Design and Simulation of Optimized Color Interpolation Processor for Image and Video Application

Rashmi Betina[1] Naveen Kumar G. N[2]
[2]Assistant Professor
[1]Department of Electronics & Communication Engineering
[1,2]CMRIT, Bangalore, India

Abstract— In this project, the design of an optimized structural based interpolation processor is proposed. This proposed system provides the block level design in MATLAB Simulink® workspace. This block level design reduces the complexity of design. The Verilog code is generated using the Xilinx system generator automatically based on the design in the MATLAB Simulink® workspace which reduces the human errors. The architecture of the proposed system is highly efficient. The chip area and the power consumption of the design are highly optimized in the proposed system. The number of gate counts and the design utilities are highly reduced.

Keywords: MATLAB Simulink®; block level design; chip area; power consumption.

I. INTRODUCTION

At present all the cameras are digitalized. These digital cameras are incorporated into all electronic gadgets such as cellular phones, laptops to vehicles. The digital cameras use Color Filter Array (CFA) to capture the image which are developed by CCD or CMOS image sensor. A CCD sensor consists of a single amplifier for all the pixels where as in CMOS image sensor each active pixel has its own amplifier. CMOS image sensor consumes less power than the CCD sensor. In most of the image capturing devices, the region colors are captured with one sensor and an array of color filters by using Color Filter Array.CFA is used to reduce the cost and packaging. CFA allows the photons of one color components and it blocks the photons of other components and it acts as a coating on the pixel. Therefore, these color filters are used to separate the light from the sensor according to the wave lengths. Wave length of the light decides the intensities at each pixel location. Therefore, CFA generates the sub sampled color image. In the entire image, only one third of captured pixels have genuine values from the sensors. Remaining pixels are interpolated from these genuine values. CFA uses alternating color filters to sample only one color of a pixel location. There are many number of CFA patterns used in different types of digital cameras. Bayer Filter, RGBE filter, CYGM are the some of the patterns used in digital cameras. Widely used pattern for CFA is the Bayer pattern. In Bayer CFA as shown in the figure below the Red, Green and blue pixels are separated as each pixel contains only one color that is two colors are vanished in a single pixel. The original image should be reconstructed using these pixels. There are many high efficient algorithms which are proposed for the reconstruction of an image. All the three pixels are added in order to construct an original image.Many interpolation algorithms have been proposed so far. The interpolation process with adaptive edge enhancement is adopted to reduce the blurring effect and to increase the clarity of the image. Adaptive edge enhancement refers to the method where based on the anisotropic weighing model the edge enhancement may or may not be included in the interpolation process. Here only addition, subtraction, division and shift operations are performed. This makes the design complexity less. The clarity of the interpolation image is increased by considering the DH value than the DV value in the image matrix. Many interpolation algorithms with high efficiency have been proposed for the reconstruction of full image from the CFA image. As in [1] Proposes the interpolation process which is adaptive and that uses 2-D Gaussian process. Here the edge indicator is used in order to grasp the edge information of the image. Here the robustness is achieved based on the stochastic characteristics of edge indicators which are oriented uniformly. The superiority of this algorithm is shown in terms of peak signal-to-noise ratio and mean square error. As in [2] the study on zooming and enlarging the image is done. This is done using the single sensor cameras which employs Bayer CFA. With the implementation of this the cost and complexity are highly reduced. This zooming framework helps to preserve the spectral characteristics of an image and also provides the adaptive edge-sensing mechanism. The zooming technique gives the simulation results with high accuracy and sharpness. It gives the reliable performance.This paper discusses about the problems that occurs due to the 2-D interpolation. The main problems are misguidance color artifacts, interpolation color and aliasing. With metric neighborhood modeling the level of misguidance color in two respective images can be compared. The problem of missed pixels can be solved with demosaicing algorithm. By applying the filter bank technique the aliasing problem is addressed in 2-D interpolation. By using a nonlinear iterative procedure the reduction of interpolation artifacts are done [3]. As in [4] it introduces the new technique for demosaicing the image. This new technique deals with the difference in green-red and green-blue signals using optimal direction filtering. Here the missing green pixel is estimated using the linear minimum mean square-error estimation (LMMSEE) technique. Hence the green pixels are improvised. In this paper, to improve the performance of the interpolation a gradient-base method has been proposed. This method uses the Gaussian low-pass filter to enhance the performance. In this method it is assumed that the frequency of green plane in an image is same as that of the red and blue planes of the particular image. Using this appropriate mask size and Gaussian sigma values are determined. This method can easily suppress the false colors which are formed during the interpolation process. Compared to the previous methods it provides an appropriate image quality and high peak signal-to-noise ratio [5]. During the interpolation of image color artifacts are introduced. These artifacts are due to the phase shift and the signal-aliasing effects which are introduced due to the spare sampling of CFAs. It mainly discussed about the non-linear interpolation technique which gives the appropriate visual results especially at the edges which are sensible to human eye. The results of this method give a good impact than that of the previous linear interpolation techniques [9]. With the inspiration of previous technique the human vision system with linear demosaicing scheme was introduced. It usually represents the single color per special location images [10].

