The Normalized Random Map of Gradient for Generating Multifocus Image Fusion

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Abstract: ***The multifocus image fusion is a kind of method in image processing to collecting the sharp information from multifocus image sequence. This method is purposed to simplify the reader understand the complex information of image sequence in an image only. There are many methods to generate fused image from several images so far. Many researchers have developed many new and sophisticated methods. They show complicated computation and algorithm. So, that it is difficult to understand by the new students or viewer. Furthermore, they get difficulties to create the new one. In order to handle this problem, the proposed method a concise algorithm which is able to generate an accurate fused image without using a complicated mathematical equation and tough algorithm. The proposed method is the normalized random map of gradient for generating multifocus image fusion. By generate random map of gradient, the algorithm is able to specify the coarse focus region accurately. The random map of gradient is a kind of information formed independently from independent matrix. This data has a significant role in predict the initial focus regions. The proposed algorithm successes to supersede difficulties of mathematical equations and algorithms. It successes to eliminate the mathematical and algorithm problems. Furthermore, the evaluation of proposed method based on the fused image quality. The Mutual Information and Structure Similarity Indexes become our key parameter assessment. The results show that the outputs have high indexes. It means it is acceptable. Then the implementation of multifocus image fusion will increase the quality of the applied fields such as remote sensing, robotics, medical diagnostics and so on. It is also possible implemented in other new fields.***

Keywords **:** ***Multifocus Image Fusion; Random Map; High accuracy; Simple Method.***

I. INTRODUCTION

The performance of lens censor devices to sense and accumulate the noble image data are very customary in recent years and might more grow rapidly in the near future[1]. There are many scopes in daily life activities where the lens censors become the key part to get at many problems that human difficult to settle. In the robotics, the lens censor is able to squire the data with high accuracy and complexity. The remote sensing fields use lens censor to acquire a precise data. And medical diagnostics process using computer is not negligible.

All proceeds data of the above camera are images. The high power of camera make it ubiquitous nowadays. In accordance, the need of precise image data is demanded to make a sharp analysis and time-saving process[2]. The necessity of obvious information to proceed of image is something that is very important[3]. This perfect information ease the machines and even human vision to recite the whole data faster. As, the clear data is very significant, so the effort to achieve the goal is done sustainably.

The above properties is a difficult to achieved by general camera. Since it has limited Depth of Focus. In addition, the need of rich information from image data is inevitable. The collecting important information from an image always become an important research topic in image processing. The development of the field grows more and more, as it's implementation does.

The multifocus image fusion is an image processing field that merges the focus regions of images into a fused image. The multifocus image fusion has appeared for several years. It has achieved a lot of advancement. There are many methods found so far. They are able to generate fused image with high quality. In most cases, the fused image fashions are distinguished into spatial domain and transform domain fusion[2]. The spatial domain fashion is the fused image directly generated from multi images, as well as the segmenting image to build fused image, the built of grid patches images to generate block image[3]. These blocks opt the focus pixel of multifocus image[4]. Further, the fashion selects feature through the blocks, the selected feature then get learning using Neural Network, the fused image is gained from feature and weight[5]. The Guided Image Filter also gives a way to detect the initial focus region and define focus region map[6]. The detecting structure image through depth information and self- similarities to detecting focus region[7]. And so on. The secondly, it is the multifocus image fusion fashion based on temporal domain. This method create spectral domain, before selecting weight of focus region. Some of them, use wavelet transform, this method is very popular in image processing[8]. There are also some other variants of wavelet transform[9][10]. Then, the selecting wavelet coefficient through sub-band filter[11]. In addition, the other popular method is curvelet transform. The curvelet transform is combined with image block to find the suitable texture and so on[12]. The last one, it is exist in many papers recently. The method uses a set of transform domain and deep learning algorithm. This newly hybrid method can implemented in multifocus image fusion[13] [14]. In addition, the deep learning also use to find the feature of focus region[15].

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The other method uses fake data to generate focus region[16]. Then, other method applies sparse coding to find the feature map to generate image fusion and so on[17].

The remainder of the paper is structured as follow, Related work is in Section 2. The methodology applied is in section 3. Then, the section 4 provides information on experiment and result. Section 5 delivers quality assessment. The last section is summary.

