DEBLURRING THROUGH WATER IMAGE BY USING LUCY-RICHARDSON ALGORITHM

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ABSTRACT:

There has important information for ecological restoration and flow control dredging to take the picture of underwater gravels. But it is difficult to take high quality pictures in shallow water. Since underwater camera is constrained by depth in shallow water (< 40 cm), and imaging affect by water waves above the water.

In this research, the camera is set up above the water, and take the continuous picture through water wave. For reconstructing the distorted picture, each pixel can be averaged with number of pictures. The result is like simulating a long time exposure picture. But this method will lead to blur. Lucy-Richardson algorithm is a iterative method to deblur, and point spread function is the kernel for Lucy-Richardson algorithm. Point spread function can be found by setting a white broad which has a red dot in the middle in the water and observing the red dot distribution.

The result is effective in reconstructing the distorted picture by water wave and deblurring the blurred picture by simulating the long time exposure picture, and can get higher quality pictures for underwater gravels in shallow water.

1. Introduction

In the shallow water, the underwater camera is constrained by depth, so the camera has to be set above water surface, and image through the water surface. In the field, the water surface is disturbed by wind and flow, and lead to the water wave. Imaging through the water wave, light path will be changed, and lead to the distorted image which can't identify the underwater feature, show in fig. 1.

For taking a clear image and observing the underwater feature, Bulter (2002) puts an acrylic sheet (1.5 m × 1.5 m × 0.003 m) on water surface to calm the surface, show in Fig. 1(a). Whitman (2003) used a cylinder to calm the water surface. And, a camera was placed on top of the cylinder for underwater image collection, show in Fig. 1 (b). But there has some problem for these method. First, the acrylic sheet and the cylinder are very heavy and occupying the space. They are inconvenient for carrying to the field. Second, the underwater image is constrained by the size of equipment. Finally, they have to overcome the impact by the flow in the rush stream, it is difficult to operate.

Recently, due to the digital process (DIP) is available and the properties of the professional camera is promoted, we can image the underwater features in the field, then apply the DIP to solve the problem. It can reduce time effectively in the field, and supply high quality images to use, such as Chen and Wang(2010) applied mode-based filter to promote image quality, but the method will lead to lose some signal in the image, the result show in Fig. 5 (b) and Fig. 6 (b) . In this research, the DIP is also applied with different concept to solve the problem, and the result is better.

The probability density function (PDF) of the slope statistics for ocean shows Gaussian distribution with zero mean and the variance which is a function of wind speed and wind direction. Figure shows the PDF of sea surface slop obtained by Shaw and Churnside (1997). Although the slope statistics of the river water surface is not reported in any references, we assume it to be similar to that of the open ocean. If continuously multiple images can be taken, one can expect to see though the water surface when the water surface is flat (zero slope) for most of the time.

According to this supposition, we take continuous images, and obtain the PDF of each pixels statistics for intensity to count the mean intensity such as the most probable intensity, and get a probable flat water surface image. But this method will lead to blur.

For deblurring, we apply Lucy-Richardson algorithm (R-L) in this research. The R-L algorithm is an iterative technique. it is used heavily for the restoration of astronomical imagery. The algorithm requires a good estimate of the process by which the image is degraded for accurate restoration. And we can find the function of R-L algorithm in Matlab's Image Processing Toolbox. It is a implementation for working with very big images and process fast.

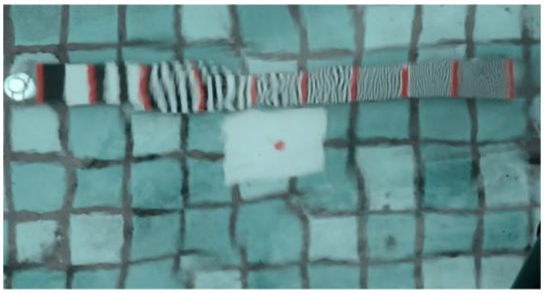

Fig. 1 Imaging through the water surface, and the image is distorted by water wave.

