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Enhancement and Processing of Underwater Images using FPGA

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Abstract

Underwater image enhancement is one of the challenging tasks in the field of marine species. While dealing to work in the marine class, the researchers face some problems related to the underwater images. As the depth of water increases, the problems related to clear image capturing becomes more. The problems vary according to the type of water, amount of light, depth of water, the distance between camera and object, etc. This paper deals with the underwater image enhancement by working on the resolution and contrast factors to preserve the information of an original image. The proposed system uses Discrete Wavelet Transform (DWT) method to enhance the quality of underwater images. 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 The color corrected and contrast-enhanced images are fused which are withdrawn from an original underwater image.

Keywords- *Image Fusion, DWT, Image Enhancement, Image Fusion, FPGA.*

I. INTRODUCTION

Earth is an aquatic planet wherein water occupies 70% of the surface. Nowadays, the area of research has increased its interest in the marine class. But to work on the aquatic objects, it is imperative to get the clear images of the underwater object. As the air interface deals with the environmental and camera problems like dust particles, natural light, reflection, focus and distance, underwater images are also facing the same challenges. The quality of the underwater image depends on the density of water, depth of water, distance between camera and object, artificial light, water particles, etc. Most occurring problems in the underwater image is light scattering effect and color change effect. If the water is clear or limpid, the image quality and visibility is good. As the depth of water increases, the water becomes denser due to sand, planktons and minerals. Due to increased density, the camera light gets reflected and deflected by particles for sometimes before reaching towards the camera and some part of camera light get absorbed by the particles. This scattering effect results in reduced visibility of image with low contrast. Secondly, the color change effect depends on the wavelength of light travel in the water. The color with the highest wavelength goes the very short distance in water. Fig 1 shows the light penetration pattern in the clear water. Blue color has the shortest wavelength, so it travels very long in the deep water. That's why the blue color is more in underwater images [5]. As the degree of attenuation varies for different wavelengths, the color change effect occurs.

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The scattering effect and color change effect combined results in reduced visibility in underwater images. It affects the resolution and contrast attribute to degrade the quality of the image. Image enhancement is one of the pre-processing methods which improves the quality of an image by increasing the perception of information in it analysis work.

Image fusion is the process by which two or more images are combined into a single image retaining the important features from each of the original images. The fusion of images is often required for images acquired from different instrument modalities or capture techniques of the same scene or objects. Important applications of the fusion of images include medical imaging, microscopic imaging, remote sensing, computer vision, and robotics. Fusion techniques include the simplest method of pixel averaging to more complicated methods such as principal component analysis and wavelet transform fusion. Several approaches to image fusion can be distinguished, depending on whether the images are fused in the spatial domain or they are transformed into another domain, and their transforms fused. The actual fusion process can take place at different levels of information representation.

II.LITERATURE SURVEY

Since last few decades, an extensive number of approaches to fuse visual image information. These techniques vary in their complexity, robustness and sophistication. Remote sensing is perhaps one of the leading image fusion applications with a large number of dedicated publications. The main principle of some of the popular image fusion algorithms have been discussed below.

Fusion using Principle Component Analysis (PCA): The PCA image fusion method [8] basically uses the pixel values of all source images at each pixel location, adds a weight factor to each pixel value, and takes an average of the weighted pixel values to produce the result for the fused image at the same pixel location. The optimal weighted factors are determined by the PCA technique. The PCA image fusion method reduces the redundancy of the image data. ϖ Super-resolution image reconstruction: Super-resolution (SR) reconstruction [9] is a branch of image fusion for bandwidth extrapolation beyond the limits of a traditional electronic image system.

Katartzis and Petrou describe the main principles of SR reconstruction and provide an overview of the most representative methodologies in the domain. The general strategy that characterizes super-resolution comprises three major processing steps which are low resolution image acquisition, image registration/motion compensation, and high resolution image reconstruction. Katartzis and Petrou presented a promising new approach based on Normalized Convolution and a robust Bayesian estimation, and perform quantitative and qualitative comparisons using real video sequences.

Image fusion schemes using ICA bases: Mitianoudis and Stathaki demonstrate the efficiency of a transform constructed using Independent Component Analysis (ICA) and Topographic Independent Component Analysis based for image fusion in this study [10]. The bases are trained offline using images of similar context to the observed scene. The images are fused in the transform domain using novel pixel-based or region-based rules. An unsupervised adaption ICA-based fusion scheme is also introduced.