II. RELATED WORKS

The multifocus images fusion process has evolved more and more. The algorithm and method also run into harder and complicated[18]. The use multiscale geometrical analysis with non local guided image filter and shearing filter banks shows high accuracy but with the tough algorithm [19].The garner of local contents (sharpness) become a feature to define focus regions[20]. This method has difficulties in formulating the filter. One method makes comparison between blurred image and original image. This method specifies the predicting of focus regions[21]. The computational complexities tried to be decrease through Sobel operator[22]. The using saliency structure also able to reduce computational complexities[23]. The need of maintain the quality is very important. Furthermore, the reduction of computational and complexities algorithm also become something that have to be achieved.

III. PROPOSES METHOD

The multifocus image fusion denotes a merging of images with distinctive focus regions to generate an image with crowded of sharp information, called fused image. The key information is commonly used up by machine, robotics and human. The fused image is more implemented to analyze the contained information inside the image.

In order to stand up the focus information, the algorithm should have ability to aware the structure.

In our proposed algorithm, there is a new method to deal with focus region through a random map of gradient. This map performs a task to forecast the initial map of focus regions. This initial map is a outlook of focus region.

The random map of gradient is a kind of filter that is able to decreases the complexities of algorithm and computation. Once it works, it could find the initial prediction of focus region directly. We can say, it does filtering process to the multifocus image to select the only focus information. Although, it able to simplify the algorithm, nevertheless algorithm can keep the focus region with high quality too. The accuracy of the initial focus region is determined through the resemblance of focus region and initial focus map. It actually adequate to select focus region with accurate boundaries. This effect influences the subsequent phase to become more simply.

The strength of random map filter is the abilities to simplify and decrease algorithm and computational complexity. The more simple process will have low cost. That is the main purposes of our proposed method.

The following stage is brought into play morphological filtering to the initial map. The morphological filtering will integrate the unconnected object and separated unknown objet to focus object.

Finally, the last stage is imitating the lens characteristics with soft boundaries border between focus and blurred regions. Furthermore, the method uses guided image filter. The detail of the algorithm is as followed where at the end the accurate fused image obtained.

A. Random Map of Gradient

The random map of gradient is a kind of map that consist of the structure of gradient. The map is built through evoking of gradient from a matrix. A matrix is a two dimensions array that fill in with the random number with the values, x, $0 < x < 1$, it has range between 0 and 1.

The evoking of random matrix number is based on the pseudo random[24]. The matrix is a nondeterministic function, so it is possible the matrix values varied time to time. These values have powerful to generate stabilized gradient. It as shown in Fig. 1.

In the Fig. 1, (a), there is an image raised from a random matrix. The image pixel has the high and low values. The high and the low values spread with random texture. This image does not have special shape of texture, but it has the peak and the shallow parts spread in the spatial space with high contrast. In the Fig. 1, (b), The image that raised from random matrix variables. The image shows the range values of pixels is a bit narrow compared to the Fig. 1, (a). It has the blurred texture. Since, the smoothing filter is put on to the image. This blurred image is look similar to the blurred part of camera image. This image does not have boundaries for blurred region. The whole parts is absolutely in blurred form.

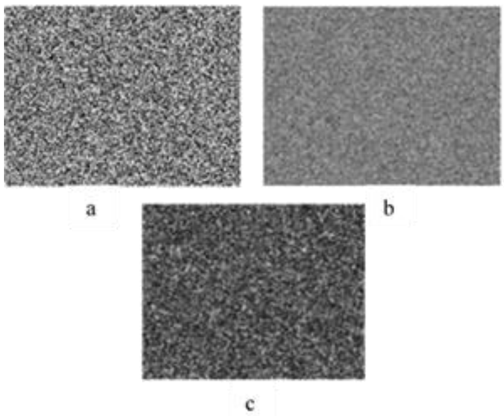


Fig.1.The Generating of random map of gradient : a random matrix image, b blurred random matrix image, c random map of gradient

In Fig. 1, (c), it is a map of gradient of the blurred form image as in Fig. 1, (b). The map of gradient has a random texture uniformly. So, there is no special shape and direction on the gradient map. It means the direction and the magnitude is in nondeterministic form. The gradient generated from blurred image also have a smooth magnitude. This smoothness gives shallow magnitude. There is not peak value and bottom values of the gradient.

