Underwater Image Enhancement using Single Scale Retinex on a Reconfigurable Hardware

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Abstract— In this paper, hardware implementation of an improved image enhancement technique using single scale retinex algorithm is proposed. Considering the real scene, the dynamic range of digital camera is narrower and hence contrast correction is required to reproduce the information in darker regions. In the proposed method, an input RGB color image is converted to YCbCr color space, and Y and Cr component is modified as the variations in blue components are nominal. In enhancing Y and Cr component, the Gaussian surround function is convolved to it and then the difference between scaled version of Y and Cr component and the convolved one is added to the original one. The algorithm is implemented in FPGA board. FPGA platform is preferred as it's ability to perform parallel algorithm due to it's inherent parallelism.

***Index Terms*— Retinex, Image Enhancement, FPGA, YCbCr**

1. Introduction

Underwater image enhancement is a challenging task as light used for optical image may suffer due to absorption and scattering. Because of this, underwater image suffers from color distortion and low contrast while travelling through water. As colors associated to different wavelengths have different attenuation rates, red color attenuates faster than green and blue [1]. An artificial light which can be incorporated for the loss of illumination would require additional power which is expensive to be equipped with an automated underwater vehicle (AUV) or remotely operated vehicles (ROV).

Human vision is capable of seeing 5 orders of magnitude simultaneously and the natural scenes can be adapted with a high dynamic range. On the other hand, the dynamic range of digital cameras are poorer which results in poor scene details and color reproduction in dark areas. In single scale retinex, Gaussian filter is used to obtain average lightness in an image over an extended area. Underwater images need to be preprocessed for applications such as video mosaic which requires previous registration of different input images.

Several underwater image enhancement techniques have been proposed in various literatures. Hitam et al. [2] have proposed a new method images called mixture Contrast

Limited Adaptive Histogram Equalization (CLAHE) for enhancing the underwater images. The proposed method is mainly used to enhance coral reefs. Erturk et al. [3] proposed a method based on Empirical mode decomposition to enhance underwater images.

Galdran et al. [4] proposed a Red Channel method which is a variant of dark channel method as the color red which attenuates more in underwater is considered to be the dark one. G.Padmavathi et al. [5] compared various filters such as homomorphic filter, anisotropic diffusion and wavelet denoising by average filter to preprocess underwater images. Among those filters, wavelet denoising by average filter produced better results.

The idea of the retinex was conceived by Land et. al. [6] as a model of the lightness and color perception of human vision. In retinex algorithm, where illumination reflectance model is used, either one or both components are enhanced and combined together to form the enhanced image. In Jobson et. al's retinex [7], the estimated reflectance in log domain is the required output image. Jobson et. al. [8], proposed an improved technique that results an output image as a weighted sum of retinex output images by using several linear LPF supporting different regions.

In color image enhancement, Jobson et. al [8], applied retinex algorithm independently to each of the R,G,B components. When retinex algorithm is applied independently to these components, the component ratio of RGB at each pixel may change as they are processed independently. This may result in color change in the output image[9].

In [10]. authors proposed a new algorithm by converting RGB model to HSV model and applying retinex algorithm only to V component. The output image is obtained by combining the original H, S component with the modified V component.

2. Single Scale Retinex (SSR)

The Retinex takes an input digital image I and produces an output image R on a pixel by pixel basis as in the following equation :

$$R(x, y) = \log(\mathrm{I}\ (\mathrm{x,y})) / \log(\mathrm{I}(\mathrm{x,y})*\mathrm{M}(\mathrm{x,y}))$$

Where $M(x, y) = \exp\ (x^2 + y^2)/\sigma^2)$ is a constant which controlsthe extent of M, and σ represent spatial convolutions.

The input image can be written as the product of two components s(x,y) the reflectance component which represents the light reflected from all the objects in the scene being imaged, and $i(x, y)$ which represents the illumination component as in the following equation

$$I(x, y) = i(x, y)\ \mathrm{r}(x, y)$$

Since the illumination component varies very slowly across the scene in the following equation

$$I(x, y) = I0\ \mathrm{r}(x, y)$$

$$R(x, y) = \log\ (\ I0\mathrm{r}(x, y) / I0\ \mathrm{r}(x, y) * M(x, y)$$

By performing the same operation on each color channel, the output color image can be written as equation below.

$$R(x, y) = \log\ (I1\ (x, y) / I1\ (x, y) * M(x, y))$$

$$...i\mathrm{e}\ \{R, G, B\}$$

$Ri(x, y)$ is dependent upon the size of the surround mask which is parameterized by σ.

