Measure of Image Focus using Image Segmentation and SML for Light Field Images

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***Abstract*— In this paper, a detection method of in-focused regions in the light field stack images is proposed. Its main motivation is that the focus measure with region-based image algorithms can be more meaningful than the focus measure with pixel-based algorithms which just consider individual pixels or associated local neighborhoods of pixels in the focus measure process. After we employ the normalized cut method to segment the light field stack images, we apply the sum-modified-Laplacian operation to the corresponding segmented regions. This process provides a focus measurement to select suitable in-focused areas of the stack images. Since only sharply focused regions have high responses, the in-focused regions can be detected. In addition, the all-focused image can be reconstructed by combining all in-focused image regions.**

I. INTRODUCTION

The problem of selecting the best-focused region of the image from a set of differently focused images of the same scene often arises in many areas. Acquiring a clear and well-focused image is relevant in computer vision. Since in-focused image region usually indicates a meaningful objective. Therefore, focus measurement algorithms play important roles in many fields such as autofocus or all-focused image applications, remote sensing and biomedical imaging. Moreover, a dataset of differently focused image acquisition is also required process. A light field image generates a set of images focused at different depth levels, which suggests that one can determine the object, foreground, or background region. Then, to acquire a set of stack images with the same scene by captured in a single shot, a light field camera [1] such as Lytro camera [2] and Raytrix camera [3] provide this information.

In recent years, many focus measurement techniques have been reported, e.g., Subbarao and Tyan [4], presented the simplest focus measure using variance of image gray levels. Zhang et al. [5], introduced focus measure was based on image moments and proved the monotonicity. While, Nayar and Nakagawa [6] proposed a focus measure which was sensitive to noise using the sum-modified Laplacian. In Ref. [7] several focus measure methods have been evaluated. Almost all of the prior methods are applied with pixel-based image algorithm. One limitation of pixel-based method is that it is sensitive to noise. Then, the proposed method is implemented by region-based image algorithm.

II. PROPOSED METHOD

The goal of the proposed method is to improve the focus measurement using image segmentation. The overall diagram of the proposed method is shown in Fig.1. First, segmented images are obtained by averaging image which comes from the source stack images. Then, the measure of image focus is detected with the focus measurement procedure. Lastly, we generate a fused image with containing in-focused regions.

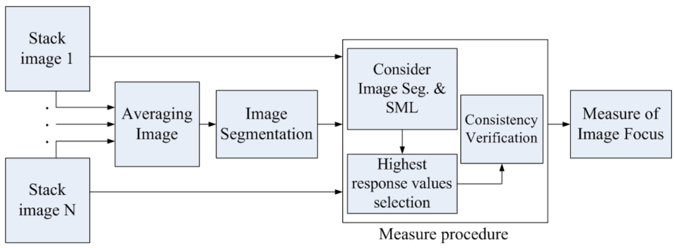

Fig. 1 Procedure of the proposed method

A. *Light field stack images*

We utilize Lytro light field camera [2] as a device for the image datasets. We split the raw light field file to different focal depth layers by the Lytro desktop software [2]. It provides the images which display same location view with the various focus as shown in Fig.2.

Fig. 2 The differently focused images

B. Image segmentation

We use one of the graph theoretic algorithm, namely, the normalized cut (Ncut) [8] for region clustering. The idea of graph-based image segmentation is that the set of points is represented as a weighted undirected graph **G = (V, E)**, where **V** is the set of nodes, **E** is the set of edges connecting the nodes, and the weight on each edge **W**(*i, j*) is a function of the similarity between nodes *i* and *j*. The graph can be partitioned into two disjoint sets **A** and **B** = **V**-**A** by removing the edges connecting the two parts. The degree of dissimilarity between the two sets can be computed as a total weight of the removed edges.

