Removal of Underwater Turbidity Using an Optical Imaging Platform

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Abstract - To design and study under water imaging system in this paper we will use CODE V optical simulator. The effect of underwater turbidity will be studied with the help of optical parameters such as Modulation Transfer Function (MTF), Optical Transfer Function (OTF), and Point Spread Function (PSF). Point spread function (PSF) option computes the characteristics of the images of point objects including the effects of diffraction. It is used when the structure of polychromatic images are aberrated and to analyze it when it is out of focus. These test parameters will be then used for the design and implementation of restoration filter that will remove under water distortion completely. The prior estimated parameters will be used in a Bayesian Restoration Filter using least square approach.
Experimental results show how the proposed algorithm is better than existing methods both qualitatively and quantitatively.

Index Terms: Code V, Image restoration, PSF, Turbidity

1. Introduction

To deal with underwater images (underwater image processing), first we need to consider the physical properties of medium (water) which mainly causes the degradation effects usually that is not present in normal images (air). The visibility of underwater images is poor due to light attenuation as a result of which poorly hazy. Large number of individual particles in water generally that is invisible to the naked eye causes the cloudiness or haziness called as Turbidity. Turbidity leads to the blurring of image features. The blur in underwater images also occurs due to defocusing (out of focus image- reducing the sharpness and contrast) and misplaced focal point.

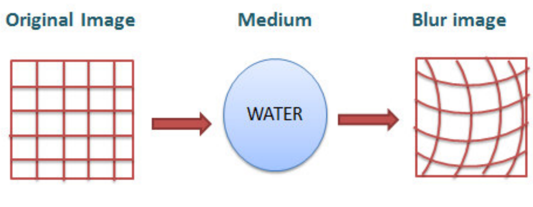


Figure: Occurrence of blur in underwater images

The main problems occur in underwater images are blurring, noisy, poor visibility, low contrast, bluish appearance. But we are mainly concentrating on blur and noisy images.The application of CODE V for analyzing and designing optical problems is required to overcome the blur and noise in underwater images. Blurred images can be reconstructed by having a knowledge of system PSF. Usually the PSF can be measured using the Image Transmission Theory.one dimensional PSF calculation can be done by deconvolution method and two dimensional PSF calculations can be done using mathematical methods. These measured functions are then applied to the wiener filter to recover the original image.

Here to calculate PSF and MTF using image transmission theory which requires mathematical methods and compact hardware and distance reconstruction is about 1 – 2m[1] . In some cases, to recover the blurred images we need to buy that particular camera(to check the lens used in the camera) from which it was taken this leads experiment to be much more expensive.

In this section we gave a brief review of current method for underwater image processing, problem and difficulties found. Our scope is to give an efficient and effective method to reconstruct the blurred and noisy underwater images. In this way we would like to guide the reader a best method that suits his applications and problems.

In section 2 we give a brief explanation of CODE V following the Point Spread Function, section 3 Brief introduction about existing method, section 4 is about proposed system following the PSF estimation using code V and implementing the measured function in matlab to recover the original image (deblurred image). Section 5 is of results and comparison and finally the section 6 sketched with conclusion.

2. Code V and Point Spread Function

Code V is powerful tool for analyzing and designing optical systems and its problems and it can be used to design a new optical system as per the requirements and for fabrication. It provides a toolkit that is easy to use for optical techniques and calculations. It can reliably produce the results in less time and cheaper than those produced with other software. It has some key productivity features like built in lens modules, prism models, new lens wizard, user friendly, fastest optimization capability, supplied with patent lens search, fabrication support features etc. Key optimization features like RMS blur, PSF, MTF, easy definition of user defined constraints, fast and accurate PSF and MTF optimization, unique quality etc. code v supports Analysis features like Polarization ray tracing, diffraction, illumination analysis accurate calculations of system performance, diagnostic evaluation options, 1D and 2D image analysis etc.It provides the accurate analysis algorithms and quality assurance to maintain this accuracy. It supports tolerancing and fabrication features.

Point Spread Function (PSF) describes the response of an imaging system to an object or point source. Generally PSF is an impulse response of a system.

