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A FPGA Based Architecture to Convert a RGB Image into lαβ Color Space

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ABSTRACT: This paper proposes a novel FPGA based architecture to convert a RGB Image into lαβ color space. In correlated color space images, each channel represents color intensity value of a color where correlation exists between the different channels. But, such correlated color space images suffer from undesirable cross-channel artefacts. That is why; many real life applications, such as giving color effect of one image to another, de-correlated color spaces are needed. One such color space is lαβ color space which is based on data-driven human perception and it was developed by Ruderman et al. in 1998. For this virtue of ℓαβ color space, an attempt has been made in this paper to design a FPGA based architecture to convert a RGB image into ℓαβ color space. The proposed system has been implemented using VHDL, synthesized on Xilinx Virtex 2p 2vp2fg256-6 and simulated on the Modelsim 6.2c from Mentor Graphics Corporation. The proposed architecture is capable to operate at the clock frequency of 179.840 MHz and takes only 7 clock cycles to get each set of result for a pixel.

KEYWORDS: FPGA, VHDL, De-Correlated color space, RGB, ℓαβ.

I. INTRODUCTION

Color space of a digital image is a mathemetical, virtual model which permits to represent, create, visualise and reproduce of colors of the image. Such color space may be classified into correlated color space and decorrelated color space. In a digital image of typical correlated color model, there is correlations between the different color channels. For example a trichromatic very popular color model is RGB which is similar to human visual system[1-6] where the pixel color is obtained by mixing primary colors red, green and blue. In this space each pixel is a triplet corresponding to Red, Green and Blue components of a RGB image at a speficic spatial location. The number of bits used to represent pixel values of the component images determines the bit depth of an RGB image. Some disadvantages of such correlated color model is its non-linearity and perceptual non-uniformity. Moreover these models suffers from cross-channel artifacts. If we want to change the appearance of a pixel's color in a coherent way, we must modify all color channels in tandem. This hampers the color modification method. That's why there is a need for decorrelated orthogonal color space[1-6]. YCbCr, YIQ, ℓαβ are such decorrelated color model.

Lαβ color model was developed by Ruderman et al.[7] which minimizes correlation between channels for many natural scenes. Presuming the human visual system is ideally suited for processing natural scene, this model is based on data-driven human perception research[8]. This color space has three de-correlated, principal channels corresponding to an achromatic luminance channel(l) and two chromatic channels α and β, which roughly correspond to yellow-blue and red-green opponent channels. During application of typical operations in different color channels, undesirable cross-channel artefacts may be avoided by exploiting little correlation between the color axes in lαβ space. Furthermore, Lαβ

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color space is logarithmic which allows first approximation of uniform changes in channel intensity to be equally detectable.

These into lαβ color model plays an important role in many real life image processing applications such as- giving color effect of one image to another[8-9], colorization of a grayscale image using a another reference/source color image[10-11] etc. Now a days in many applications where computation time is higher, we need a dedicated system which works faster[12-14]. In an endeavour to develop a fast and dedicated FPGA based system for grayscale image colorization which needs many small different small modules. One such small module is RGB to lαβ conversion which is implemented in this article.

This paper is organized as follows: Section II process to convert a RGB image into lαβ image described in the paper[9]. Section III depicts the system architecture and brief discussion on various components of the system. Section IV shows the experimental results and finally Section V concludes and remarks about the work.

II. COLOR CONVERSION METHODOLOGY

The color conversion method is discussed in details by Reinhard et al[9]. The color conversion from RGB color model to ℓαβ color space is done in three steps. In first step, the conversion between RGB to LMS space is done using **Eq. 1**.

$$\begin{bmatrix} L \\ M \\ S \end{bmatrix} = \begin{bmatrix} 0.3811 & 0.5783 & 0.0402 \\ 0.1967 & 0.7244 & 0.0782 \\ 0.0241 & 0.1288 & 0.8444 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

In second step, LMS is converted to **LMS** color space by taking the logarithmic values of them as shown in **Eq. 2 to Eq. 4**.