$$cut(A,B) = \sum_{u \in A, v \in B} w(u,v) \quad (1)$$

The classification can search the cut in the graph with minimum weight. However, the minimum cut might just separate only a few nodes from the rest of the graph. This can be avoided using the normalized cut [8] which includes the connectivity or degree of each node.

$$Ncut(A,B) = \frac{cut(A,B)}{\sum_{u \in A, t \in V} w(u,t)} + \frac{cut(A,B)}{\sum_{v \in B, t \in V} w(v,t)} \quad (2)$$

where *cut(A, B)* is the total connection from nodes in *A* to nodes in *B*, the denominator is the total connection from nodes in *A* to all nodes in the graph, and other denominator is the total connection from nodes in *B* to all nodes in the graph. The method can be summarized as follows:

(1) Given an image or image sequence, set up a weighted graph **G** = (**V**, **E**), compute the edge weights and summarize information into **W** and **D** where the matrix **W** is represented as:

$$W(i,j) = e^{\frac{-\|F_{(i)}-F_{(j)}\|_2^2}{\sigma_I^2}} * \begin{cases} e^{\frac{-\|X_{(i)}-X_{(j)}\|_2^2}{\sigma_X^2}} & if\ \|X(i)-X(j)\|_2 < r \\ 0 & otherwise \end{cases} \quad (3)$$

where **X**(*i*) is the spatial location of node *i*, and **F**(*i*) = **I**(*i*) is the intensity value. If nodes *i* and *j* are more than *r* pixels away. Let the matrix **D** is a $N \times N$ diagonal matrix with $\mathbf{d}(i) = \Sigma_i \mathbf{W}(i, j)$ on its diagonal.

(2) Solve $(\mathbf{D} - \mathbf{W})\mathbf{x} = \lambda \mathbf{D}\mathbf{x}$ for eigenvector with the smallest eigenvalues.

(3) Use the eigenvector with second smallest eigenvalue to bipartition the graph by finding the splitting points so that Ncut is minimized.

(4) Decide if the current partition should be subdivided by checking the stability of the cut. The stability criterion is defined to measure the degree of smoothness in the eigenvector values.

(5) Recursively repartition the segment parts, otherwise exit.

Fig.3. shows the image segmentation result via normalized cut.

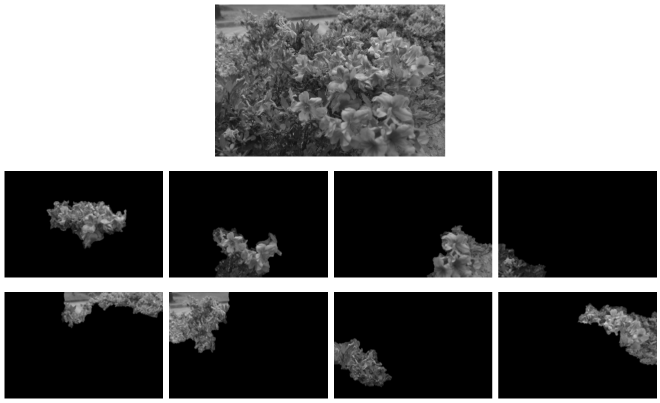

Fig. 3 Image segmentation

C. Sum-modified-Laplacian (SML)

Sum-modified-Laplacian [6] is developed to compute a local measure of the quality of image focus. In Ref. [7] addresses that SML can provide better performance in the focus measurement criterion.

$$\nabla_{ML}^2 I(x,y) = |2I(x,y) - I(x - step, y) - I(x + step, y)| + |2I(x,y) - I(x, y - step) - I(x, y + step)| \quad (4)$$

In order to accommodate for possible variations in the size of texture elements, a variable spacing (step) is used between the pixels to compute ML. In this paper, 'step' equals 1.

$$F(x,y) = \sum_{i=x-N}^{i=x+N} \sum_{j=y-N}^{j=y+N} \nabla_{ML}^2 I(i,j) \quad for\ \nabla_{ML}^2 I(i,j) \geq T_{SML} \quad (5)$$

The SML coefficient of the segmentation results from previous Section is computed in this Section.

