# Performance Evaluation of Image Processing Algorithms for Underwater Image Enhancement in FPGA

Alex Raj S. M.[1], Khadeeja N.[1], Supriya M. H.[2]

[1](*Department of Electronics and Communication, Government Engineering College Bartonhill Thiruvananthapuram, Kerala, India*)
[2](*Department of Electronics, Cochin University of Science and Technology, Kochi, Kerala, India*)

***Abstract:*** *Underwater photography is challenging due to poor illumination and varying environment condition. Due to the insufficient illumination provided by the Automated Underwater Vehicles (AUV), the obtained degraded images need to be enhanced. Image enhancement techniques have to be implemented in hardware to be used with AUVs. Field Programmable Gate Arrays (FPGA) have been proved to be a better option for being used in image processing techniques due to it's inherit parallelism. Various spatial domain techniques for image enhancement techniques such as power law transform, contrast stretching, Histogram Equalization, Histogram Stretching, Negative transformation are used to preprocess an underwater image. In this paper a comparative analysis of above image enhancement algorithm implemented in FPGA is done.*
***Key words:*** *FPGA, Image Enhancement, Histogram, Power law transform.*

## I. Introduction

Submarine environment is rich in underwater cultural heritage. Underwater archeology deals with studying this rich cultural heritage. Underwater imaging practices to seize the data like coral reefs, detecting oil pipe lines as well as telecommunication cables, ship wrecks etc.[1] Hence researches are being undertaken in deep sea regions. Sea was the major route for commercial activities in ancient times. The great part of trade has been though ships. The shipwrecks were often common in those times due to the ever-changing and unexpected storms in these regions. Hence shipwrecks light to the ancient culture and hence the archeologist are keen in this. Shipwrecks can be called as the moments in time, which gives much information about the people and culture. Even the scientific methods of archeology may force into a controlled destruction.

Underwater imaging is quite difficult due to the poor illumination. The light rays travelling through the water undergoes scattering attenuation and sometimes it gets absorbed by the water molecules and other suspended particles in the underwater. As the depth of ocean increases, which in turn results in the visually degraded images. Due to the scattering effect of the light in the aquatic environment, the artificial light source to be provided for adequate illumination. Disastrously these artificial lightning tend to illuminate the scene in a non-uniform fashion Every sensor which produces spatially distributed intensity values of electromagnetic radiation which can be digitized and stored in RAM is suited to image capturing. [2]Depending on the application, the image capturing systems are varied, they differ in mode of acquisition and its speed, spatial resolution spectral and dynamic range, sensor systems etc.

The greater the need for accuracy, the more hard and software is used in image capturing and processing. Field Programmable Gate Arrays (FPGAs) and Application Specific Integrated Circuits (ASICs) help the designers to a greater extend. The main difference depends on cost tool availability design flexibility and performance. The field programmability, reusability, simpler design cycle and lower cost make FPGA more preferable to ASIC. FPGA have special hardware the block RAM, memories high-speed I/O, etc. in built which can be used to get better performance.

Xu et al [3] proposed object based multilevel contrast stretching method for image enhancement. The method first divides the image into its constitute objects, And separately stretches the image contrast at inter object level and intra object level. It can avoid introducing artifacts such as ringing and blocking.Tae et al. (1998)[4] has discussed a block-overlapped histogram equalization system for improving the contrast of an image sequences using numerous applications. The conventional histogram-based contrast enhancement technique is limited in real time application due to a large computational and storage requirements and it also exhibit quality degradation caused by possible loss of infrequently distributed pixel intensities, which may result in terrible loss of vital information. Jiang Duan [5] in Local contrast stretch based tone mapping for high dynamic range images presents a local tone mapping method to render high dynamic range images on conventional displays. It adaptively stretch contrast in local areas to reproduce local contrast and effectively uses bilateral filtering to smooth the image prior to contrast stretching operation. In Histogram equalization using neighborhood metric Eramian et.al [6] has proposed a new method for histogram equalization, in which

the histogram is further subdivided using local image properties, called neighborhood matrices. The choice of metric is characterized by how the bin are to be subdivided, and possibility for contrast enhancement.