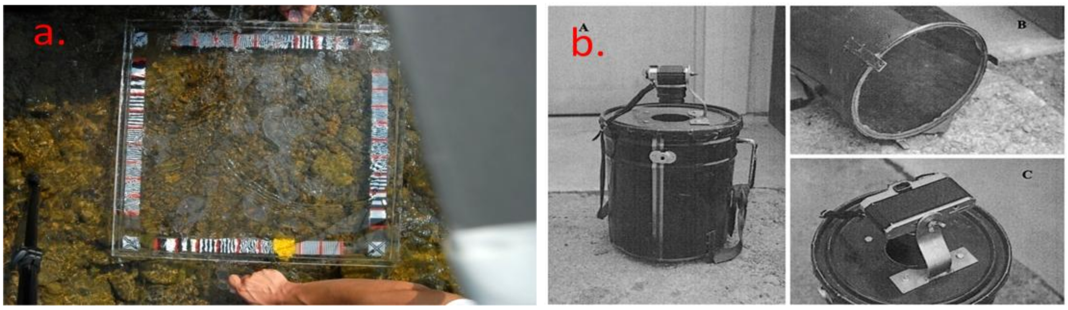

Fig. 2 (a) the acrylic sheet to calm the water surface (b) the cylinder and camera set up(Whitman, 2003).

2. Methodology and Experiment

2.1 Mean-Based Filter

Underwater image which images through the water wave leads to the distorted geometry boundary for underwater features. So the mean process is applied, and this process is regarded as long time exposure. First, we set the camera steady upon the water and take continuous images through the water wave. After field sampling, we divided image, and applied the mean process. Each pixel is averaged with number of images to simulate a long time exposure image. This method can effective keep the correct geometry boundary, but the result will lead to blur.
This is equation for mean-based filter：

$$img_{mean}(x,y) = \frac{1}{T_2 - T_1} \sum_{t=T_1}^{T_2} img(x,y)_t \ .$$

The image blurred process follows this equation ：

$$g(x,y) = h(u,v) * f(x,y) + \theta(x,y).$$

where $f(x,y)$ is the original image without blurring, $h(u,v)$ is the spatial representation of the degradation function, θ is the noise term, and the symbol "$*$" represents the two-dimensional convolution, $g(x,y)$ is the blurred image, it is degraded by degradation function and noise, and it is equal to $img_{mean}(x,y)$ in mean process. The function $h(u,v)$ is also referred to as the point spread function (PSF), and it receives this name because it describes the effect when a point of the object from which the image is taken, is spread over several pixels.

2.3 Lucy-Richardson algorithm

If the PSF can be defined, the Lucy-Richardson algorithm can be applied to deblur. The algorithm is an iteration method based on the Bayes' theorem or on a maximum-likelihood formulation under the assumption of Poisson distribution. Given a priori estimate of the deblurred image, this estimate is improved iteratively, each time it gets closer to the original image. The purpose of each iteration is to maximize the probability that if the deconvolved image were blurred again with the PSF, then the result would be the same degraded image.

Clearly, as in many other iterative methods, it is necessary to define a criterion about the number of steps needed before stopping. Since deblurred images have different grades of distortion, the number of iterations needed will vary in each case .Indeed, there is no other standard criterion to define when to stop the iteration, than the desired accuracy in each particular application .In there we apply R-L algorithm with different iterations, and define the best result of iterations by minimum mean square error, and iterative times is set in 5 to 30 times, a example shows in Fig. 2. Due to a too much number of iterations will lead to increase the noise.
This is the equation for standard R-L algorithm：

$$\hat{f}^{(r+1)}(x,y) = \hat{f}^{(r)}(x,y)\left[h\ (-u,-v) * \frac{g(x,y)}{h\ (u,v) * \hat{f}^{(r)}(x,y)}\right].$$

where $\hat{f}^{(r)}$ is all the estimated image without the water effect after r iterations, $\hat{h}^{(r+1)}$ is the estimate of PSF after r+1 iterations which is found by observing the red point target distribution. g is the blurred image which is effected by water wave.

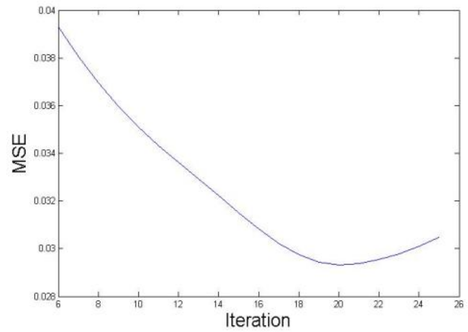

Fig. 2 The MSE is changed with iteration, and the best iterative result is found by minimum MSE.