The proposed schemes feature improved performance when compared to approaches based on the wavelet transform and a slightly increased computational complexity. The authors introduced the use of ICA and topographical ICA based for image fusion applications. These bases seem to construct very efficient tools, which can complement common techniques used in image fusion, such as the Dual-Tree Wavelet Transform. The proposed method can outperform the wavelet approaches. The Topographical ICA based method offers a more accurate directional selectivity, thus capturing the salient features of the image more accurately.

Region-based multi-focus image fusion: Li and Yang first describe the principle of region-based image fusion in the spatial domain [11]. Then two region-based fusion methods are introduced. They proposed a spatial domain region-based fusion method using fixed-size blocks. Experimental results from the proposed methods are encouraging. More specifically, in spite of the crudeness of the segmentation

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methods used, the results obtained from the proposed fusion processes, which consider specific feature information regarding the source images, are excellent in terms of visual perception.

The presented algorithm, spatial domain region-based fusion method using fixed-size blocks, is computationally simple and can be applied in real time. It is also valuable in practical applications. Although the results obtained from a number of experiments are promising, there are more parameters to be considered as compared to an MR-based type of method, such as the wavelet method. Adaptive methods for choosing those parameters should be researched further. In addition, further investigations are necessary for selecting more effective clarity measures.

Image fusion techniques for non-destructive testing and remote sensing application: The authors present several algorithms of fusion based on multi-scale Kalman filtering and computational intelligence methodologies [12]. The proposed algorithms are applied to two kinds of problems: a remote sensing segmentation, classification, and object detection application performed on real data available from experiments and a non-destructive testing/evaluation problem of flaw detection using electro-magnetic and ultrasound recordings. In both problems, the fusion techniques are shown to achieve a modest superior performance with respect to the single-sensor image modality. The joint use of the eddy current and ultrasonic measurements is suggested because of the poor results that are obtained by processing each single recorded type of signal alone. Therefore, both measurements are jointly processed, and the information used to perform the classification has been extracted at three different levels: pixel, feature, and symbol.

The numerical performance of these techniques has been compared by using the probability of detection and probability of false alarm. Experiments performed on real data confirmed the effectiveness of the proposed SL based approach, by maximizing the probability of detection and achieving an acceptable probability of false alarm with respect to the PL and FL fusion techniques.

III.METHODOLOGY

The requirement for the successful image fusion is that images have to be correctly aligned on a pixel-by-pixel basis. In this project, the images to be combined are assumed to be already perfectly registered. The Figure 2 shows the top level block diagram of image fusion using wavelet transform. The two input images image1and image 2 that are captured from visible and infrared camera respectively are taken as inputs. The wavelet transform decomposes the image into low-low, low-high, high-low, high-high frequency bands. The wavelet coefficients are generated by applying the wavelet transform on input images. Wavelet coefficients of the input images are fused by taking the average of input images. The resultant fused image is obtained by applying the inverse wavelet transform.

