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RECONFIGURABLE PLATFORM BASED DESIGN IN FPGA FOR UNDERWATER IMAGE COLOR CORRECTION

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ABSTRACT

Color correction is a serious constraint that comes into play in underwater imagery. Optical properties of light cause issues that can severely degrade the quality of underwater photography. As light with different energies travel through water, it is absorbed at higher rates, it contributes to severe bluishness of the underwater captured images. Thus it creates challenges for imaging in underwater. Attenuation of longer wavelengths occurs more rapidly when compared to shorter wavelengths, resulting overall blue color to the captured image. Scattering, independent of wavelength of visible light is one of the reasons for image loss and it does not influence color. In marine biology studies related to species identification and ecosystem monitoring and surveillance, examination of color is required. Color filters and manual post-processing are used for flooding objects with white light from a very close distance in underwater imaging techniques. However, these techniques are inefficient since it doesn't render correct colors, and it works only for fixed setups, as loss of color depends upon distance. Using post processing methods for underwater images, underwater monitoring of natural and human-engineered environments can be sufficiently enhanced to a great extent. In this paper, hardware implementation of underwater image color correction is performed in Field Programmable Gate Array (FPGA) to be used in Automated Underwater Vehicles (AUV). FPGA platform is preferred as its ability to perform parallel algorithm such as image processing algorithms due to its inherent parallelism.

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KEY WORDS
Underwater Image, FPGA, Color Correction, AUV

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INTRODUCTION

Recovering process of underwater images involving retrieval of correct colors is a challenging task. This is due to the fact that illumination done for image capture is extremely altered in water since water is refractive and turbid medium. Relevant Image modifications are caused mainly due to following reasons: different attenuation of different wavelength, scattering and absorption of radiation by the underwater environment. For this task, many qualitative techniques based on imaging have been proposed in the literature. They are based on image restoration techniques or subjective techniques such as image enhancement methods. The information regarding medium physical parameters is essential in first case and image adjustments based on certain criterions are performed in second case. Gray world hypothesis is one of the most popular criteria in which average of the captured image is supposed to be gray. Implementing automatic methods based on this assumption yield good results. The color space consists of two opponent color components which encode α and β (yellow-blue and red-green chromaticities), and a luminance component (achromatic).This is applied for color discrimination in human color visual mechanism. With the help of lαβ color space, the chromatic components are relatively altered by displacing their distributions closer to the white point (white balancing).Histogram cut off and stretching of the luminance component is done to advance the contrast of the image. So, by performing a color correction similar to that in human visual system is the way to tackle the difficulties of underwater images based on color constancy. The average information in each image channel tends to gray that is captured color image averages to gray (achromatic). The main drawback of gray-world systems is that they will not reproduce correct colors if extremely huge number of colors is absent in the scene.

The *lαβ* color space described by Ruderman et al, [1] examines the human eye insight of natural images. In human color visual mechanism, color space consists of a luminance component l and two adversary color constituents α and β. In applications like 3D imaging, documentation, navigation etc, color correction of underwater images or videos is a significant task. G. Biancoa et. al. [2] present a new method which deals with uniform illumination and gray-world assumptions used in the lαβ space for color correction. White balancing of chromatic components (αandβ) and l,the luminance element is processed to improve the contrast of the image. This procedure is appropriate in underwater imaging to eliminate unwanted color casts and in the gray shades, greenish-blue components are removed.

Underwater monitoring can be improved by automatically capturing underwater color images using robots. In [3] adaptive illumination, a precise-color imaging method is used. A multi-color controllable light source is used to mix the illumination in a distance-dependent way. The color mix pays accurately for loss of color and produces an image and its composition of color which is alike to represent the object in air. Objects closer or far away from the camera will not be rendered appropriately because of the distance-dependent behavior of adaptive illumination. This work helps to capture color-accurate underwater images based on color which facilitates surveillance operations and automating underwater monitoring.

Erik Reinhard and Tania [4] explain a universal technique for correction of color and it takes characteristics of color of one image from other. It describes that a color space with de-correlated axes is a helpful means for manipulating color images. Calculation of standard deviation and mean of the data points generates convincing output results providing suitable input images. The important approach is to select an appropriate color space to perform simple operations .The representation of an image (three channel) in any color spaces results in correlation between different channel values, which is not needed.