2.4 Simulated ideal red point and Find PSF

For finding the PSF, there has a target in the water, which is a white board and has a red point in the middle in our experimental set. The target will be distorted by water wave, and it will be blurred after the mean operation. The PSF can be estimated by observing the red point distribution. So a ideal red point has to be decided and compare with the blurred one. We select a frame on the target's image which is include the red point's part. We subtract the intensity green from red. This step can let we get the distribution without the noise and lead to the intensity of background is zero.

Next a ideal red point distribution has to estimate. It can class as center, radium and intensity. For center of the ideal red point, the least squares method is applied by estimating the center of the blurred red point. For radium and intensity, we are estimated by trail and error, the distribution radium of the blurred one is took as an index, and divide into ten parts to be the ideal red point radium, and the intensity is estimated from 45 to 90 value with 5 interval. Then we attempt this variable value to calculate by modifying R-L algorithm, and the results are the estimated PSFs, it should have 100 results. Finally, the standard R-L algorithm is applied to deblur with all the estimated PSFs, it also should get 100 deblurred images, and we select the best result by calculating the minimum MSE of the blurred red point and the deblurred one.
This is the equation for estimate the PSF from modifying R-L algorithm：

$$\hat{h}^{(r+1)}(u,v) = \hat{h}^{(r)}(u,v)\left[\hat{f}(-u,-v) * \frac{g(u,v)}{\hat{f}(u,v) * \hat{h}^{(r)}(u,v)}\right].$$

where $\hat{f}$ is the distribution of simulated the ideal red point, $g(u,v)$ is the distribution of the blurred red point which is processed by mean algorithm and effect by water wave, $\hat{h}^{(r)}$ is the estimate of PSF after r iterations.

2.5 Equipments and Experimental set up

Recently, newly developed professional digital SLR is provided Full HD format (1920X1080), and the different lens can be installed for different scene with different focal length to get the high quality video, and the video will be divided into images to use. It can increase the imaging efficiency**.** In this research, Nikon D7000 is operated, and the fps of Full HD is 30 frames a second.

For managing the complex underwater scene in the field, AF-S Micro NIKKOR 60mm f/2.8G ED is installed on Nikon D7000. The Lens features are ED(Extra-low Dispersion) glass element for superior sharpness and color correction by effectively minimizing chromatic aberration and Nano Crystal Coat and high-performance Nikon Super Integrated Coating delivers superior color reproduction, while substantially reducing ghosting and flare.

After DIP process, the image quality have to evaluate. For this reason, a frame is set under the water which is pasted on MTF bar, and imaged. MTF bar can define the image quality by the efficiency of identifying the black and white intensity, show in Fig. 3 (a). There has a target which is imaged under the water, it is a white board which has a red point in the middle, the target is applied to deblur, show in Fig. 3 (b).

The images is taken in a pool in National Cheng Kung University. The depth is approximately 30cm, and the artificial wave is made by slapping the water surface. The experimental set is show in Fig. 4. Each data the video is recorded 1 minute, and the video can be divided 1800 images, and the images is selected in middle video to avoid shacking by triggering the record button on the camera.

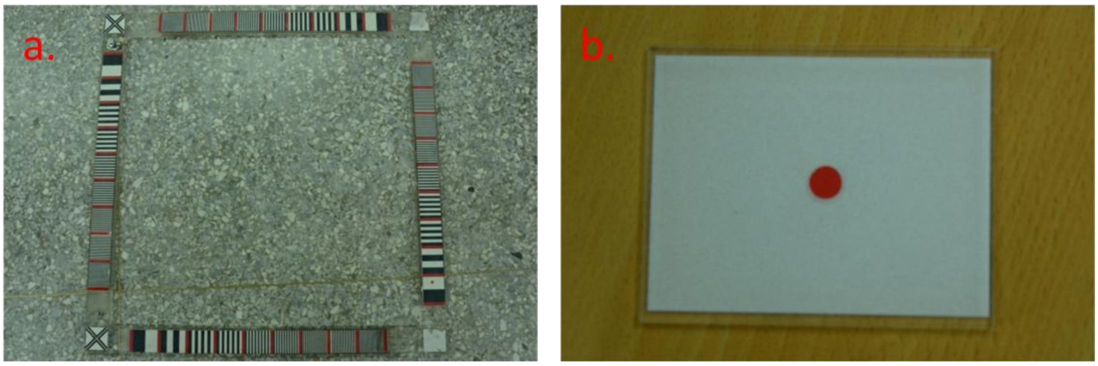

Fig. 3 (a) The MTF fame(50X50cm), due to the test site, in there we only use one side MTF bar to be imaged on the image. (b) the red point target to be a deblurred reference, the white board is

17.5X19.5cm, and the diameter of red point in the middle is 1cm.