System Response is a product of optical medium and system. It is given as,[1]

$$H(a,b) = H_{opticalsystem}(a,b)H_{medium}(a,b) \qquad (1)$$

PSF is the fundamental unit of an image and it plays a major role in image formation and it is the main brick that builds the acquired image. It is the 3 dimensional diffraction pattern of light which is emitted from a point source and transmitted to the image plane. It also describes the 2 dimensional distribution of light. It expresses the normalized intensity distribution of point source image. PSF is used as an indicator to identify the objective lens problems. Its analysis is used to determine the resolution and to identify the problems with the microscopic images. It is used to analyze the out of focus images, to generate and display aberrated structure of image.
In under water images, PSF can predict the underwater light propagation and under water image quality. When the image is degraded, we can restore it by estimating the PSF of an image system with the deconvolution but we should have a better knowledge of degradation and then it must be estimate and modeled.

In underwater imaging, degradation sources are – turbidity, floating particles light propagation properties in water(optical properties) and these are incorporated in to PSF.

By definition,

$$g(a,b) = f(a,b) * h(a,b) + n(a,b) \qquad (2)$$

Where, g(a,b) = observed image, f(a,b) = original image, h(a,b) = PSF, n(a,b) = noise

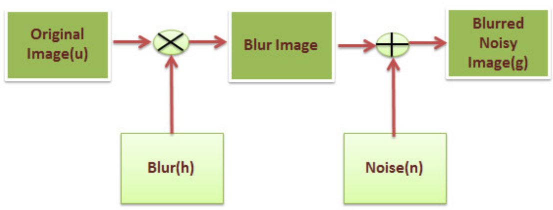


Figure: Block Diagram of image Blurring

In frequency domain,

$$G(a,b) = F(a,b)H(a,b) + N(a,b) \qquad (3)$$

Here H is called optical Transfer Function(OTF) and its magnitude is called Modulation Transfer Function (MTF). These functions are used when image is degraded with contrast and resolution.

3. Existing Technology

As per our literature survey, the method used to recover the blurred image is the first step is to calculate the Point Spread Function(PSF) by mathematical method and using this function in wiener filter.

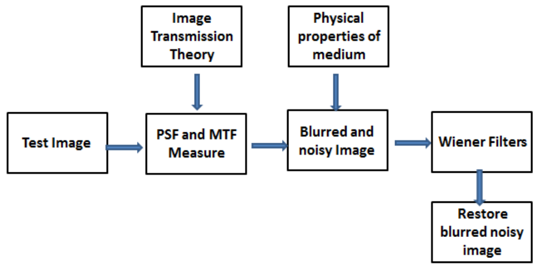


Figure: Existing Technology

Standard wiener filter is used for deconvolution process and is given by,

$$w(a,b) = h^*(a,b)\frac{h^*(a,b)}{|h(a,b)|^2 + \frac{S_n}{S_f}} \qquad (4)$$

Where, S_n = noise power spectrum

S_f = original image

And the spectrum of restored image is,

$$f(a,b) = g(a,b)\frac{h^*(a,b)}{|h(a,b)|^2 + \frac{S_n}{S_f}} \qquad (5)$$

4. Proposed Method

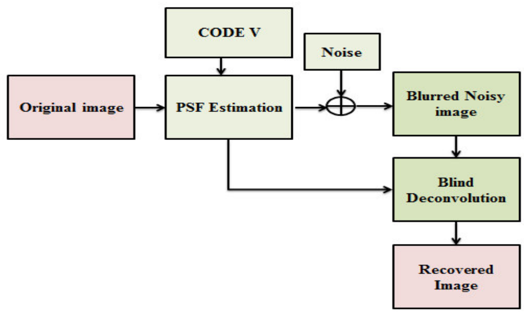


Figure: Proposed method

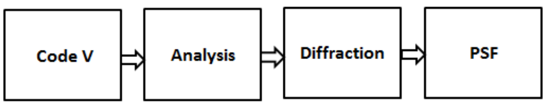
In Proposed one, we are taking the original image adding blur and noise (Gaussian) make it a blurred noisy image. In which the PSF is estimated by using Code V and the blind deconvolution method is used to recover the original image.
In addition this we also generate the PSF value in matlab using fspecial function and adding this to the orginal image and then comparing this with that obtained from Code V

After recovering the image, we calculate the PSNR values and RMSE values for both for matlab generated PSF added image and Code V generated PSF added image for comparison.

PSF estimation Using Code V

In Image Processing, Deconvolution (Blind Convolution) is a technique that allows us to recover the scene or image from a single or set of blurred images by using a PSF. PSF is estimated from an image or image set and deconvolution is performed. Relative motion between the camera and the object during the image capturing leads to blur. Estimation of the blur parameter is a key in restoring blurred images. The identification of PSF can be used as an identification of parameters of blurring. To restore the blurred image it is necessary to establish the parametric model of degradation function and accurately identify the PSF parameters.
The two important blur parameters in PSF are length (d) and angle (ɵ), if these two parameters of blurred image is available then we get the PSF and then the blurred image can be restored.

