A REVIEW OF UNDERWATER IMAGE ENHANCEMENT BY WAVELET DECOMPOSITION USING FPGA

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Abstract - *Underwater images affect due to poor color contrast and poor visibility. These problems emerge due to the scattering of light and refraction of light while penetrate into rarer to denser medium. 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. 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. 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 The color corrected and contrast-enhanced images are fused which are withdrawn from an original underwater image.*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; Color 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. Due to the virtue of its multi-resolution, directivity, and non-redundancy, wavelet transform has been applied in image processing field successfully.

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. In this method, the enhancement mapping applied to a particular pixel is a function of the intensity values of pixels immediately surrounding the pixel. Hence the number of times that this calculation should be repeated is the same as the number of pixels in the image. They have implemented their algorithm on FPGA for hardware implementation. They are improving the performance by doing the parallel processing. The algorithm is implemented in Xilinx Spartan 3 AM on Altium Nano board NB3000 board using Altium Designer.

Xiu Li, et al. [3], proposed two parameters due to underwater images quality degraded. These are light scattering and color distortion. Also, they defined that the light scattering occurs due to light be reflected and deflected a number of times by the suspended particles in the water and color distortion due to absorption degrees and its vary according to the wavelength. They proposed a novel technique based on dark channel prior and luminance adjustment. Their technique resolves these.

C. Ancuti, et al. [4], proposed Classical image enhancement techniques have been modified to adapt to the underwater imaging. These methods do not depend on physical modeling of underwater scenario. The most popular method is underwater image and video enhancement using fusion to combine different weighted images using saliency, luminance, and chrominance via filtering. This was the first recorded work for the enhancement of underwater images using fusion approach based on Laplacian pyramid. The authors also validated the selection of white balancing algorithm for underwater images. Although the contrast of the output images appears increased, the problem associated with it is, as reflected in the results section, the processed images are not uniformly enhanced and does not appear natural.

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. The low frequency and high frequency components are fused via a multiscale fusion process. The low frequency components are fused by weighted average, and the high frequency components are fused by local variance. These fused low frequency and high frequency components can be reconstructed as a final enhanced image. 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 and can be utilized in image matching application for underwater environments.

3. PROPOSED WORK

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.

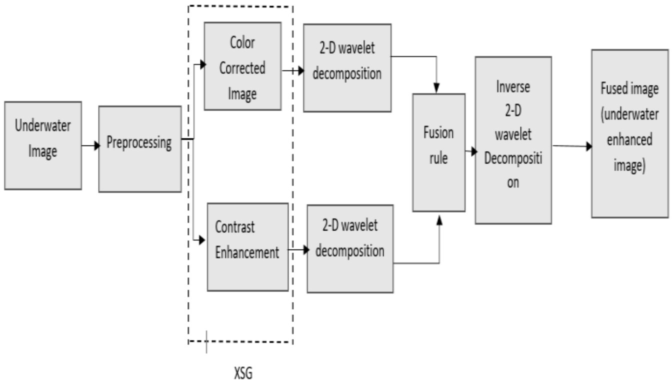

Fig.1 proposed block diagram of underwater image enhancement by wavelet decomposition

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.

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.

Color Correction:

For color correction, the image is converted from RGB (Red-Green-Blue) to HSV (Hue-Saturation-Value) color space. In HSV color space the histogram of the Value component is stretched over the whole range. This operation improves the brightness of the available colors in the image. Then the Hue and Saturation are concatenated with the corrected value component and hence the image is converted back to the RGB color space. In RGB color space, once again the histogram is stretched over the whole range (0 to 255) to achieve the color correction in all three channels. The histogram stretching is based on the mathematical expression given in the Eq. (1).

$$P_{out} = (P_{in} - i_{min})\left(\frac{O_{max} - O_{min}}{i_{max} - i_{min}}\right) + O_{min} \quad (1)$$

where P_{out} and P_{in} are the pixels of output and input images respectively. i_{min}, i_{max}, O_{min} and O_{max} are minimum and maximum values of intensities for input and output images respectively. It overcomes the limitations of underwater environments, removes the color casts and produces a natural appearance of the underwater image. It overcomes the limitations of underwater environments, removes the color casts and produces a natural appearance of the underwater image.

Contrast Enhancement:

To enhance the contrast of the underwater images, we adopted the contrast limited adaptive histogram equalization (CLAHE). CLAHE differs from ordinary AHE in its contrast limiting. The CLAHE introduced clipping limit to overcome the noise amplification problem. The CLAHE limits the amplification by clipping the histogram at a predefined value before computing the Cumulative Distribution Function (CDF). In CLAHE technique, an input original image is divided into non-overlapping contextual regions called sub-images, tiles or blocks. The CLAHE has two key parameters: Block Size (BS) and Clip Limit (CL). These two parameters mainly control enhanced image quality. The image is getting bright when CL is increased because input image has the very low intensity and larger CL makes its histogram flatter. As the BS is bigger, the dynamic range becomes larger and the contrast of the image is also increasing. The two parameters determined at the point with maximum entropy curvature produce the subjectively good quality of the image with using the entropy of image.

The CLAHE method applies histogram equalization to each contextual region. The original histogram is clipped and the clipped pixels are redistributed to each gray level. The redistributed histogram is different with ordinary histogram because each pixel intensity is limited to a selected maximum. But the enhanced image and the original image have the same minimum and maximum gray values.

Multi-scale Fusion Process:

In the proposed fusion strategy (shown as Fig.1), color corrected image and contrast 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.

Decomposition, 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. Fig. 2, 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

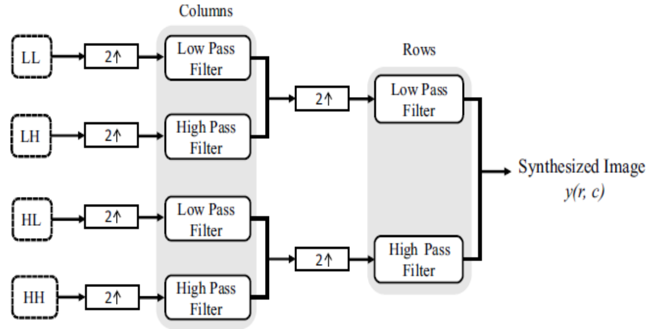

Figure 2:- One-level-2D wavelet-based inverse composition

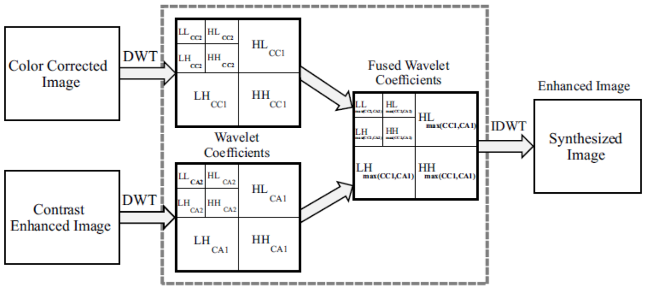

Figure 3: Two-level-2D decomposition, fusion of coefficients and image synthesizing

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. 3, a complete picture of two level discrete wavelet-based decompositions, fusion and inverse composition of enhanced image is shown.

4. 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. A review of underwater image enhancement is presented covering basic enhancement technique, issues and challenges and existing techniques for underwater image enhancement. This paper presents the implementation of underwater image enhancement on FPGA based on fusion by wavelet decomposition.

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BIOGRAPHIES

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