In the succeeding sections the prerequisite background on different image processing algorithms are given, the next chapter contains the hardware implementation and results and discussion. By analyzing the quality measurement parameters the histogram equalization method gives the better result.

## II. Prerequisite Background

Digital still color cameras have gained significant popularity in recent years, There are two distinct aspects of image processing, the colourometric perspective and generic image perspective.[6] Images are captured as points in space, each with a certain level of intensity with reference to certain spatial coordinates and stored in memory as numbers reflecting the relative strength. Storing images in color requires more information than grayscale images.

Image enhancement simply means, transforming an image f(x, y) into image g(x, y) using T. Where T is an operator on f(x, y) defined over a specific neighborhood about point (x, y) the pixel values g(x, y) and f(x, y) are related by the expression: [7]

$$g(x, y) = T[f(x, y)] \tag{1}$$

**2.1. Image Inverting:** In grayscale image, each byte has an intensity value between 0 and 255, 0 being the lightest shade and 255 is the darkest shade. To invert image, is simply subtracting 255 from the current pixel value. It can be mathematically represented as:

$$g(x, y) = L - 1 - f(x, y) \tag{2}$$

Where g(x,y) is the transformed pixel. L is the maximum intensity level [7].

**2.2 Thresholding**: Thresholding is simple method of image segmentation. To threshold a color image, different threshold values can be assigned to each RGB plane, and combine them together to get the threshold image.

**2.3. Power law transform:** Image intensity values can be modified by taking nth power and nth root of current intensity values.
This can be mathematically expressed as:

$$g(x, y) = cf(x, y)^{\gamma} \tag{3}$$

Where c and $\gamma$ are positive constants.
This equation can be modified as:

$$g(x, y) = c(f(x, y) + e)^{\gamma} \tag{4}$$

Power law curves with fractional values of gamma map a narrow range of dark input values into a wider range of output values.

**2.4. Contrast stretching:** The contrast of an image is basically the measure of dynamic range, it can be viewed as the spread of histogram. Entire range of intensity values contained in an image is called the dynamic range. If wide range of pixels fall under low intensity region, results a rather low contrast image. In order to retrieve the information from those low intensity regions, contrast stretching is one of the easiest methods. Contrast stretching is restricted to a linear mapping of input pixels to the output pixels. Let a and b be the lower and upper limit of the intensity values that will be extended. c and d are lower and upper intensity levels of the unmodified picture. If the input pixels restricted to a certain range, it can be stretched to entire range linearly.[8]
This can be mathematically expressed as:

$$g(x, y) = (f(x, y) - c)[(b - a) / (d - c)] + a \tag{5}$$

**2.5 Histogram Equalization:** The histogram of a digital image with gray level in the range [0, L-1] is a discrete function of the form:

$$H(r_k) = n_k \tag{6}$$

Where $r_k$ is the kth is gray level and $n_k$ is the number of pixels in the image having the level $r_k$. A normalized histogram is given by:

$$P(r_k) = n_k / n \tag{7}$$

$P(r_k)$ gives the estimate of the probability of occurrence of gray level $r_k$

The sum of all components of a normalized histogram equals to 1.In the dark image the components of the histogram are concentrated on the low side of gray scale.

Histogram equalization is a common technique for enhancing the appearance of images. Histogram equalization is a technique for adjusting image intensity. f(x,y) is the intensity values of the image at (x,y).The intensity values range from 0 to L-1, Where L is the number of possible intensity values.

$P_n$ =number of pixel with intensity n/total number of  pixels

The histogram equalized image g(x,y) is defined by:

$$g(x, y) = (L-1) \sum P_n$$

(8)

We can transform the histogram to produce a new enhanced image The transformation follows:

$$g(x, y) = T(f(x, y))$$ 
$0 <\_ r <\_ 1$

(9)

This maps a level in g(x, y) for every pixel in f(x, y).