PSF can be calculated using FFT (Fast Fourier Transformer), this function is inbuilt in Code V. But we need to select the grid size and region of interest. PSF option is first calculates the pupil function from the ray traced OPD's calculated from the exit pupil. This pupil function is then embedded in Fourier Transform grid and at last FFT is used to calculate the PSF.



For example we have calculated the PSF for microscope lens . The PSF matrix and its graphical and color plot which are obtained from Code V are as shown below.

				1	1	1				
			1	3	8	3	1			
	1	1	2	5	23	5	2	1	1	
		2	3	3	11	3	3	2		
1	1	1	8	21	100	21	8	1	1	1
	1	1	9	18	90	18	9	1	1	
	1	1	5	15	49	15	5	1	1	
	1	1	4	6	14	6	4	1	1	
		1	2	6	10	6	2	1		
			2	2	3	2	2			
		1	1	1	2	1	1	1		
			1	1	2	1	1			
					1					

Figure: PSF matrix generated from Code V

Observe that in the middle of this matrix it contains higher values compare to that of surrounding values which means middle high values represents the more blur than surrounding. So we will take this middle values as 7*7 matrix.

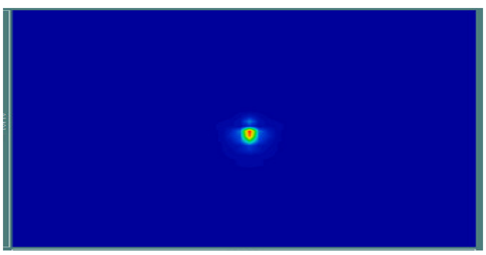


Figure: Color plot of PSF

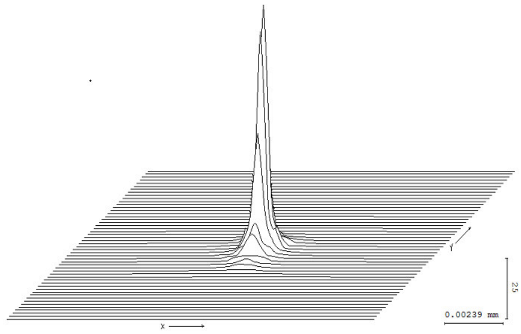


Figure: Graphical Plot of PSF

After Estimating the PSF, deconvolution process has to be done to recover the original image. The deconvolution(inverse filtering) method used here is Blind Deconvolution method because since having only better knowledge of degradation it is possible to recover the original image effectively so even if we have poor knowledge of degradation(PSF) we can reconstruct the original image from blur and noise.

To perform the deblur the image, Blurred image and Code v generated PSF are used for blind deconvolution process. This reconstructs the original image.

$$f(a,b) = \frac{g(a,b) - n(a,b)}{h(a,b)} \qquad (6)$$

Once we obtain the recovered image then PSNR and RMSE error metrics are to be calculated and used between images for comparison. RMSE is the Root Mean Square Error that Calculates the average of squared errors(difference between the estimator and estimated one). As the RMSE value is low then error content will also be low and vice versa. It can be calculated as,

$$MSE = \frac{\sum_{X,Y} [I_1(x,y) - I_2(x,y)]^2}{X,Y} \qquad (7)$$

Where,
I_1 and I_2 are the images to be compared
X and Y are the rows and columns of the images

PSNR(peak error) is the Peak Signal to Noise Ratio, if the signal strength is more than the noise power then PSNR value increases and vice versa. If the PSNR value is good then the image quality will all be good (PSNR value raises the image quality will also raises) and vice versa. It can be calculated as,

$$PSNR = 10\log_{10}\left(\frac{R^2}{MSE}\right) \qquad (8)$$

Where, R= maximum fluctuation in image

5. Results

(a)

(b)

Figure: (a) Original Image (b) (image with matlab generated PSF) blurred image

(c)

(d)

Figure: (C) blurred image (with code v generated PSF) (d) reconstructed image

Result comparisons:

PSNR1	PSNR2
22.0019	**22.6512**

PSNR 1 and PSNR 2 are calculated for Images (a) & (b) and (a) &(c) respectively

RMSE1	RMSE2
6.0902	**5.8056**

RMSE 1 and RMSE 2 is calculated for images (a), (b) and (a), (c) respectively.