B. Morphology Filtering

Morphological filter is a kind of processing in image data that based on structure operation. This operation will support to find genuine construction of the object [25]. The filter operates to eliminate the noise or small uncorrelated objects and make connecting the correlated object. This makes the morphological operation suitable to increase the image performance[26].

There are some operations that correlated with the morphological filter, such as erosion, dilation, opening and closing operations.

Dilation operation is a unification operation that is held by vector addition of set elements. The dilation operation is implemented in binary (0, 1) or grayscale image with range pixels value between 0 and 1. This operation yields an increment dimension of shape. The S and T are structure elements respectively. Then S is dilated by the structure of T, the mathematical morphological equation is $S \oplus T$. If s is sub element of set S, symbolized with the $s \epsilon S$. Then dilation operation is mathematically formulated as follow:

$$(S \oplus T) = \cup_{s \in S} S_t \quad (1)$$

S_t is dilation translation of S by t [27]. Since dilation is an operation on structure level of image, pixel level. So, it serves the advantages for image smoothing, segmenting and so on. The characteristics of dilation operation are the unification of the structure that makes it larger and larger.

Erosion operation is the adversary of dilation operation. It works to reduction dimension region or object. The erosion operation also operates at pixel level too. It implemented in binary image (0, 1) and gray image with range (0 -1). The S and T are structure elements respectively. The erosion of structure S by T is symbolized $S \ominus T$ [28]. The $s \epsilon S$ means s is subset of S. S-t is erosion translation S element by t. Then the erosion operation is formulated as in(2):

$$(S \ominus T) = \cap_{t \in T} S_{-t} \quad (2)$$

The formula above delivers that the erosion process makes the distinctive of two regions. Practically, it has ability to separate the relating uncorrelated object in the binary image level.

Opening operation is a sequence operation that involves erosion and dilation operations. The opening operation has order erosion followed by dilation operation. This operation is symbolized with (○). The opening operation of image, S with the structuring element T is formulated $S \circ T$. So, mathematically we can compute as in (3):

$$S \circ T = (S \ominus T) \oplus T \quad (3)$$

This operation offers smoothing image application, removing noises and connecting related objects.

As opening operation, closing operation is also a sequence operation too. It involves erosion and dilation operations. Closing operation is symbolized with (●). The sequence of closing operation is dilation followed by erosion procedure. So, for image, S and structuring element, T the closing operation is as following equation:

$$(S \bullet T) = (S \oplus T) \ominus T \quad (4)$$

Based on the above equation, it gives the characteristic of the closing operation. Closing operation generally removes the hole and fills the gap among parts of region.

C. Guided Image Filter

Guided image filter is a filtering process in image processing that the output influenced by the capacity of guidance image. The guidance image is a kind of reference image which comes from input image or another image. Furthermore, the process using guided image filter involves two images and produces one filtered image [29]. The detail of guided image filter is as in (5):

$$F_i = \sum_j SW_{ij} (S)_{t_j} \quad (5)$$

The filtered image at pixel i, Fi; SW_{ij} is sliding window with pixel i at the center. Then S and t is input image and guidance image respectively. Otherwise, i and j are index pixels. The feature of this filtering process is the output image has linear characteristic with guidance image.

IV. RANDOM MAP OF GRADIENT GENERATING MULTIFOCUS IMAGES FUSION

Our proposed method is multifocus image fusion with random number image reference. In this method we try to simplify the process of generating fused image. In new method, we emphasize the beginning of the procedures to be concerned. We attempt to find out the predicted focus region with a very simple way and as accurate as possible.

Gradient operation involves generating image gradient, normalization of all gradient maps into range from zero to maximum one (0 – 1) and gradient subtraction operation. The gradient normalization heads to creation of similarity range between input images gradient and reference image gradients.