D. Fusion procedure

The SML coefficient information is combined as:

$$F_{i,j} = C_{i,j}^m \\ \text{where} \\ m = \underset{n}{\text{argmax}}\{S_{i,j}^n\}, n = 1, \dots, N \quad (6)$$

where $F_{i,j}$ is a final coefficient in the fused image at (*i, j*). While $C^m_{i,j}$ is a maximum SML coefficient information at (*i, j*). $S^n_{i,j}$ is SML information at *n* stack source image. *N* is a number of stack images.

E. Consistency verification (CV)

After fusing the combined SML coefficient, we check the result by consistency verification. The process utilizes majority filter with the considering window size to achieve a quality of the result. Then, the final SML coefficients information will be created. A majority filter is implemented with 3×3 window size.

F. *All-focused Imaging*

Finally, the all-focused image is merged all the selected regions related to the final SML coefficients, which are obtained by the CV process.

III. EXPERIMENT RESULTS

In order to evaluate our proposed method, the all-focused images are used to compare the proposed method with the conventional methods. We present the result of the proposed method with different sample images. We have implemented experiments on 512 × 341 and 512 × 512 pixel images.

We introduce some objective criteria such as the peak signal-to-noise ratio (PSNR) and the root mean square error (RMSE) are utilized to perform the image results.

A. *Peak signal-to-noise ratio (PSNR)*

The peak signal-to noise ratio is expressed as:

$$PSNR = 20 \times log_{10}(\frac{MAX_I}{\sqrt{MSE}}) \quad (7)$$

where

$$MSE = \frac{1}{M \times N} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} [R(i,j) - I(i,j)]^2$$

where R and I are the reference image and computed image respectively, with the image size is $M \times N$ pixels. MAX_I is the maximum possible pixel value of the image, in this paper is 255.

B. *Root mean square error (RMSE)*

The root mean square error is expressed as:

$$\text{RMSE} = \sqrt{\frac{\sum_x \sum_y [R(x,y) - I(x,y)]^2}{M \times N}} \quad (8)$$

where R and I are the reference image and computed image respectively, with the image size is $M \times N$ pixels.

Fig. 4 illustrates the sample image datasets which are taken by Lytro light field camera [2]. The camera provides the images which display same location view with the various focusness. The resolution of Fig. 4(a) and (b) are 512 × 341 pixel images while Fig. 4(c) is 512 × 512 pixel image.

Fig. 4 Sample image datasets

Fig.5 to Fig.7 show the measure of in-focused regions of the stack image. The result demonstrates only regions with a sharp focus.