$$\mathbf{L}=\log(L) \quad (2)$$
$$\mathbf{M}=\log(M) \quad (3)$$
$$\mathbf{S}=\log(S) \quad (4)$$

Finally, the ℓαβ color space is achieved using another conversion from **LMS** space using **Eq. 3**.

$$\begin{bmatrix} \ell \\ \alpha \\ \beta \end{bmatrix} = \begin{bmatrix} 0.5774 & 0.5774 & 0.5774 \\ 0.4082 & 0.4082 & -0.8165 \\ 0.7071 & -0.7071 & 0 \end{bmatrix} \begin{bmatrix} \boldsymbol{L} \\ \boldsymbol{M} \\ \boldsymbol{S} \end{bmatrix} \quad (5)$$

Now, to ease the designing of the system architecture for this color conversion, **Eq. 1** is decomposed into smaller equations which are shown in **Eq. 6 to Eq. 17**.

$L_1=0.3811\times R$ (6) $L_2=0.5783\times G$ (7) $L_3=0.0402\times B$ (8) $L=L_1+L_2+L_3$ (9)
$M_1=0.1967\times R$ (10) $M_2=0.7244\times G$ (11) $M_3=0.0782\times B$ (12) $M=M_1+M_2+M_3$ (13)
$S_1=0.0241\times R$ (14) $S_2=0.1288\times G$ (15) $S_3=0.8444\times B$ (16) $S=S_1+S_2+S_3$ (17)

Further, **Eq. 5** is decomposed into smaller equations as shown in **Eq. 18 to Eq. 25**.

$T_1=\mathbf{L}+\mathbf{M}$ (18) $T_2=T_1+\mathbf{S}$ (19) $\ell=0.5774\times T_2$ (20)
$T_3=0.4082\times T_1$ (21) $T_4=0.8165\times \mathbf{S}$ (22) $\alpha=T_3-T_4$ (23)
$T_5=\mathbf{L}-\mathbf{M}$ (24) $\beta=0.7071\times T_5$ (25)

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III. SYSTEM ARCHITECTURE

The system architecture for the proposed methodology is shown in **Fig. 1**. There are 29 modules in the architecture out of which 13 are Multiplier module, 5 are Adder module, 2 are Subtractor module, 3 are Shifter module, 3 are LOG module and 3 are Register module. Each module is controlled by a global clock. These modules are discussed in details in the rest of this section.