6. Conclusion:

The difficulty associated with the existing method to recover the original image is that to calculate PSF it requires Mathematical methodologies (matlab calculations) it is difficulty and takes more time to estimate. here it necessary to understand and learn functions in matlab before using it to calculate PSF and to analyze the lens of the camera from which the particular image has been taken we need to buy that particular camera it becomes expensive.

So these difficulties can be overcome by using code v to generate PSF values as it takes only few seconds to generate and it is user friendly and easy to learn and use. And more and more lenses are in built in Code V and we do not need to buy the camera to analyze the lens for image recovery.

Our result analysis shows the comparison between two PSFs, one is estimated from matlab calculations and other is estimated using Code V.PSNR comparison table showing that both the values are almost equal so we use code v to generate PSFs easily in less time consumption than that of mathematical method as it consumes less time to generate when to compared to matlab calculations.

On the other side, RMSE comparison table shows that the image with code v generated PSF has less error occurrence than the image with matlab generated PSF.

So we are concluding that Code v cab be used to estimate Point Spread Function (PSF) and using it analyzing underwater images then implementing code V generated PSF in matlab to produce and effective and efficient method to recover the original image from blur and noise.

References

[1] Raimanodo Schettini and Silvia Corchs "Underwater Image Processing: State of the Art of Restoration and Image Enhancement Methods", *EURASIP Journal on Advances in Signal Processing*, 2010.

[2] Code V reference manual.

[3] Z.Liu, Y.Yu, K.Zhang and H.Huang, "underwater image transmission and blurred image restoration,"*optical Engineering,*vol.40,no6, pp 1125-1131,2001.

[4] B. McGlamery, "A computer model for underwater camera system," in *Ocean Optics* VI, S. Q. Duntley, Ed., vol. 208 of Proceedings of SPIE, pp. 221–231, 1979.

[5] Mauricio Delbracio , Publo Muse , Andres Almansa "Non – parametric Sub – Pixel Local Point Spraed Function Estimation," *Image Processing online*, 2012.

[6] Y. Y. Schechner and N. Karpel, "Recovery of underwater visibility and structure by polarization analysis," *IEEE Journal of Oceanic Engineering, vol*. 30, no. 3, pp. 570–587, 2005.

[7] J. Mertens and F. Replogle, "Use of point spread and beam spread functions for analysis of imaging systems in water," *Journal of the Optical Society of America*, vol. 67, pp. 1105–1117, 1977.

[8] W. Hou, D. J. Gray, A. D. Weidemann, G. R. Fournier, and J. L. Forand, "Automated underwater image restoration and retrieval of related optical properties," in *Proceedings of the IEEE International Geoscience and Remote Sensing Symposium (IGARSS '07)*, pp. 1889–1892, 2007.

[9] F. Petit, A.-S. Capelle-Laiz´e, and P. Carr´e, "Underwater image enhancement by attenuation inversion with quaternions," in *Proceedings of the IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP '09)*, pp. 1177–1180, Taiwan, 2009.

[10] E. Trucco and A. Olmos, "Self-tuning underwater image restoration," *IEEE Journal of Oceanic Engineering*, vol. 31, no. 2, pp. 511–519, 2006.

[11] R. Eustice, H. Singh, and J. Howland, "Image registration underwater for fluid flow measurements and mosaicking," in *Proceedings of the IEEE Oceans Conference Record*, vol. 3, pp. 1529–1534, 2000.

[12] Z. Wang, A. C. Bovik, H. R. Sheikh, and E. P. Simoncelli, "Image quality assessment: from error visibility to structural similarity," *IEEE Transactions on Image Processing*, vol. 13, no. 4, pp. 600–612, 2004.

[13] W. Hou and A. D. Weidemann, "Objectively assessing underwater image quality for the purpose of automated restoration," in *Visual Information Processing XVI*, vol. 6575 of *Proceedings of SPIE*, Orlando, Fla, USA, April 2007.

[14] D. M. Kocak and F. M. Caimi, "The current art of underwater imaging—with a glimpse of the past and vision of the future," *Marine Technology Society Journal*, vol. 39, no. 3, pp. 5–26, 2005.

[15] D. M. Kocak, F. R. Dalgleish, F. M. Caimi, and Y. Y. Schechner, "A focus on recent developments and trends in underwater imaging,"*Marine Technology Society Journal*, vol. 42, no. 1, pp. 52–67, 2008.

[16] S. Bazeille, I. Quidu, L. Jaulin, and J. P. Malkasse, "Automatic underwater image pre-processing," in *Proceedings of the Caracterisation du Milieu Marin (CMM '06)*, 2006.