Fig. 5 The in-focused image region of the stack images

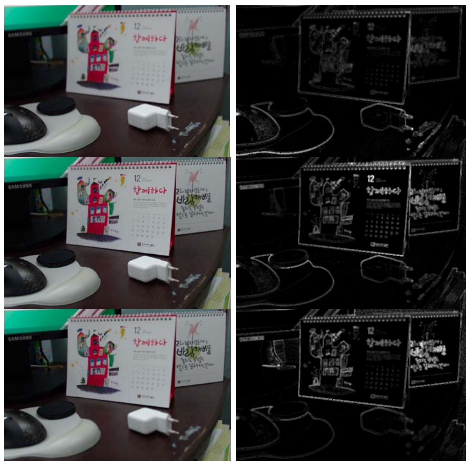

Fig. 6 The in-focused image region of the stack images

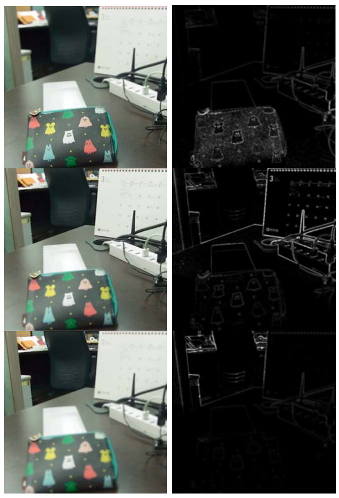

Fig. 7 The in-focused image region of the stack images

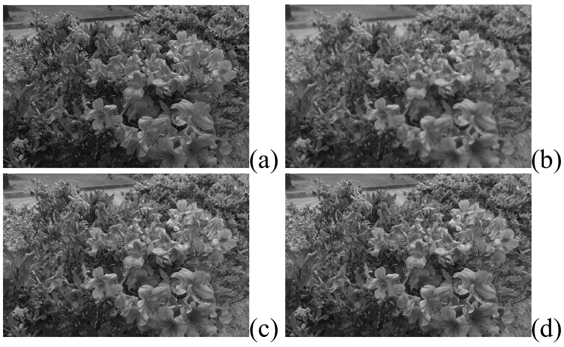

Fig. 8 All-focused image: (a) reference image, (b) averaging image, (c) SML method image, (d) proposed method image

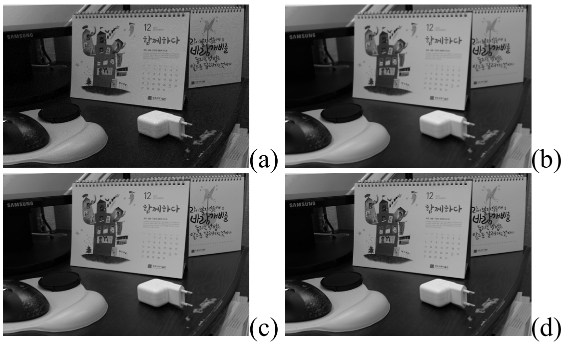

Fig. 9 All-focused image: (a) reference image, (b) averaging image, (c) SML method image, (d) proposed method image

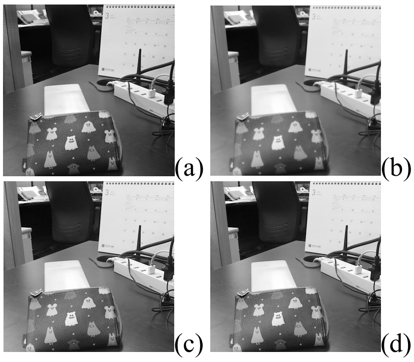

Fig. 10 All-focused image: (a) reference image, (b) averaging image, (c) SML method image, (d) proposed method image

Fig. 8 to Fig 10. illustrate the result of all-focused images using different focal measurement. Fig. 8-10(a) are the reference images, while Fig. 8-10(b) show the fused images via averaging method. Fig. 8-10(c) display the result images using SML method, and Fig. 8-10(d) are the all-focused images applied with the proposed method. To evaluate the performance objectively, we compare the proposed method with conventional methods. We use RMSE and PSNR with respect to the reference image [2]. We also obtain the superior results as shown in Table I.

TABLE I
PERFORMANCE OF DIFFERENT FOCUS MEASUREMENT METHOD

Image	Criteria	Pixel Avg.	Pixel-based SML[6,7]	Proposed method
Flower	RMSE	11.3432	7.0385	7.0248
	PSNR(dB)	27.0430	31.1890	31.2058
Stuffs	RMSE	5.5221	4.1545	4.1360
	PSNR(dB)	33.2928	35.7621	35.8004
Wallet	RMSE	11.3377	9.5787	9.5760
	PSNR(dB)	27.0415	28.5048	28.5072

IV. CONCLUSIONS

In this paper, we presented a measure of image focus method. The proposed method used image segmentation via normalized cut to cluster image into small regions. After that, we applied the corresponding regions with sum-modified-Laplacian and verified the results with consistency verification. Finally, the all-focused image could be reconstructed. From the experiment results, we have confirmed that the proposed method measured the in-focused region efficiently. In addition, the results produced by the proposed method outperformed conventional method in terms of RMSE and PSNR.

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