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An Image Stabilization Technology for Digital Still Camera Based on Blind Deconvolution

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Abstract – We have developed a new image stabilization technology for still images based on blind deconvolution and introduced it into consumer digital still cameras. This technology allows us to reduce processing time and ringing artifacts, the common problems in image deconvolution, without deteriorating deblurring performance.

I. INTRODUCTION

A number of studies on image deconvolution have been conducted in the past ten years [1] and lately some of them have been proposed for application to hand-blur correction in digital still cameras [2]. It is difficult, however, to introduce them into actual products, because image deconvolution requires precise blur detection and long processing time, and generates ringing artifacts in restored images.

We have developed a new image stabilization technology for digital still cameras that is based on image deconvolution in case of unknown blur, “blind deconvolution”, and reduces processing time and ringing artifacts.

In this paper we describe our newly developed algorithm and the image stabilization system in which the algorithm has been implemented. Then we present some experimental results of this algorithm and system.

II. PROPOSED ALGORITHM

There are three problems when image deconvolution is applied to image stabilization in digital still cameras. First, the blur has to be estimated precisely without using gyro sensors. Second, ringing artifacts in the deconvolved image need to be suppressed. Third, the processing time has to be shortened. To solve these problems, we propose a new algorithm called “Hand-blur Refiner”. It consists of three distinctive functions as follows:

A. Double-exposure-based PSF Detector

Ayers proposed a method for estimating a PSF, “Point Spread Function”, generated by a motion blur from a single blurred image, as shown on the diagram in Fig. 1 [3]. This method, however, has the following problems due to its iterative optimization procedure: (a) It requires a long processing time until it converges, and (b) It might get trapped in a local minimum resulting in a wrong PSF. We propose new method to solve these problems. Two pictures are taken sequentially, one is a regular image and the other is a short-exposure image. The latter is used as the initial estimation of the deblurred

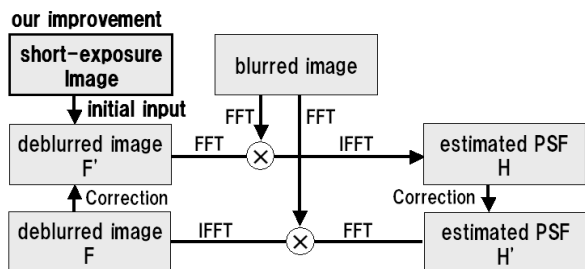


Fig. 1 Block diagram of Ayer’s blind deconvolution method and our improvement

image. This improvement enables an accurate PSF detection and shorter processing time.

B. Edge-based Ringing Reduction

Although several methods to suppress ringing artifacts have been proposed, almost all of them decrease the effect of image deblurring. We propose a new method to reduce the ringing by blending the blurred image and the deconvolved image using weights based on edge strengths of the blurred image. The resulting pixel values in low contrast areas, where ringing is visible, are based mostly on the blurred image, while the restored image is used in the edge areas, where the deblurring effect is more noticeable. This method removes ringing artifacts without deteriorating the deblurring performance.

C. Efficient Deconvolution Filter

Under ideal conditions, the deblurred image is created by applying an inverse filter calculated from the PSF to the blurred image. However, calculating an inverse filter from the PSF has an ill-posed problem. There are no clear and simple methods to determine a filter size and its coefficients. We propose a new algorithm to determine the minimum size for an effective deblurring filter. This algorithm first trims the filter coefficients depending on their contribution to deblurring, and then further reduces its size by applying a windowing function.

III. SYSTEM CONFIGURATION

A block diagram of the Hand-blur Refiner is shown in Fig. 2. At the shutter button pressed, both regular and short-exposure images are taken into a frame memory. Next, a DSP estimates the PSF using both images, calculates deblurring filter coefficients and sets up the FIR filter. Then the FIR filter performs both filtering and deringing on the regular image and outputs the result to the LCD monitor and the memory card.

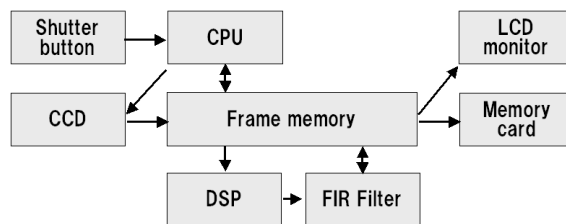


Fig. 2 Block diagram of the Hand-blur Refiner

IV. EXPERIMENTAL RESULTS

We have evaluated the performance of the Hand-blur Refiner, and shown as follows:

A. Blur Detection Performance

Tests were conducted for 1/15 second exposure time and focal length of 105 mm (35mm equivalent). We placed a board with a dot pattern in front of a resolution chart and took 100 pictures of them.

