UNDERWATER IMAGE ENHANCEMENT BY WAVELET DECOMPOSITION USING FPGA

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Abstract – *Underwater vision is a significant issue in ocean engineering. Atmospheric images and underwater images undergo from medium scattering and light distortion, leading to the low contrast and visibility of images. The problems result in limited usage of the images. In terms of detection, the objects in the image hardly seen and not detectable while having a low possibility of tracing. The main purpose of underwater image fusion is to combine multi-images about the same object into a high-quality image with abundant information. A Field Programmable Gate Array (FPGA) is a reconfigurable hardware, providing better features than DSP and other hardware devices due to their product fidelity and sustainable advantages in digital image processing. FPGA has a large impact on image and video processing; this is due to the potential of the FPGA to have parallel and high computational density as compared to a general purpose microprocessor.The fusion of multisensory image data has become a useful tool in underwater image application. This paper proposes underwater images enhancement by wavelet decomposition based image fusion implementation on FPGA. The color corrected and contrast-enhanced images are fused which are withdrawn from an original underwater image.*

***Key Words*: *Underwater image; Colour correction; Contrast enhancement; Wavelet decomposition; Image fusion*;**

1.INTRODUCTION

Nowadays, research area trends have been increased in the marine stream. But to work on the aquatic objects, it is necessary to obtain the clear images of the underwater objects. As the air interface deals with the environmental and camera problems like dust particles, natural light, reflection, focus and distance, underwater images also faces the same problems. Underwater image quality depends on density of water, depth of water, distance between camera and object, artificial light, water particles, etc. increase in the depth of water, the water becomes denser because of sand, planktons, and minerals. As density increases, the camera light gets deviates back and deflects by particles for some time along the path to the camera and other part of camera light gets absorbed by the particles. This scattering effect causes the reduced visibility of image with low contrast. Also, the color change effect depends on the wavelength of light travel in the water.

Fusion is an important technique within many disparate fields such as remote sensing, robotics, and medical applications. Image fusion algorithm based wavelet transform is that, the two images to be processed are sampled to the one with the same size and they are respectively decomposed into the sub images using forward wavelet transform, which have the same resolution at the same levels and different resolution among different levels; and information fusion is performed based on the high-frequency sub images of decomposed images; and finally the resulting image is obtained using inverse wavelet transform. The result of image fusion is a single image which is more suitable for human and machine perception or further image-processing tasks.

Most of the image enhancement implementations found in the literature are based on MATLAB and C/C++. MATLAB is a high performance language for technical computing and the excellent tool for algorithm development and data analysis. Reconfigurable hardware in the form of FPGA is considered as a practical way of obtaining high performance for computationally intensive image processing algorithms. FPGA's have been traditionally configured using Hardware Description Languages (HDL) Verilog and Very High Speed Integrated Circuits (VHSIC) HDL (VHDL). C-based HDL shave also been used. Another area where research is ongoing is to develop and employ high-level design tools which will bring down the development time required for deploying signal processing solutions using FPGA. Xilinx System Generator (XSG) is one such tool that enables the use of Math works model-based design environment Simulink for FPGA design.

2. LITERATURE SURVEY

We have done literature survey on the underwater image and conclude that the hybridization of algorithms is done for better visualization like wavelet fusion and contrast enhancement, improving contrast and color correction etc. J. Wang, et al. [1], proposed The image fusion method is mainly divided as three ways: the first is a direct fusion method, which is used to fuse two source images of spatial registration into an image using some simple processions such as direct selecting or weighted average. The second algorithm is based on pyramid decomposition and reconstruction, which is eventually formed through reconstruction. The third method is the fusion algorithm based on the wavelet transform, which fuses images pertinently in the feature fields of each layer using multi-resolution analysis and Mallat fast algorithm. Alex, et al. [2], proposed on adaptive histogram equalization technique to improve the enhancement of images. In the adaptive histogram equalization technique, the pixels are mapped based on it local gray scale distribution. Xiu Li, et al. [3], proposed two parameters due to underwater images quality degraded. They proposed a novel technique based on dark channel prior and luminance adjustment.