**2.6. Median Filtering:** Images are prone to noise, it requires a preprocessing to eliminate unwanted pixel intensities from the image. Median filter slides along the entire image pixel by pixel fashion and replace each pixel value with the median of neighboring pixels. At boundaries, the first and last pixel values, are missed, hence these pixels must be repeated. It's one of the major issues imposed in median filtering. Median filtering preserves edges and removes noise to a great extent.

**2.7. Mean Filtering:** Mean filtering is also called as averaging filter replaces each pixel intensity by the average of neighboring pixels. Let f(x,y) be the input image intensity at the points (x,y), g(x,y) be the transformed image. The average filtering can be mathematically expressed as:

$$g(x, y) = \sum_{k=-m}^{m} \sum_{l=-m}^{m} W_{Kl} f(x_{i+k}, y_{j+l})$$ 
for  i,j = (m+1),…,(n-m)        (10)

## III.    Design and Hardware Implementation

The study [10] had proven that Xilinx is the better choice for image processing application. Hence the hardware is modelled in Altium designer with Altium Nano board 3000 as development platform, and synthesized in Xilinx Spartan 3 AN. Application specific hardware is designed.
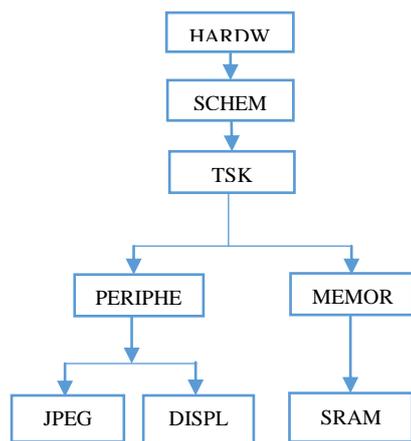
Fig 1: Hardware Design
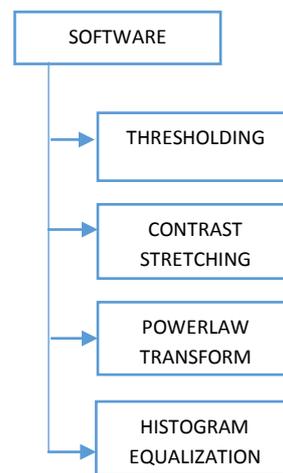
Fig 2: Software Design

## IV.    Result and Discussion

The study of underwater imaging revealed that, as the light waves get absorbed by the water molecules, additional lighting is needed for the imaging. In open Ocean, the light waves penetrate more and results in a bluish image, where as in coastal waters the light waves penetrate comparatively less and resulted in green. The additional illumination provided by the imaging device itself changes the color property of images. Most of the images obtained is either green or blue in color. Hence the image is saturated in one of the RGB color channels.

The operation taken out in this analysis is per pixel fashion, and each color component is extracted. In this method the gain of saturated pixel is limited and per pixel operation is carried out. Various image processing algorithms such as inversion, thresholding have also been implemented in FPGA. The result of various enhancement process have been analysed. Comparative analysis of Peak Signal to Noise Ratio (PSNR) and Structure Similarity Index Matrix (SSIM) of different image enhancement techniques have been analyzed for different underwater images and is shown in Table 1 and Table 2. The Histogram equalization method gives the better enhanced result than other techniques.



Fig 3: Histogram Equalized Image on Altium NB3000TFT



Fig 4: Original Image



Fig 5: Inverted Image



Fig 6: Threshold



Fig 7: Power law transform gamma=0.5



Fig 8: Power law transform gamma =2



Fig 9: Histogram Equalization



Fig 10: Contrast Stretching high



Fig 11: Contrast Stretching low

**Table 1: PSNR Value**

| Method | Image1 | Image 2 | Image 3 |
|---|---|---|---|
| Contrast High | 47.557 | 21.744 | 42.67 |
| Contrast Low | 25.458 | 30.028 | 33.53 |
| Histogram Equalization | 32.827 | 40.764 | 46.54 |
| Power law low | 18.753 | 16.53 | 18.75 |
| Power law high | 28.15 | 21.160 | 26.64 |