Then we evaluated the results of both the Ayers' method and our Double-exposure-based PSF Detector. Table 1 shows their success ratios and processing times. Not only the processing time has become 100 times shorter, but also the success ratio has improved by 40%.

Table 1 Comparison of conventional method and proposed method

	Conventional	Proposed
Success ratio	56 %	96 %
Processing time	30 sec	0.3 sec

B. Ringing Reduction Performance

The blurred images were created by applying 20 different blur patterns to no blurred image of a test chart, and were deconvolved without ringing reduction and with our Edge-based Ringing Reduction shown in Fig. 3. Then we calculated each PSNR between restored image and no blurred image. The results are shown in Table 2. The average PSNR using our method has gone up by 5 dB.

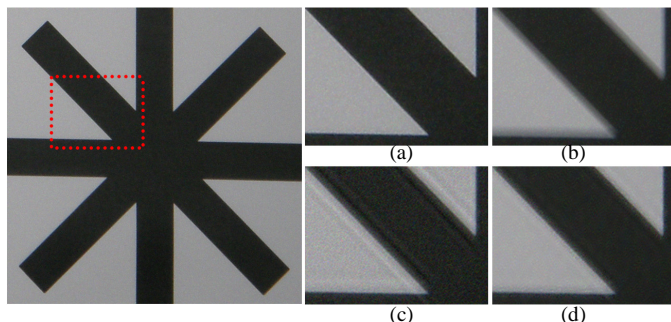


Fig. 3 Example images: (a) No blurred image, (b) Blurred image, (c) Restored image without ringing reduction, (d) Restored image with ringing reduction.

Table 2 PSNR comparison for both methods

	without ringing reduction	with our ringing reduction
PSNR	27 dB	32 dB

C. Overall Performance

The total performance of image stabilization is evaluated by using a prototype camera in which the Hand-blur Refiner is implemented. The evaluation method is original and involves calculating MTF, which characterizes the sharpness of the image. For that we use a standard CZP, "Circler Zone Plate", which allows us to measure the MTF in all directions. As shown in Fig. 4, when the blur increases, the MTF value decreases. The gray line is the MTF curve for blurred images and the black line is for their restored equivalents.

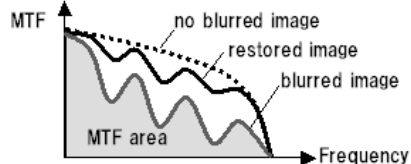


Fig. 4 MTF values for blurred and restored images

Evaluation results of the system using this method are shown in Fig. 5. The filled diamond points indicate the values for blurred images taken with the camera held in hand. The square points indicate the results for restored images. Each point is an average of 100 test results for each exposure time in the 1/125–1/8 second. The curves are approximated by a quadratic function using those points. We analyze exposure time for both curves and define T_B as the blurred image exposure time and T_R as the restored image exposure

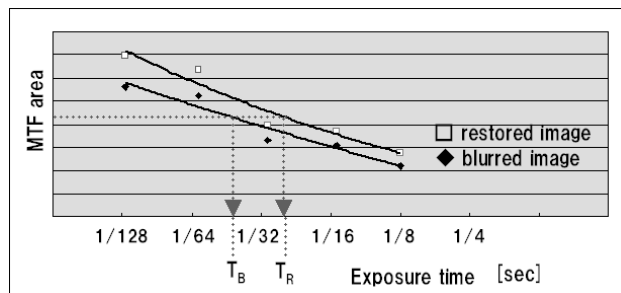


Fig. 5 Deblurring results for different exposure time

time for the same MTF area value. We also define the exposure time step as $N [EV]$, where

$$N = \log_2(T_R/T_B). \quad (1)$$

Next we calculate exposure time differences for all points to acquire exposure time step range. Using this indicator we can conclude that it is possible to take pictures with a 0.7–1.4 EV longer exposure time step while maintaining the same amount of blur. The average processing time for 8 megapixel image is 3.1 seconds, with the maximum at 4.9 seconds.

Table 3 Total performance of our system

Exposure time step	0.7 – 1.4 EV
Processing time	Ave. 3.1 sec (Max 4.9 sec)

Finally, we present restored images using the Hand-blur Refiner, as shown in Fig. 6.



(a) Original image with hand-blur (b) Restored image

Fig. 6 Example images with our system

V. CONCLUSION

We have developed a new image stabilization technology based on blind deconvolution and implemented it in digital still cameras. Evaluation results show that in the 1/125–1/8 second exposure time range we have achieved a 0.7–1.4 EV exposure time step gain while reducing the processing time to 3 seconds on average.



Fig. 7 Camera in which the Hand-blur Refiner is implemented

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