A. Generating Normalized Gradient Map

The generating of gradient map consist of generating gradient reference image and generating gradient of input images. The gradient of reference image, R^g is shown in (6). The this gradient is normalized as shown in (7). Where, R_N^g is the normalization of R^g.

$$R^g = mag(\nabla I) \quad (6)$$

$$R_N^g = \frac{R^g}{max\,(R^g)}\, x\, 1 \quad (7)$$

The gradient of input images involve generating gradient of input images M(x, y) and N(x, y). This generating process is performed through derivative operation as in (8) and in (10). The both gradient map is then normalized as in (9) and (11). This processing is very important to design the accurate initial map.

$$M^g(x, y) = mag(\nabla M) \quad (8)$$

$$M_N^g = \frac{Gr^M}{max\,(Gr^M)}\, x\, 1 \quad (9)$$

$$N^g(x, y) = mag(\nabla N) \quad (10)$$

$$N_N^g = \frac{Gr^N}{max\,(Gr^N)}\, x\, 1 \quad (11)$$

B. Predicting Grainy Gradient Map

Then, the gradient subtraction performs as in (12) and (13) to produce initial focus region. This process involves normalized random map of gradient and normalized gradient input images. This process to provide the residual gradient. This residual gradient can be served as grainy gradient map ($GN_{grainy\ M,N}$) for both input images, M and N respectively.

$$GN_{grainy\ M} = M_N^g - R_N^g \quad (12)$$

$$GN_{grainy\ N} = N_N^g - R_N^g \quad (13)$$

In order to prevent the existence of negative values, the grainy gradient map is threshold to have the range value between 0 – 1.

$$GN_{grainy\ M,N} = \begin{cases} 0, & GN_{grainy\ M,N} \leq 0 \\ 1 & Otherwise \end{cases} \quad (14)$$

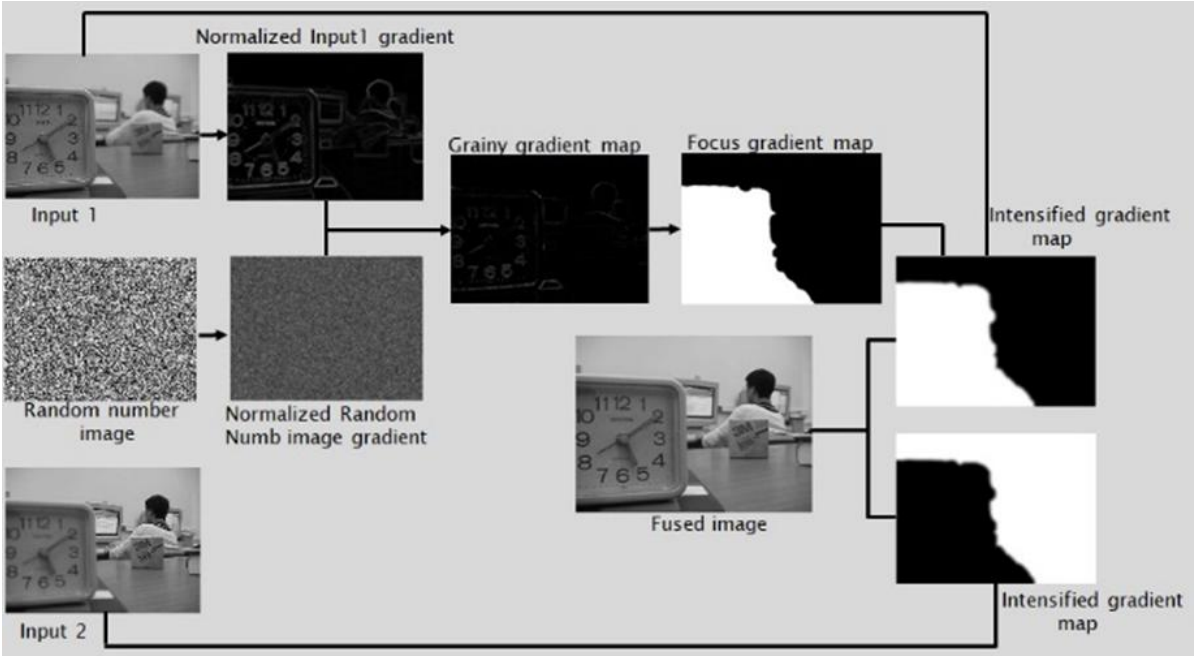


Fig. 2.The schematic diagram of proposed method

Then grainy gradient map shows the predicted shape of the focus gradient map.