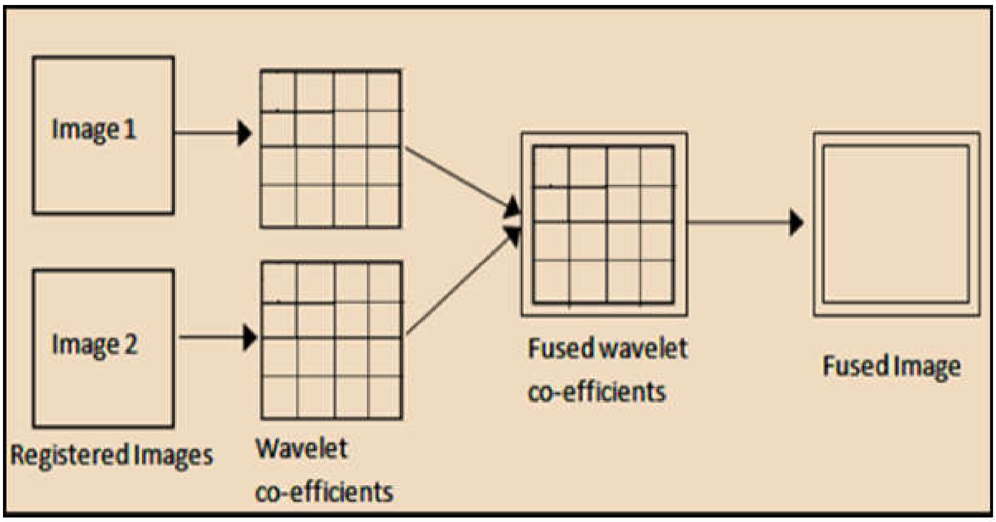

Fig .Block diagram of IDWT based image fusion

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The most complex and significant step in this algorithm is to carry out the wavelet transformation. The wavelet transforms are applied to images. The wavelet transform consists of low-high, the high-low and high-high frequency bands of the image at different scales (Vladimir 2001). Since larger absolute transform coefficients correspond to sharper brightness changes and a good fusion rule to be selected at every point in the transform domain. The fusion takes place in all the resolution levels and main features at each scale are conserved in the new multi-resolution representation. Finally, a new image is constructed by applying inverse wavelet transform on fused image. Due to compactness, orthogonality and availability of directional information, the IDWT can successfully extract the main features at different scales. The wavelet transform based image fusion technique produces the more naturally fused image even when the images to be combined are very different. An area–based maximum selection rule and a consistency verification step are proposed for feature selection. Better fusion results, both visually and quantitatively can be achieved using wavelet transform when compared to averaging and lapacian pyramid based image fusion Wavelet-based image fusion technique is more robust under transmission and decoding errors, and also facilitates progressive transmission of images. Wavelet based fusion at higher compression avoid blocking artifacts. The designing and modeling of fusion of two images has been performed by averaging and 2-D IDWT with different filters like Haar, Daubechies and Biorthogonal filters in MATLAB Simulink. The results of all fusion techniques for different set of images have been carried out. High PSNR and clear fused image has been achieved by 2-D IDWT with 9/7 Daubechies filter.

There are two important questions in image fusion field: selection of wavelet name and fusion rule when wavelet transform is applied to multi-focus image fusion. Fusion rule is the kernel of image fusion and it directly influences the speed and quality of image fusion. So, this paper not only study these two questions, but also involve the important part of image fusion rule, fusion operator and conduct fusion experiments on these aspects. Since multiple evaluation criteria of image fusion exist, this paper mainly compares the fusion effect through the Similitude Measure so as to select the best wavelet basis function, the best fusion rule.

IDWT architecture based on modified lifting scheme is designed and is used in image fusion. The input images of size 100 x 100 have been chosen to validate the proposed fusion algorithm based on IDWT.

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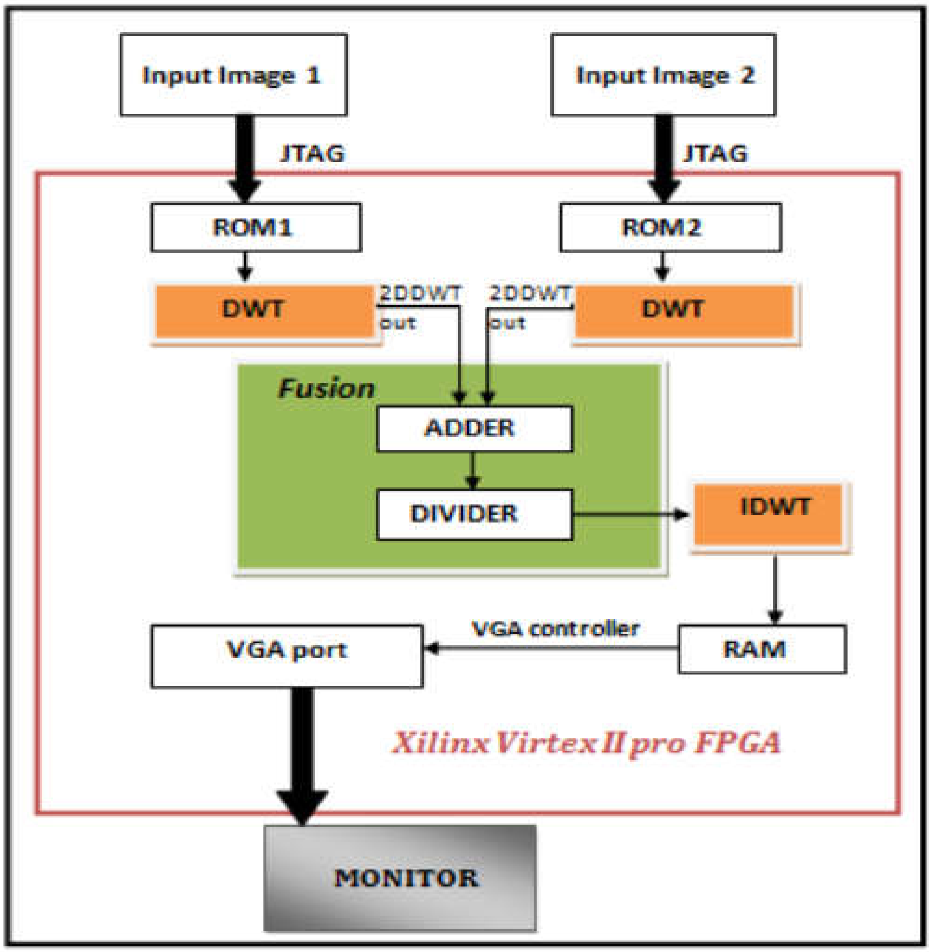