Erik [5] introduced a color space, called lαβ, which reduces relationship between channels for large number of natural scenes. This is based on the hypothesis that for processing natural scenes a human visual system is perfectly suited.

Arjan Gijseni et al, [6] used computational color constancy, an important requirement for computer vision applications. In image processing or computer vision related topics like human–computer interaction, extraction of color features, and color appearance models, color is a vital cue. The colors in images depend on the inherent features of surfaces, objects and the light source's color. For vital color systems, the effect of light source needs to be eliminated. The purpose of color constancy procedures is verification of the (first three) target images (under three different colored light sources) in such a way that they emerge alike to the (fourth) canonical image.

Prabhakaret al,[7] futured a preprocessing tool for images to boost the excellence of the underwater images. The work combines homomorphic filtering, bilateral filtering, wavelet de-noising, and contrast equalization. On degraded underwater images, these filters are used consecutively. The anisotropic filters are used for smoothing the image in preprocessing algorithms. To improve the perception of underwater images, KashifIqbal et al,[8] proposed a method based on slide stretching. Firstly, RGB algorithm for contrast stretching is performed to balance the contrast of colors in images and after that the saturation and intensity stretching of HSI is used to increase the true color and to rectify the issues of lighting. Interactive software has been developed for the enhancement of underwater image. Alex et.al [9] have implemented homomorphic filtering to enhance underwater images in FPGA.

Modern hardware based solutions for image processing algorithms increasingly utilize Field Programmable Gate Arrays (FPGA) [10-11]. Through parallelism, FPGAs are able to accelerate the execution of image processing algorithms and improve their performance. Considering the cost for making application specific integrated circuits (ASICs), FPGAs are well suited to be used as a prototype for limited number of end users.

In this paper FPGA implementation of underwater image color correction in lαβ space is explained. Xilinx System generator is being used for implementing the design in FPGA. Hardware co-simulation is carried out using Xilinx Virtex 4 development board.

MATERIALS AND METHODS

The algorithm relies on gray-world and unvarying illumination suppositions are performed in the lαβ space model. Color correction is achieved by the white balancing of α and β, while the luminance component is utilized to improve the contrast of the underwater image. The underwater RGB image has to be converted to lαβ space for further analysis.

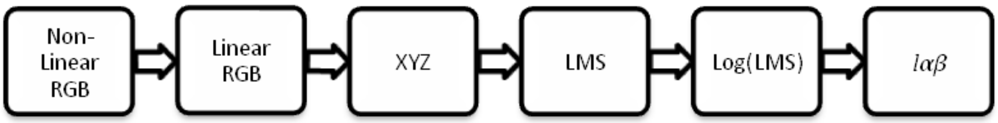

Fig. 1: Conversion of non linear RGB model to *lαβ*

As shown in [Fig. 1], non-linear RGB image is rectified by the non-linearity correction (gamma correction) so as to get RGB coordinates [5][12]. Then conversion into XYZ tri stimulus values is obtained by multiplying the RGB coordinates $f_i(m,n)$ with $T_{xyz,ij}$ matrix as in equation 1 and 2.

$$x_j(m,n) = T_{xyz,ij} f_i(m,n) \quad (1)$$

$$f_i(m,n) = \begin{bmatrix} 0.5141 & 0.3239 & 0.1604 \\ 0.2651 & 0.6702 & 0.0641 \\ 0.0241 & 0.1228 & 0.8444 \end{bmatrix} \quad (2)$$

From this device-independent XYZ space, image is converted to LMS space using the $T_{lms,ij}$ matrix as in equation 3 and 4.

$$l_j(m,n) = T_{lms,ij} x_i(m,n) \quad (3)$$

$$T_{lms,ij} x_i(m,n) = \begin{bmatrix} 0.3897 & 0.6890 & 0.0787 \\ -0.2298 & 1.1834 & 0.0464 \\ 0.0 & 0.0 & 1.0 \end{bmatrix} \quad (4)$$

Now, the data is transformed into logarithmic space, and finally these axes were de-correlated by utilizing Principal Components Analysis (PCA). It can be achieved by multiplying $l_{log,i}(m,n)$ vector by the decorrelation matrix $T_{pca,ij}$ as in equation 5 and 6.Thus, the vector coordinates of image in lαβ space is obtained. The three consequential principal axes are orthogonal, where the axis l represents an achromatic channel, while the other two (α andβ) channels are chromatic yellow-blue and red-green opponent channels.