**Table 2: SSIM value**

| Method | Image 1 | Image 2 | Image 3 |
|---|---|---|---|
| Contrast High | 0.9248 | 0.4397 | 0.8330 |
| Contrast Low | 0.8166 | 0.7534 | 0.7912 |
| Histogram Equalization | 0.7494 | 0.9466 | 0.8873 |
| Power law low | 0.7405 | 0.6740 | 0.7578 |
| Power law high | 0.7148 | 0.3470 | 0.1170 |

**Table 3: Device Utilization**

| | |
|---|---|
| Number of slices | 6044 |
| Number of slice flip-flops | 5296 |
| Number of 4 input LUTs | 8634 |
| Number of | 8340 |
| Number used as RAM | 270 |
| Number used as ROMs: | 24 |

## V.     Conclusion

In underwater images one of the color channels are highly saturated than the other two. In the tested images the green and blue channels are saturated due to the non-uniform lighting and light propagation properties. In order to check the robustness of the algorithm it has been tested for a large data set. The power law transform with different gamma values do not introduce unpleasing artifacts. The large amount of memory blocks available in FPGA can be accessed parallely.Hence the time required to process each pixel reduces considerably. The low cost and fast performance makes the FPGA a better choice for image processing application. This work aimed to implement the basic image processing algorithms for underwater images effectively in Altium Nano board 3000.Hence the above result on tested images had proven that the FPGA is stipulated in the field of image processing.

## References

[1].    Retrieved from **:** http://www.bbc.co.uk/history/ancient/archaeology/marine_01.shtml
[2].    Erhardt – Ferron ;Theory and Applications of Digital Image Processing university Of Applied sciences of fenburg hochschule for technik undwirt schaft
[3].    Beilei Xu; Yiqi Zhuang; Hualian Tang; Li Zhang, "Object-based multilevel contrast stretching method for image enhancement," Consumer Electronics, IEEE Transactions on , vol.56, no.3, pp.1746,1754, Aug. 2010.
[4].    Kim, Tae Keun, Joon Ki Paik. and Bong Soon Kang. Contrast enhancement system using spatially adaptive histogram equalization with temporal filtering. Consurner Electronics, IEEE Transactions on 44, no. I (1998): 82-87
[5].    Jiang Duan; Wenpeng Dong; Rui Mu; Guoping Qiu; Min Chen, "Local contrast stretch based tone mapping for high dynamic range images," Computational Intelligence for Multimedia, Signal and Vision Processing (CIMSIVP), 2011 IEEE Symposium on , vol., no., pp.26,32, 11-15 April 2011
[6].    Eramian, M.; Mould, D., "Histogram equalization using neighborhood metrics," Computer and Robot Vision, 2005. Proceedings. The 2nd Canadian Conference on , vol., no., pp.397,404, 9-11 May 2005
[7].    Rafael C. Gonzalez, Richard E. Woods, ``Digital Image Processing," 2nd Edition, Prentice Hall; ISBN: 0201180758; January 15, 2002.
[8].    Jagatheeswari, P.; Kumar, S.S.; Rajaram, M., "Contrast Stretching Recursively Separated Histogram Equalization for Brightness Preservation and Contrast Enhancement,"Advances in Computing, Control, & Telecommunication Technologies, 2009. ACT '09. International Conference on ,vol.,no.,pp.111,115,28-29Dec.2009doi: 10.1109/ACT.2009.37
[9].    K.S. Sim, C.P. Tso, Y.Y. Tan, Recursive sub-image histogram equalization applied to gray scale images, Pattern Recogn. Lett. 28 (2007) 1209–1221.
[10].   Shrikanth G., and Kaushik Subramanian. "Implementation Of Fpga-Based Object Tracking Algorithm." Postgraduate Thesis,(SVCE, India) (2008).Vol. 1. IEEE, 2009