C. Determine Focus Region

The creation of focus gradient map is then using morphological filter. Generally, the operations of morphological filtering have two purposes. The first, we remove the noise and small unrelated object operation (RNO) as shown in the equation below:

$$GN^{foc\ M,N} = RNO((GNrainy^{M,N}), K) \quad (15)$$

The RNO is morphological operation that purposes to remove noise objects (RNO). $G^{foc\ M,N}$ is focus gradient map for both M and N images. K is window kernel. The morphological filter work based on window kernel operation. The kernel selects between two grainy gradients maps which one has larger object. The selected object will give label to buffer.

That works is done for whole image. Through this method we are able to construct RNO operations. The second, we perform integrating disconnecting parts of the region (IDR) operation. The sliding window is also applied to this operation. The purpose of this operation is to collect and combine as much as possible related objects. Further, this operation also improves the less perfected connection. It raises the genuine character of the object shape.

The other aim of the operation is to cover the holes or small black point on the object. The holes are able to deliver the bad impact to the fused image. That why we concern about the small black holes in the gradient maps. Then, the operation has the equation as follow:

$$GN^{foc\ M,N} = IDR((GNrainy^{M,N}), K) \quad (16)$$

Those processes are able to manage grainy gradient into focus gradient map. This focus gradient map delivers the accurate focus region image. It shows sharp boundaries.

The sharp edge in focus region actually is quite different with the camera lens has. It moves gradually from focus regions to blurred regions.

D. Intensified Gradient Map

Furthermore, we need to optimize the focus gradient map into a intensified gradient map (GN^{inf}). The intensified gradient should move smoothly. The smoother the moving of the weight from the focus edge into the blurred edge the better the fused image is. The operation for this purpose is through guided image filter. This filter is reliable to optimize the weight of focus gradient map. The operation is as the equation below:

$$GN^{inf\ M,N} = GF_{k,\sigma}(G^{foc\ M,N}, I) \quad (17)$$

The intensified gradient is GN^{inf}, GF is guided filter operator, k and σ are kernel size and regularized parameters respectively. Then, the intensified gradient map is composed.

E. Synthesizing Images

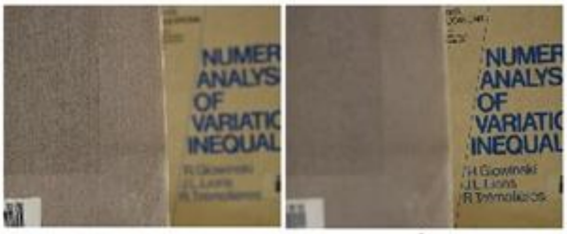
The final stage of our method is fusion operation. This operation involves input images and intensified gradient map. The procedure is according to the following equation:

$$I^{fused} = GN^{inf} * I^{M} + (1 - GN^{inf}) * I^{N} \quad (18)$$

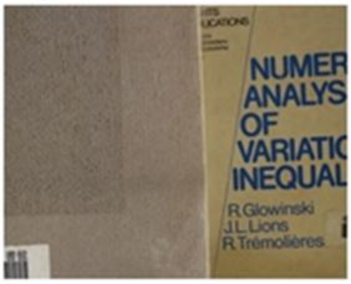
The last equation is as in (18) gives fused image (I^{fused}) based on fusion optimized weight of gradient map and multifocus images. The input images which have the perfect information about the objects are kept as long as the procedures run. Through simple and easy procedure, we are able to generate the fused image with high accuracy. The detail of the process is as shown in Fig. 2.