Different values of σ enhance different features of the input image, equation below.

$$Ri(x, y) = 1/k\ (\ \textstyle\sum^{\mathrm{K}}_{\mathrm{k=0}} \log(\mathrm{I}\ (\mathrm{x,y}))/\log(\mathrm{I}(\mathrm{x,y})*\mathrm{M}(\mathrm{x,y})))$$

SSR shows exceptional promise for dynamic range compression but does not provide good tonal rendition. In fact, a distinct trade-off controlled by the scale of the surround function exists between dynamic range compression and tonal rendition, and one can be improved only at the cost of reducing the other.

The basic form of the single scale retinex (SSR) is given by

$$S_i(x1,x2) = I(x1,x2) - k.\{c.I_i(x1,x2) + \{ I_i(x1,x2)*G(x1,x2) \} \}$$

In the proposed work, the input RGB image is converted to YCbCr model. The Individual components of YCbCr color model are, luminance component and chroma components. Y is luminance component and Cb and Cr components stand for difference of the blue and red with the reference value respectively. In underwater scenario, red components attenuates faster than R and G component. As a result, red color need to be enhanced more compared to the other two. Hence the component Cb is kept constant and the other two components, Y and Cr are enhanced by applying single scale algorithm and finally the enhanced components and the original Cb components are combined. Contrast stretching is also applied to this output to form the final output image. The algorithm is implemented in virtex 4 FPGA development board using Xilinx system generator and hardware co simulation was carried out. Figure(1) shows the design flowchart for a single component either Y or Cr.

3. Hardware Implementation

In case of real time image processing applications, such as vision system used in AUVs and ROVs, the biggest bottleneck is the time required to process the images captured by the camera. Many image processing algorithms require several operations need to be performed on every pixel in the image. Due to the inherent parallelism shown by FPGA, the different operations can be partitioned into subsystems, all of which can be run concurrently with each other. Figure (2) shows part of the Xilinx system generator blocks used to implement the algorithm in virtex 4 FPGA development board.

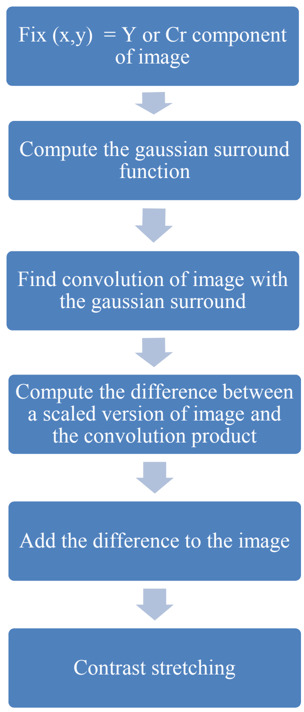

Fig 1. Proposed Algorithm

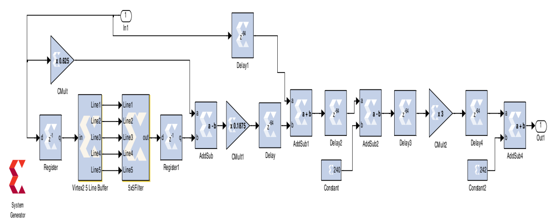

Fig 2. FPGA subsystem Implementation

4. Results

Hardware co simulation was carried out using Xilinx systemgenerator. The target platform was virtex 4 FPGA board. Figure 3. shows the original image and figure 4. shows the enhanced image. Figure 5 and 7 are the original color images and figure 6 and 8 are the enhanced output images. Experimental results confirm that the proposed method is able to improve the local contrast and image details.

Fig. 3. Original image

Fig. 4. Enhanced image

Fig. 5. Original underwater image

Fig. 6. Enhanced underwater image

Fig. 7. Original underwater image

Fig. 8. Enhanced underwater image

4.1 Device Utilization

Table (1) shows the device utilization of virtex 4 FPGA for the proposed algorithm. Device utilization shows that only a minimum percentage of total available resources is being used for the proposed design which ensures much complicated design can also be implemented in FPGA.

Device Utilization Summary			
Slice Logic Utilization	Used	Available	Utilization
Number of Slice Registers	3,224	393,600	1%
Number used as Flip Flops	3,211		
Number used as Latch-thrus	13		
Number of Slice LUTs	3,379	196,800	1%
Number used as logic	1,035	196,800	1%
Number of fully used LUT-FF pairs	1,014	49,200	2%
Number of unique control sets	3,769		
Number of slice register sites lost to control set restrictions	843	3,769	22%
Number of fully used LUT-FF pairs	2,536	3,769	67%

Table 1. Device utilization in FPGA

5. Conclusion and Future Work

A novel method for enhancing underwater images by applying single scale retinex algorithm to the Y and Cr component of the YCbCr model image is implemented in FPGA successfully. It has been also shown that image processing algorithms which require parallel computation can effectively be implemented in an FPGA. Results shown better enhancement using SSR. But there are uneven contrast enhancement which results due to Gaussian filtering. This can be minimized if multi scale retinex algorithm is implemented. Then contrast enhancement can be made uniform throughout the image.

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