In order to reduce the design complexities and memory requirements the VLSI architecture has been employed. By using the common computational kernel this VLSI architecture can interpolate various colors. It reduces the circuit complexity and this can also be verified using FPGA device. This chip uses two line buffers and 10k gates [11]. For th implementation of real time images, a low-complexity algorithm which is implemented using VLSI architecture is proposed. This is implemented using an edge-detector, an anisotropic model and a filter based compensator. It reduces the gate counts highly compared to previous algorithms and the power consumption is also very less. It reduces the power consumption by 8% and also decreases the CPSNR quality [12].

II. PROPOSED SYSTEM AND ITS ARCHITECTURE

In this paper, VLSI implementation of adaptive color interpolation processor with edge enhancement is designed and implemented using MATLAB Simulink® software.Implementing in MATLAB Simulink® reduces the complexity of design and increases the ease of designing and also reduces the code complexity by generating the code automatically without human errors. This design allows us to check the result in each and every stage of the block and the all the outputs are displayed graphically. In the proposed system, VLSI implementation of adaptive color interpolation processor with edge enhancement is designed and implemented using MATLAB Simulink® software. Implementing in MATLAB Simulink® reduces the complexity of design and increases the ease of designing and also reduces the code complexity by generating the code automatically without human errors. This design allows us to check the result in each and every stage of the block and the all the outputs are displayed graphically.

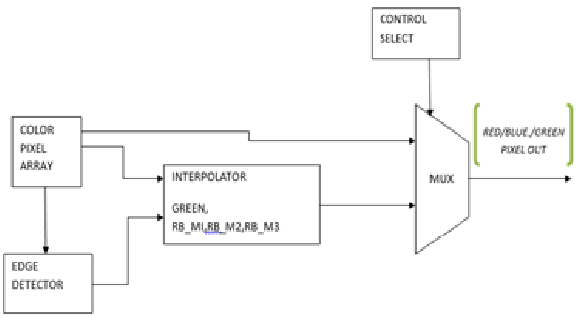

Fig. 1: Proposed architecture of optimized interpolation process.

Fig.l shows the overall module of the proposed system. This module consists of the following blocks: The color pixel array, An Edge Detector, Interpolator (includes one green and 3 red-blue interpolators), A multiplexer, A control select for a multiplexer.

A. Color Pixel Array

Color pixel array is nothing but the array of values which are given as inputs. These are derived from an image in a matrix form. These values are saved using a register bank. These values are derived from the MATLAB.

B. Edge Detector

Fig.2 shows the edge detectors architecture. An edge detector identifies the points in the digital image at which image brightness changes sharply or more formally. Here the inputs are taken from the matrix of pixels called color pixel array. It consists of adders and subtraction blocks.The input to the edge detector is the matrix of pixel values of a digital image. Here the addition and subtraction operations are done during the processing of the edge detector. To calculate the edge information the total difference (TD) is calculated. This total difference is calculated using the parameters such as difference in vertical direction (DV) and difference in the horizontal direction (DH) [12].

$$TD = DV + DH \qquad (1.1)$$

After the process the outputs TD, DV, DH are given to the interpolators. The output signal TD provides the edge intensity of the pixel. The direction information is given by the output DV and DH.

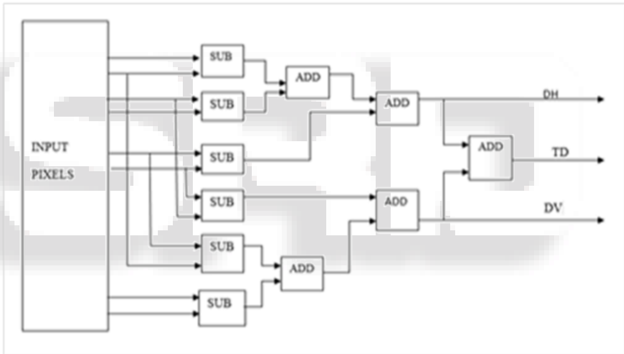

Fig.2: Edge Detector Architecture.