C. Ancuti, et al. [4], proposed Classical image enhancement techniques have been modified to adapt to the underwater imaging. The most popular method is underwater image and video enhancement using fusion to combine different weighted images using saliency, luminance, and chrominance via filtering. M. S. Hitam, et al. [5], there are many image-base methods in underwater Image enhancement. Global and local image contrast Enhancement is widely used to improve the appearance of underwater images. Hitam et al., proposed a method called Mixture contrast limited adaptive histogram equalization (clahe). Clahe is operated on RGB and HSV color models, And the two results are combined together with Euclidean Norm. Ahmad et al. A. S. A. Ghani and n. A. M. Isa [6], proposed a new method called dual image Rayleigh-stretched contrast-limited adaptive histogram Specification, which integrated global and local contrast correction. Yafei Wang, et al. [7], proposed fusion process involves two inputs which are represented as color corrected and contrast enhanced images extracted from the original underwater image. Both the color corrected and contrast enhanced images are decomposed into low frequency and high frequency components by three-scale wavelet operator.

In this paper, an efficient fusion-based underwater image enhancement approach using wavelet decomposition is presented. The experimental results demonstrate that the proposed approach effectively improves the visibility of underwater images.

3. System Development

The fusion strategies used in spatial domain from the previous different methods, a fusion-based underwater image enhancement using FPGA is proposed in the frequency domain. Here low frequency and high-frequency components are decomposed from the color corrected image and contrast-enhanced image by wavelet to employ the fusion process.

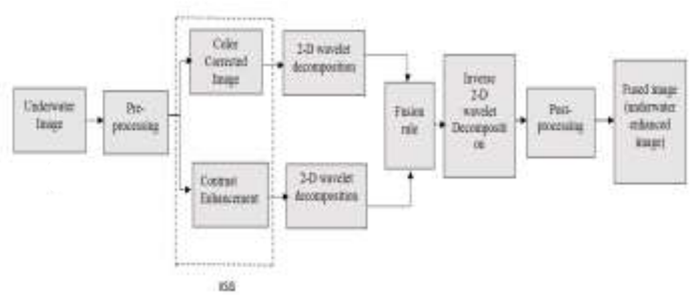

Fig.1: Proposed block diagram of underwater image enhancement by wavelet decomposition

The proposed enhancing strategy consists of three main steps: color correction (first input of fusion process) in Section II-A, contrast enhancement (second input of fusion process) in Section II-B and multi-scale fusion process for the two inputs in Section II-C.

3.1 Preprocessing

In preprocessing, the image will be resized to the fixed dimension. After resize of the image in this we will check the color space of input image whether it is grey or color and according to features extraction of preprocessing image will be done.

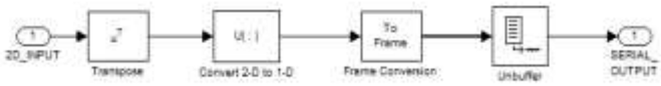

Fig2: Image Pre-Processing

3.2 Color Correction

Underwater imaging is influenced by non-uniform color cast due to absorption of the propagated light. Color cast corresponds to the varying degrees of light attenuation. Different wavelengths of light are attenuated at different rates in water. In our experiments, a simple and effcient white balance operation is used to enhance the image appearance by discarding color casts.

The color of a gray image is its distribution of light and dark pixels. To correct the color, color constancy is applied to an image to fill the full dynamic range of the image. We can correct out the gray levels in the center of the range by applying piece wise linear function according to the equation.

New pixel = μ* (old pixel - $\lambda 1$) + $\lambda 2$

Where new pixel is its result after the transformation.

μ is color corrected gain factor.

$\lambda 1$ is Average Illumation white balance color pixel.

λ 2 is constant can help to acquire more pleasing results has been observed.

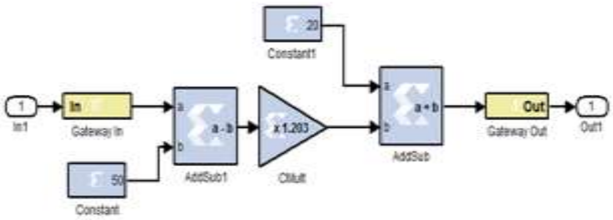

Fig3: XSG blocks for color correction model.

This white balance method derives the first input of the fusion process from original underwater image efficiently. It overcomes the limitations of underwater environments, removes the color casts and produces a natural appearance of the underwater image. However, white balance method is not sufficient for the improvement of visibility. To obtain a better enhanced image, the second input of the fusion process is defined in order to enhance the contrast of the underwater image.