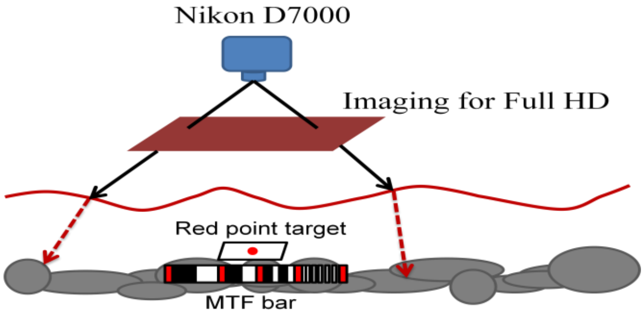

Fig. 4 Experimental set

5. Result

There has two examples to be given for flow type, the water surface one is smooth, the other is disturbed by slapping. Fig. 5 shows smooth one and Fig. 6 shows disturbed one .Fig. 5 (a) and Fig. 6 (a) shows the mean-based filtered image of 300 continuous images. The geometric characteristics, such as boundary of the red point target and MTF bar code are kept by mean-based filter process in both flow type. But the edges of underwater features are blurred by this process, just like be covered with a membrane. Fig. 5 (d) and Fig. 6 (d) shows the result of deblurred process by R-L algorithm. In all image is clearer than the blurred one, and also black and white is sharper, the blurred red point is also converged. The MTF curve is obvious promote on high frequency. Fig. 5 (b) and Fig. 6 (b) shows the mode-based filtered image of 300 continuous images (Chen and Wang, 2010), similarly, it can get a good result to reconstruct image, even the image quality is higher than mean-based filtered image.