$$l_{l\alpha\beta,j}(m,n) = T_{pca,ij} l_{log,i}(m,n) \quad (5)$$

$$T_{pca,ij} = \frac{1}{\sqrt{6}} \begin{bmatrix} \sqrt{2} & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & \sqrt{3} \end{bmatrix} \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & -2 \\ 1 & -1 & 0 \end{bmatrix} \quad (6)$$

HARDWARE IMPLEMENTATION

The proposed method is executed in field-programmable gate array (FPGA) which is a device that can be reprogrammed by a designer or customer even after manufacturing it. Similar to application-specific integrated circuit (ASIC), FPGA configuration is described using hardware description language (HDL).Any logical function performed by ASIC, is easily implemented using FPGAs. Relative to an ASIC design, FPGAs offer advantages for many applications such as the ability for updating the functionality, partial reconfiguration of any part of the design and much low non-recurring engineering expenses.

The main advantage in performing image processing using FPGA [8] implementation is due to it stability to exploit both spatial and temporal parallelism. The FPGA implementation can be designed to partition the image into sections and later on, distributing each section into corresponding pipelines. Thus data processing can be done concurrently. So, constraint of parallelization in FPGA is due to the mode of processing the data and hardware limitations of the system. Xilinx System generator is used to implement the proposed design in FPGA.

The following are the various Xilinx system generator model blocks that are being used for implementing the design in FPGA using Xilinx system generator. [Fig. 2] shows the overall implementation model. [Fig. 3-6] shows various subsystem models for implementing the design.

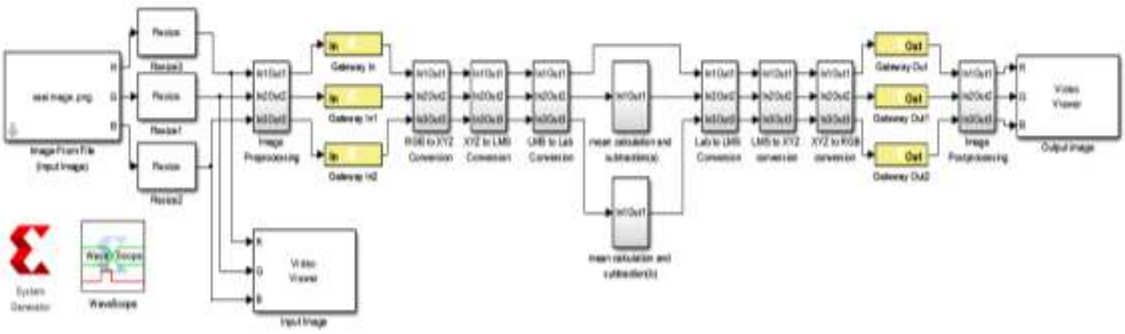

Fig. 2: Implementation of the color correction algorithm using system generator blocks