3.3 Color Enhancement

Despite the color casts caused by light absorption, underwater images are also affected by low contrast due to backward scattering of light. Contrast enhancement is widely utilized in image processing because it brings out more details of images.

A color intensity transform can also reduce the highlight a range of pixels i.e white balance pixels while keeping others pixels further reduce to enrich the colors.

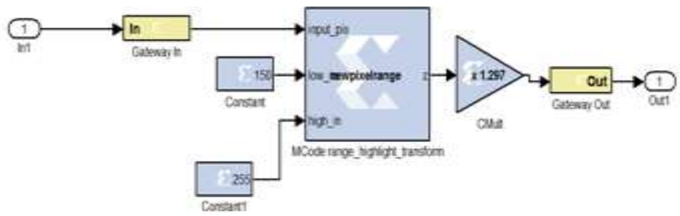

Fig4: color enhancement XSG module

3.4 Multi-scale Fusion Process

In the proposed fusion strategy (shown as Fig.1), color corrected image and color enhanced image are the first and second inputs respectively. By applying the wavelet operator each input is decomposed into low frequency and high-frequency components. Then, different fusion principles are utilized to fuse the low frequency and high frequency components. The weighted average is enforced to fuse low-frequency components, while local variance is employed in the fusion of high frequency components. The new low frequency and high frequency components are generated, After the fusion process. Finally, the enhanced image is obtained by reconstructing the new low frequency and high frequency components.

3.5Decomposition, Fusion and Inverse Composition

The wavelet-based fusion algorithm consists of a sequence of low pass and high pass filter banks that are used to eliminate unwanted low and high frequencies present in the image and to acquire the detail and approximation coefficients separately for making the fusing process convenient. one level, 2- dimensional decomposition of the input image into its detail and approximation coefficients is described. Each input image is filtered and down-sampled. The factor of 2 in the algorithm is used to divide the information contained in the input signal into two equal parts at each step of filtering so that the information can be analyzed deeply. There are two steps in level one; the first step is achieved by applying the low pass and high pass filters with down-sampling on the rows of the input image x(r, c). This generates horizontal approximations and horizontal details respectively. In the next step, the columns in the horizontal coefficients are filtered and down-sampled into four sub images Approximate (LL), Vertical detail (LH), Horizontal detail (HL), and the Diagonal detail (HH).

At the second level of decomposition, the decomposed approximate image (LL) of the first level becomes the input image and the process is repeated to scale down coefficients. Each input image is decomposed into its wavelet coefficients by using the procedure as described above. In our case both enhanced images: the color corrected and the contrast enhanced versions of the input image are decomposed into their wavelet coefficients then both decompositions are fused by using coefficients of maximum values.

After combining coefficients of both enhanced images into fused coefficients, the inverse composition is applied to get the synthesized image. For the inverse composition, the reverse process is carried out with the help of up-sampling and filtering steps using filter banks to get a synthesized or enhanced image *y(r,c)*. Since we are dealing with discrete data sets

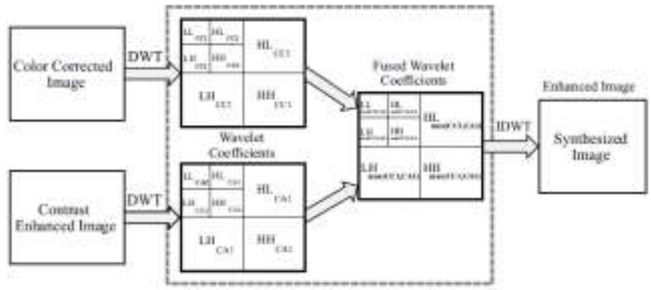

Figure 5: Two-level-2D decomposition, fusion of coefficients and image synthesizing

so in digital image processing, each input image is decomposed into its coefficients and inversely composed into a synthesized image by using discrete wavelet transform (DWT) and Inverse discrete wavelet transform (IDWT) respectively. In Fig.5, a complete picture of two level discrete wavelet-based decompositions, fusion and inverse composition of enhanced image is shown.

3.6 Image Post-processing

The image post processing blocks are used to convert back to floating point type as shown in Fig6. It also includes a buffer block which converts scalar samples to frame output at lower sampling rate, followed by convert 1-D to 2-D, transpose blocks.