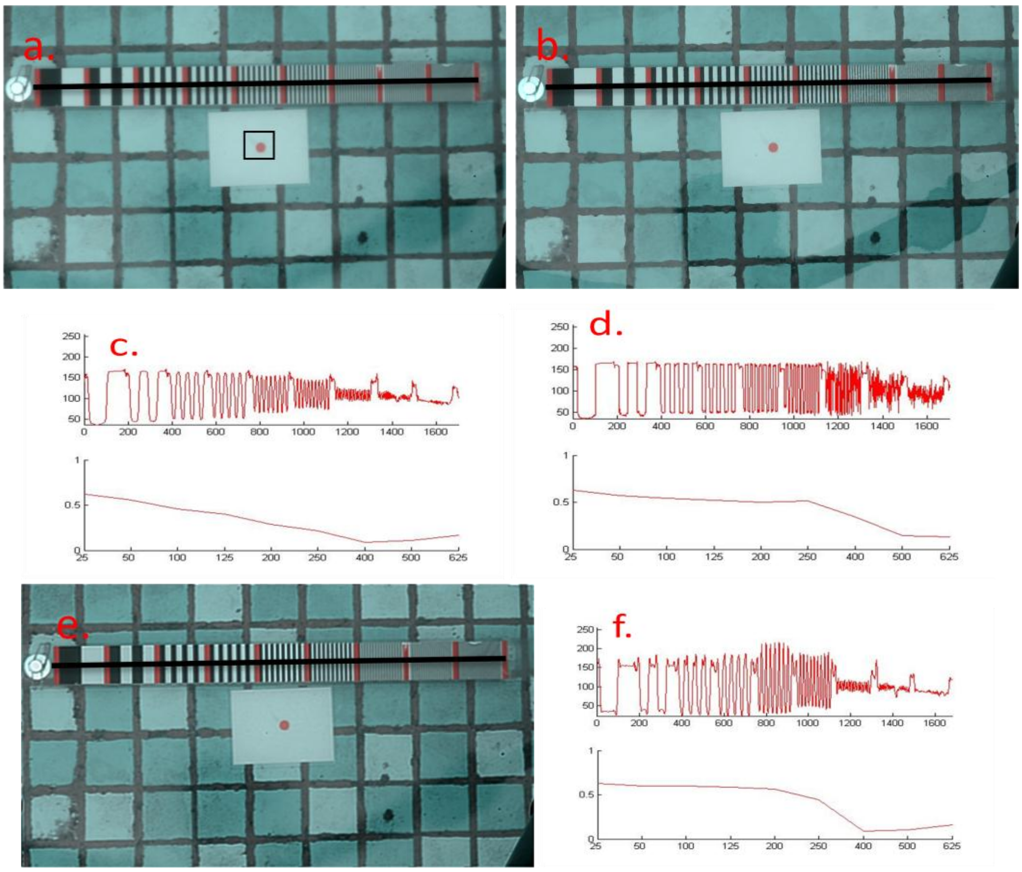

Fig. 5 The result of DIP process from the images of smooth water surface, the black lines on the image in (a) (b) (c) are applied to compare with MTF bar code. (a) The result after mean-based filter, in the flat water surface it is still slight blur. The image in the block frame is applied to find the blur kernel(PSF), the MTF curve show in (c). (b) The mode-based filtered image, the MTF curve show in (d). (e) The result is deblurring from mean-based filtered image with R-L algorithm, the MTF curve

show in (f).

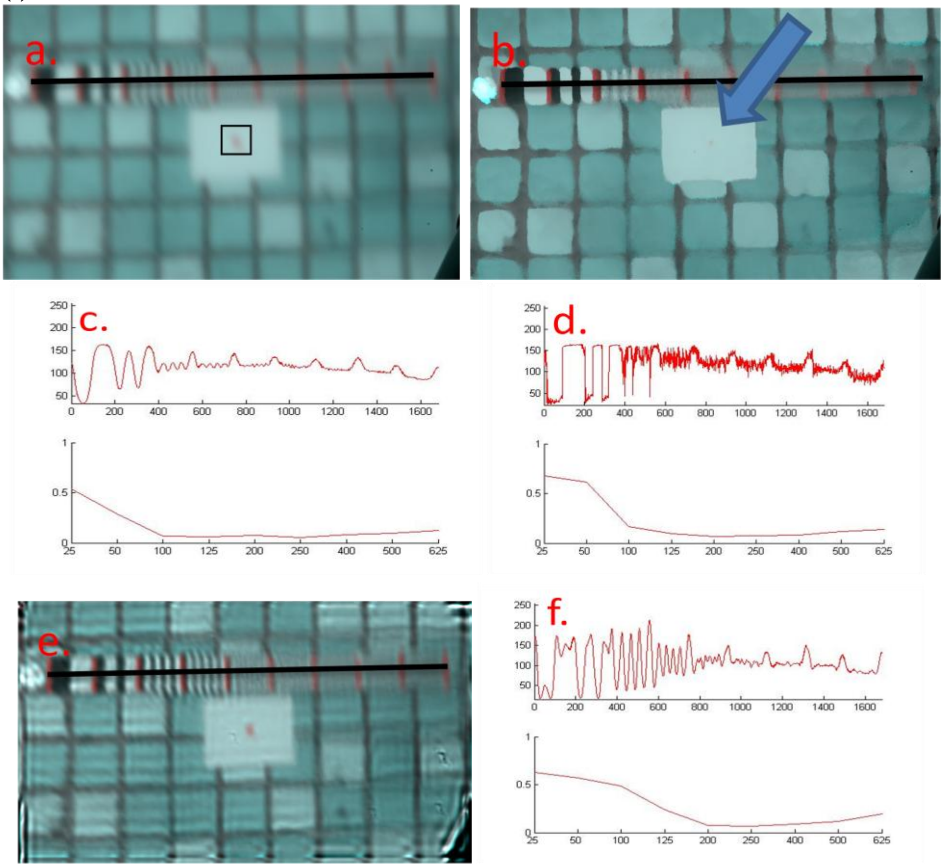

Fig. 6 The result of DIP process from the images of distorted water surface, the black lines on the image in (a) (b) (c) are applied to compare with MTF bar code. (a) The result after mean-based filter, in the disturbed water surface it is serious blur. The image in the block frame is applied to find the blur kernel(PSF), the MTF curve show in (c). (b) The mode-based filtered image, the MTF curve show in (d), and the red point of mode-filtered image is lost. (e) The result is deblurring from mean-based filtered image with R-L algorithm, the MTF curve show in (f).

5. Conclusion

The mode-based filter and R-L algorithm method can promote the image quality effectively. In smooth, the results are close, both of them has good result, and it seem that the MTF of mode-based filter is steadier. But in the disturbed water surface, the MTF curve of R-L algorithm method is better than mode-based filter in high frequency. Although the mode-based filter has a good result and the signal is steady on MTF, it leads to lose the signal, the red point is disappeared by mode process, show in Fig. 6(b). For getting the high quality image and avoiding losing the signal , R-L algorithm method supply a good result.

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