V. EXPERIMENT AND RESULT

The proposed method is applied to some data. The first data is the book image.It gives the fused image as see in Fig. 3, (c). The input images are pointed in Fig. 3, (a) and (b). We evaluate the mutual information, MI_f^{PQ} of fused image and input images [30]. The P and Q are input images, fused image is *f* and *I*(*f*, P) and I(*f*, Q) are mutual information between fused image, *f* and input images P and Q. H(*f*), H(P) and H(Q) are the entropy of the *f*, P, Q respectively.



a b



c

Fig.3. The pair of input images for experiment 1, (a), (b); c. the fused image (bottom)

The assessment as in (15):

$$MI_f^{PQ} = \left[\frac{I(f,P)}{H(f)+H(P)} + \frac{I(f,Q)}{H(f)+H(Q)}\right] \qquad (15)$$

The obtained indexes is as show in column 5 of Fig.10. In order to convince the method, the evaluation also in similarity, SSIM(P,Q) between reference image, P and fused image ,Q [31]. The evaluation as in (16):

$$SSIM(P,Q) = \frac{(2\mu_P\mu_Q + C_1)(2\sigma_{PQ} + C_2)}{(\mu_P^2+\mu_Q^2+C_1)(\sigma_P^2+\sigma_Q^2+C_2)} \qquad (16)$$

$C_1 = (K_1L)^2, C_2 = (K_2L)^2$, L is a dynamic range with value (255). K_1 =0.01, K_2 = 0.03. The index 1 means it has almost identical properties.

The experiment 2 uses data as shown an input image in Fig. 4, (a) and (b). The fused image is as displayed in Fig. 4, (c). The images have a dynamic scene condition. This dynamic scene is to reassure the robustness of the method.

In the experiment 3, as displayed in Fig. 10. (No.Exp.3) The input images are as shown in column 2 and 3. The fused image is in column 4.

a b

c

Fig.4.The pair of input images for experiment 2 (top); c. fused image

The experiment 4, the data of inputs are as pointed in Fig. 7, (a) and Fig. 7, (b). In this experiment, the fused image exhibits the high accuracy as the previous data. Here, there are also exhibit an initial dense map as in Fig. 8. The Fig. 8, (a) points the initial map of focus regions. The Fig. 8(b) points the sharp dense map of focus region. And Fig. 8, (c) points optimized dense map. The boundaries of all maps shows the increasing accuracy from coarse edge to soften one. The fused image is as pointed in Fig. 9.

Finally, the last dataset is pointed in Fig. 10, (No.Exp.5). The input images are as shown in column 2 and 3. The fused image is in column 4. The last column is Quality Metric for all dataset.

Here, we apply 5 dataset to complete testing our method. The result exhibits as see in Fig.10.(Quality Metric column).

They designate that the random map of gradient is able to evoke all in-focus image with high accuracy. This method does not need a hard mathematical equation and tough algorithm.

The Quality Metric column in Fig.10 exhibits the Mutual Information and Structure similarity index. Our proposed method shows the high indexes for both parameters. The experiments show that the MI and SSIM indexes have the different parameters. The highest index of MI is the data number 3, otherwise the data number 1 is the highest index of SSIM. But all processes allow the fused image on the acceptable result.

a b

Fig.7. The pair of input images for experiment 4

a b c

Fig.8. The focus map for experiment 4;a. initial focus map; b. Sharp edge focus map; c. Optimized focus map

The proposed method successes to substitute a tough equation and hard algorithm procedures in multifocus image fusion topics with the kind of simple filter. Furthermore, we also disclose the ability of normalized gradient map to handle dynamic scene situation and produces the acceptable result too. These contributes are distinct that the new method is reliable.

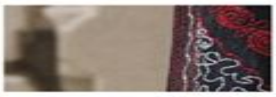
No. Exp	Input 1	Input 2	Fused Image	Quality Metric
1				MI=0.7724 SSIM=**0.9231**
2				MI=0.7546 SSIM=0.7664
3				MI=**0.8490** SSIM=0.6567
4				MI=0.7218 SSIM=0.8643
5				MI=0.7719 SSIM=0.7723

Fig.10. The results of all experiments and assessment indexes

Fig.9. Fused image for experiment 4

VI. CONCLUSIONS AND FUTURE WORKS

The Normalized random map of gradient for generating multi-focus image fusion has showed a good result. The quality metric uses to measure is based on objective measurements. They are Mutual Information (MI) and Structure Similarity (SSIM) indexes. The both methods give the high indexes for all dataset images.

The highest index of MI parameter is obtain through the experiment no.3. Otherwise, the experiment no.1 presents the highest index of SSIM. Visually, the all fused image can be understand well by human vision.

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