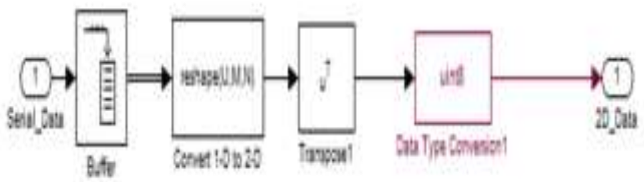

Fig6: Image Post-Processing

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4. Results And Discussion

Here, underwater image enhancement by wavelet decomposition algorithms is implemented on FPGA platform. Results for software and hardware implementation is observed and compared. Resource utilization for algorithm are observed with the help of design summary overview. Here MATLAB R2009a and ISE 13.1 softwares are used with Spartan 3e FPGA board.

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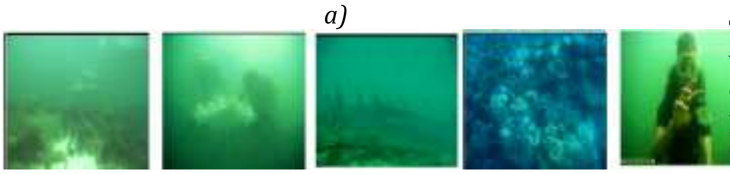
a)



b)

fig7:a)input underwater images, b)enhanced underwater images

Table-1: *System performance*

Parameters /Test cases	Case 1	Case2	Case3	Case4	Case5	Average
MSE	4.1685	8.2902	1.0098	22.8842	5.8325	8.437
RMSD	1.4289	1.6968	0.3150	2.1872	1.5540	1.43
PSNR	41.9310	38.9452	68.20000	34.5354	40.4723	44.186
CORRELAT-ION	0.8792	0.9148	0.8873	0.7232	0.9198	0.8648
SNR	17.866	14.798	44.1346	10.4700	16.4069	20.735
Entropy Of I/P Image	6.6184	7.0016	6.1234	6.3547	7.3596	6.6915
Entropy Of O/P Image	6.6150	7.0078	6.1345	6.3622	6.9622	6.6163
SSIM	0.8794	0.8759	0.8157	0.4960	0.6609	0.7455

Table-2: *Resource Utilization*

	Logic Utilization	value
1	Number of Slice Flip-flops	1
2	Number of 4 input LUTs	93
3	Number of bonded IOBs	157
4	Propagation delay(ms)	9.978
5	Max. Frequency (MHz)	100.22
6	Total power consumption(Watts)	0.0809

Table-3: *Comparative Analysis Table*

Parameter/Method	Ref[5]	Ref[3]	Proposed
MSE	2.5603	38.008	8.437
PSNR	14.04	39.8506	44.186
SNR	-	-	20.735
SSIM	-	-	0.7455
ENTROPY	6.67	6.506	0.815
RMSD	-	-	1.43
CORRELATION	-	-	0.8648

Table- 1 provides the system performance parameters value which are calculated for different cases. Table-2 provides detailed resource utilization and various Timing & Power parameters for underwater image enhancement. Table-3 details the comparative analysis with the reference values and the proposed parameters value.

5. CONCLUSIONS

The underwater images quality degraded due to scattering of light, refraction and absorption parameters. To resolve these issues and to improve the quality of an underwater image, a number of techniques are proposed in recent years. We have done literature survey on the underwater image and conclude that the hybridization of algorithms is done for better visualization like wavelet fusion and contrast enhancement, improving contrast and color correction, etc. In introduction and literature review, underwater image enhancement is presented covering basic enhancement technique, issues and challenges and existing techniques for underwater image enhancement. This work presents the mix module of implementation of underwater image enhancement on FPGA based on fusion by wavelet decomposition. The enhancement method effectively improves the visibility of underwater images and produces the lowest MSE and the highest PSNR values. The qualitative results depict that the proposed method has enhanced the quality of the hazy underwater images. The quantitative analysis shows the quality of the image is also maintained. Performance analysis of proposed method is compared with the design provided in the literature. Also, JTAG hardware co-simulation approach using Xilinx System Generator is found to be easy and efficient approach for hardware implementation over FPGA platform.

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BIOGRAPHIES

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