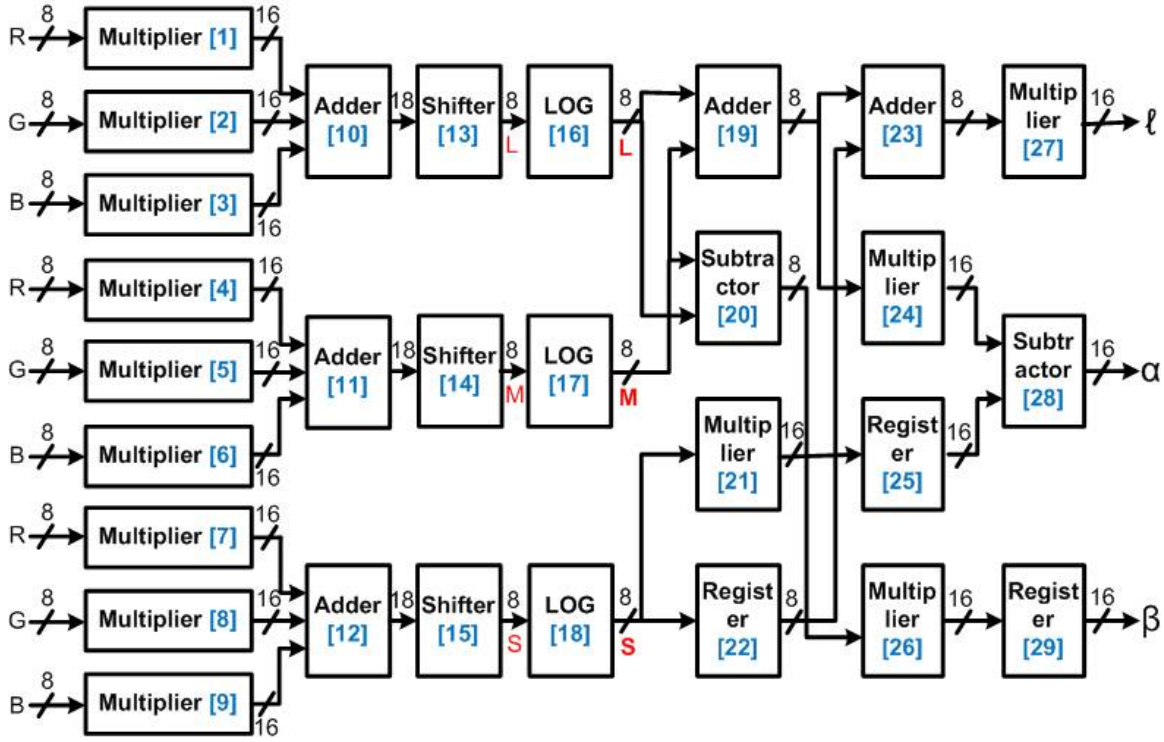

Fig. 1: System architecture of the proposed methodology

Multiplier Module

This module takes one 8-bit input, multiplies it with a predefined value and produces a 16-bit output. There are 13 Multiplier modules. Multiplier module 1, 2 and 3 execute **Eq. 6, Eq. 7 and Eq. 8** respectively. Multiplier module 4, 5 and 6 find the value according to **Eq. 10, Eq. 11 and Eq. 12** respectively. Multiplier module 7, 8 and 9 multiply the R, G and B values with the predefined constant values as shown in **Eq. 14, Eq. 15 and Eq. 16** respectively. On the other hand, Multiplier module 21, 24, 26 and 27 implement **Eq. 22, Eq. 21, Eq. 25 and Eq. 20** respectively.

Adder Module

There are two types of adder in the architecture which are 3-input adder and 2-input adder. Adder module 10, 11 and 12 are three input adder which takes three 16-bit input values, adds them and produces an 18-bit output value. These three adder modules execute **Eq. 9, Eq. 13 and Eq. 17** respectively. On the other hand, Adder module 19 and 23 are the 2-input adder which takes two 8-bit input value and produces an 8-bit output value after adding them. These two modules implement **Eq. 18 and Eq. 19** respectively.

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Subtractor Module

There are two Subtractor modules in the architecture. Subtractor module 20 takes two 8-bit values, subtracts them and produces one 8-bit output value. This module executes **Eq. 24**. Another Subtractor module, indexed as module 28, takes two 16-bit input values and produces one 16-bit output value. It implements **Eq. 23**.

LOG Module

This module takes one 8-bit input value and finds it's logarithmic value from a look up table in 8-bit. This module is used to convert the LMS space to **LMS** color space as shown in **Eq. 2, Eq. 3 and Eq. 4**.

Shifter Module

This module takes one 18-bit input value, fetches eight most significant bits of it and passes the value as 8-bit output value. There are three shifter modules which are denoted as module 13, 14 and 15 in the architecture. As the LOG module is implemented by a look up table in the present work, so the most significant 8-bits are extracted from the 18-bit input value to reduce the space complexity of the LOG module. Because, for a 18-bit input value in the LOG module, $2^{18}\times8$ spaces are required to store the logarithmic values of all combinations in 18-bit whereas only $2^{8}\times8$ spaces are required for an 8-bit input value.

Register

There are two types of registers in the architecture which are one 8-bit register and two 16-bit registers. This module has been implemented to hold the input value for one clock cycle. The necessity of this module is to synchronize the data flow in the architecture.