Fig. Top level block diagram of hardware implementation

The wavelet transforms of the images has been computed. The registered images have been passed as input signals through two different one-dimensional digital filters H0 and H1 respectively. H0 and H1 digital filters perform high pass and low pass filtering operations respectively for both the input images. The output of each filters are followed by sub-sampling by a factor of 2. This step is referred as the Row compression and resultant is called as L-low frequency component and H-high frequency component. The down sampled outputs have been further passed to two one dimensional digital filters in order to achieve Column compression. The HH-High High, HLHigh Low, LH-Low High and LL-Low Low are the output frequency components obtained after two level compressions of both the input images. The Figure 10 shows the block diagram of IDWT based image fusion process which consists of two input images, IDWT block, fusion block and IIDWT block. The HH, HL, LH and LL frequency components of one input image is fused with the HH, HL, LH and LL components of second image respectively. HH components of both images have been added and then the resultant output has been divided by a factor 2. Similarly, the average of HL, LL and LH components has been taken. This process is known as Image Fusion. This averaged result has been future followed by the reconstruction process i.e., inverse wavelet transform. IIDWT is the reverse process of IDWT. In IIDWT process, the HH, HL, LH and LL components have been first up-sampled and then filtering operation has been carried out. The sub-bands has been added or summed to get the resultant reconstructed image.

IV. EXPECTED RESULTS

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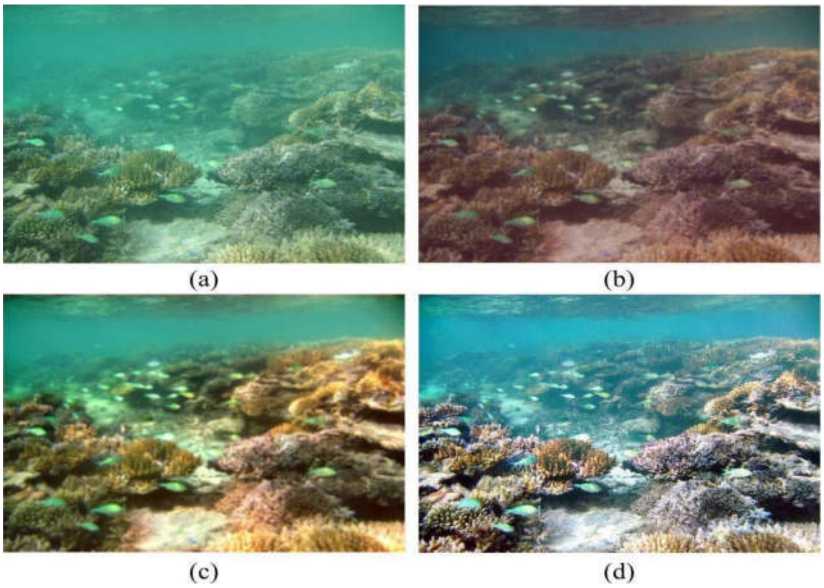

V. CONCLUSION

The underwater images quality degraded due to scattering of light, refraction an 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 image enhancement 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.

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