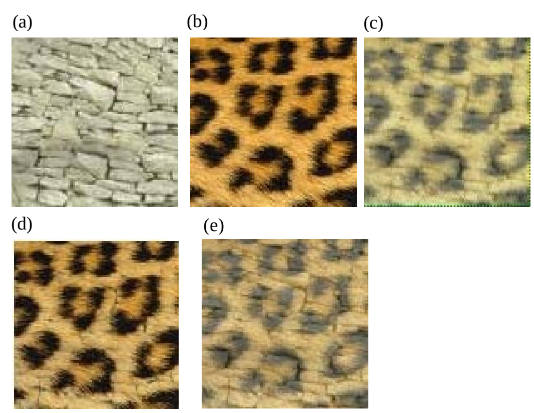


Fig. 14: Example (3) results: a) Image; b) Image; c) Fused image; d) Fused image and e) Average fusion

Table 3: PSNR between fused and input images

	Example 1	Example 2		Example 3	
Algorithm	Original image	Image 1	Image 2	Image 1	Image 2
Demosaicing fusion	25.06	9.78	25.12	12.53	19.50
Barycentric fusion	25.06	16.92	18.20	14.99	15.84
Average fusion	27.62	14.22	14.22	15.71	15.71

CONCLUSION

After applying the proposed system and check results in Table 3 we can discover that these methods produce accepted results that merge two images in one image that either contain light information from each image but clear to recognized or produce enhanced image that avoid unaccepted pixels by correct them with the perfect ones to produce accepted pixels that best compared to bad pixels but worst compered to fine ones, the results of the proposed methods reflect that the fused images by barycentric method contain more dark pixels than demosaicing method outputs with details than it.

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