IV. EXPERIMENTAL RESULTS

The proposed architecture has been implemented using VHDL, synthesized on Xilinx Virtex 2p 2vp2fg256-6 and simulated on the Modelsim 6.2c from Mentor Graphics Corporation. The proposed architecture of **Fig. 1** is capable to operate at the clock frequency of 179.840 MHz and takes only 7 clock cycles to get each set of result for a pixel. The device utilization summary of the architecture is shown in **Table I**.

TABLE 1: DEVICE UTILIZATION SUMMARY

	Usage	Total	Percentage of Usage
Number of Slices	141	1408	10%
Number of Slice Flip Flops	176	2816	6%
Number of 4 input LUTs	207	2816	7%
Number of bonded IOBs	96	140	68%
Number of MULT18X18s	12	12	100%
Number of GCLKs	2	16	12%

V. CONCLUSION

This article proposes a novel FPGA based architecture to convert a RGB Image into lαβ color space. The proposed system successfully converts standard RGB color image into lαβ color space. It has been implemented using VHDL, synthesized on Xilinx Virtex 2p 2vp2fg256-6 and simulated on the Modelsim 6.2c from Mentor Graphics Corporation. The proposed architecture is capable to operate at the clock frequency of 179.840 MHz and takes only 7 clock cycles to get each set of result for a pixel. In future authors may develop a fast and dedicated FPGA based system for grayscale image colorization.

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REFERENCES

[1] W. K. Pratt, "Digital image processing", A Wiley Interscience Publication, 1991.
[2] R. C. Gonzalez, R. E. Woods, S. L. Eddins, "Digital Image processing using MATLB", Mc-Graw Hill, 2011.
[3] Scott E Umbaugh, "Computer vision and image Processing", Prentice Hall, 1999.
[4] R. C. Gonzalez, R. E. Woods, "Digital Image Processing", Addison Wesley, 2002.
[5] S. Sridhar, "Digital Image Processing", Oxford University Press Publication, New Delhi, 2011.
[6] G. Wyszecki and W.S. Stiles, "Color Science: Concepts and Methods, Quantitative Data and Formulae", 2nd edition, John Wiley & Sons, New York, 1982.
[7] D.L. Ruderman, T.W. Cronin, and C.C. Chiao, "Statistics of Cone Responses to Natural Images: Implications for Visual Coding," Journal of Optical Society of America, vol. 15, no. 8, 1998, pp. 2036-2045.
[8] E. Reinhard, M. Ashikhmin, B. Gooch and P. Shirley, "Color Transfer between Images", IEEE Computer Graphics and Applications, vol.21, no. 5, pp.34-41, 2001.
[9] B. Tang, G. Sapiro and V. Casseles, Color image enhancement via chromaticity diffusion. IEEE Transactions on Image Processing, vol. 10, no.5, pp.701–708, 2001.
[10] T. Welsh, M. Ashikhmin, and K. Mueller, "Transferring color to greyscale images", ACM Transactions on Graphics, vol.21, no.3, pp.277–280, 2002.
[11] S. Halder, A. Hasnat, D. Bhattacharjee, M. Nasipuri, "A Proposed System for Colorization of a Gray Scale Facial Image using Patch Matching Technique", Proc. of IEEE RAICS 2013.
[12] S. Halder, A. Hasnat, A. Hoque, D. Bhattacharjee, M. Nasipuri, "Pipelining Based Floating Point Division: Architecture and Modelling", International Journal of Innovative Technology and Exploring Engineering, vol. 3, no. 1, p.p. 15-19, 2013.
[13] S. Halder, A. Hasnat, A. Khatun, D. Bhattacharjee and M. Nasipuri, "A Fast FPGA Based Architecture for Skin Region Detection", International Journal of Innovative Technology and Exploring Engineering, ISSN: 2278-3075, vol.3, no.1, pp.1-4, 2013.
[14] S. Halder, A. Hasnat, A. Hoque, D. Bhattacharjee, M. Nasipuri, "A Fast FPGA based Architecture for Measuring the Distance between Two Color Images using Manhattan Distance Metric", IJECET©IAEME, vol-4, no-3, pp.1-10, 2013.