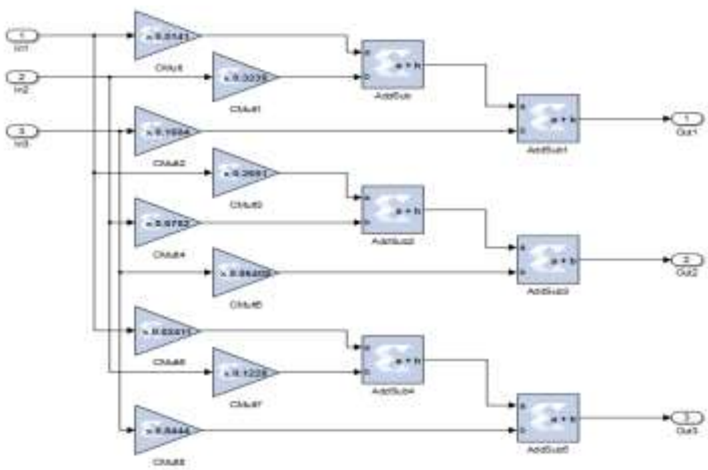

Fig. 3: RGB to XYZ conversion block

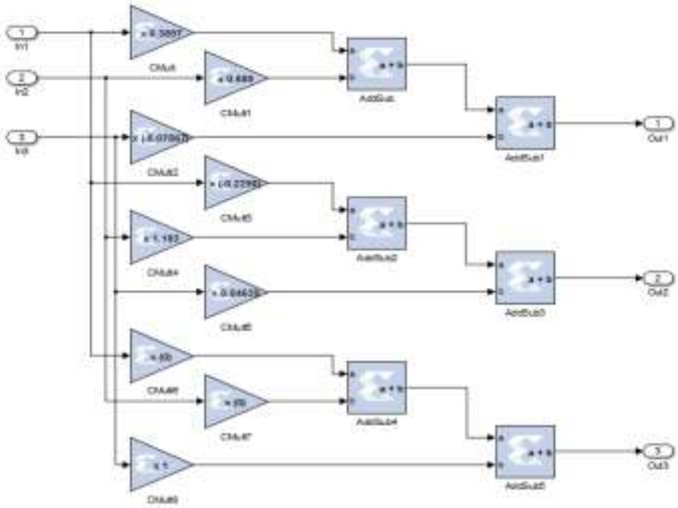

Fig. 4: XYZ to LMS conversion block

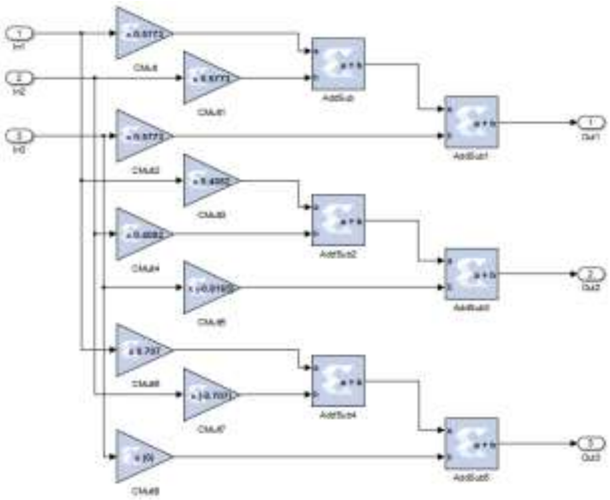

Fig. 5: LMS to Lab conversion block

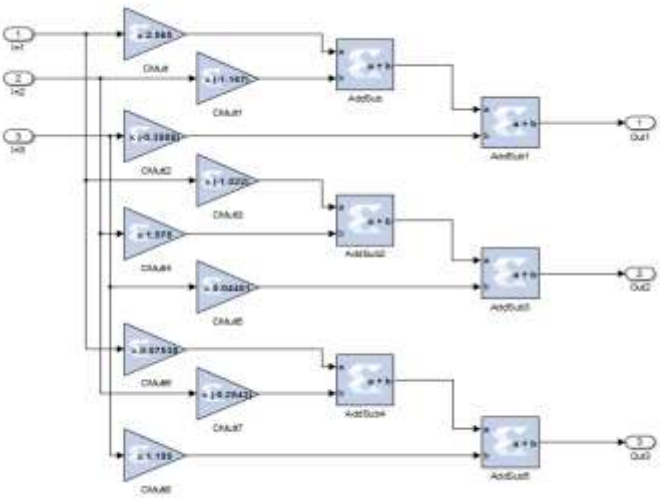

Fig. 6: Implementation of the color correction algorithm using system generator blocks

RESULTS

Hardware co-simulation is done using Xilinx system generator blocks. Various underwater color images are given as input and output images are shown in [Fig. 7].It is observed that the output image shown is free from any color dominancy. The dominant colors that are present in the input color images have been corrected by the proposed method. The output images which are free from any color dominance can be used for various automatic underwater image applications.

Fig. 7: Input images (left) and corresponding output images (right)

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CONCLUSION

This project investigates an effective tool in underwater images for color correction. The algorithm relies on gray-world and uniform illumination assumptions used in the lαβ space and it is developed, implemented and tested for color correction of underwater images. Color correction is achieved by the white balancing of chromatic components (α and β) and the luminance component is utilized to improve the contrast of the underwater image. The developed algorithm is implemented in Xilinx FPGA board (ML403) using Xilinx System Generator. Hardware co-simulation was carried out and the developed model is successfully used in conjunction with the ML403 board. From the outcomes of the experiment, it has demonstrated that this method can be used to remove unwanted greenish-blue components in underwater imaging.

CONFLICT OF INTEREST
There is no conflict of interest.

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FINANCIAL DISCLOSURE
None

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