C. Green interpolator

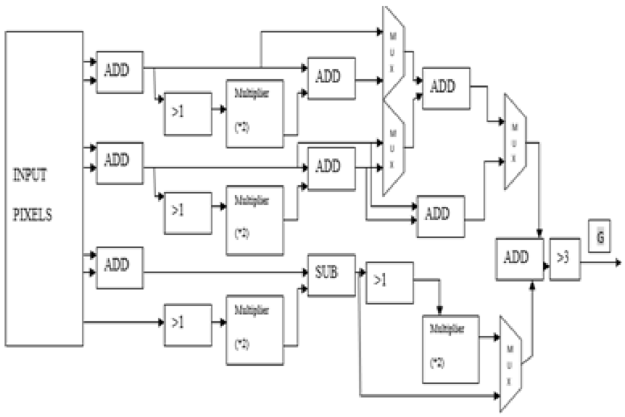

Fig. 3: Green interpolator architecture

Fig.3 shows the architecture of G interpolator. The excellence of the interpolated images can be improved by the anisotropic weighing model. In the anisotropic weighing model the information from the vertical pixels and horizontal pixels are considered as the reference. Here 75% of horizontal direction and 25% of vertical direction is considered for G interpolation to reduce the complexity of the design the shift operations are introduced instead of division operation.In the G interpolation the edge enhancement may or may not be included. This is called adaptive edge enhancement. This adaptive edge enhancement can reduce the blurring effect. This usage of edge enhancement depends on the TD value. If the TD value is less than the threshold value then the G interpolation is done without considering the edge enhancement. If the TD value is higher than the threshold value and DH is less than DV, the value of G interpolator can be calculated with edge enhancement in horizontal direction .If the TD value is higher than the threshold value and DH exceeds DV then the G interpolation with vertical edge enhancement is performed [12].

D. Red-Blue interpolators

In this design three RB interpolators are used. This is a reconfigurable design. Depending upon the values of TD, DV and DH the design is reconfigurable. For the reconstruction of red and blue pixels the neighbouring four green pixels are required [12]. The TD, DV and DH values are selected in order to apply the edge enhancement methods. These three red-blue interpolators vary from each other. The number of components used are different. The input for these are the matrix of pixel values in an image.

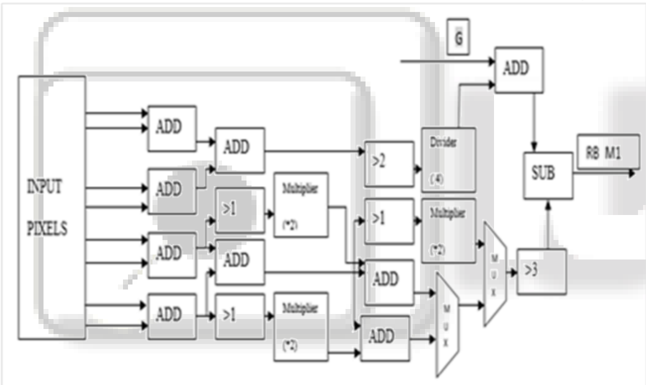

Fig. 4: RB_M1 interpolator architecture

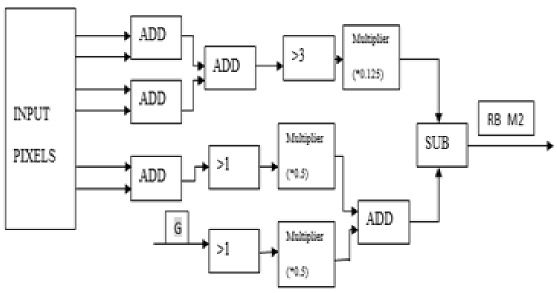

Fig. 5: RB_M2 interpolator architecture

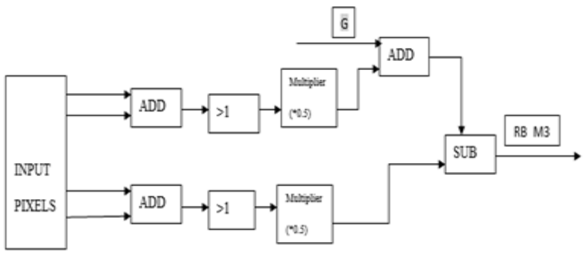

Fig. 6: RB_M3 interpolator architecture

III. RESULTS

The results in this project are obtained in both MATLAB Simulink® software as well as in Xilinx ISE design suit. The Xilinx simulation results includes the simulation waveform obtained in ISIM simulator, RTL schematic and the design utilities.

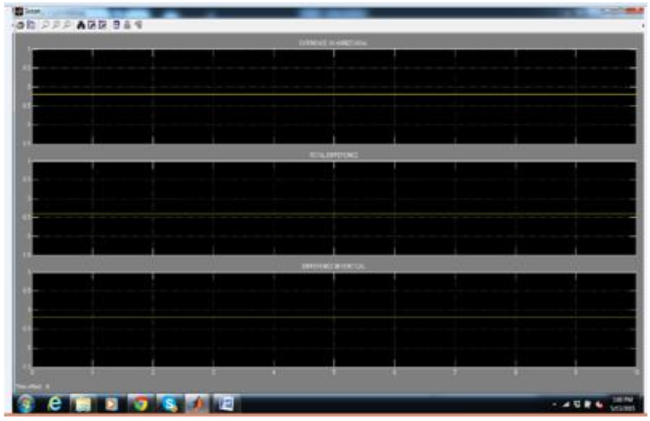

Fig.7: Edge Detector Output

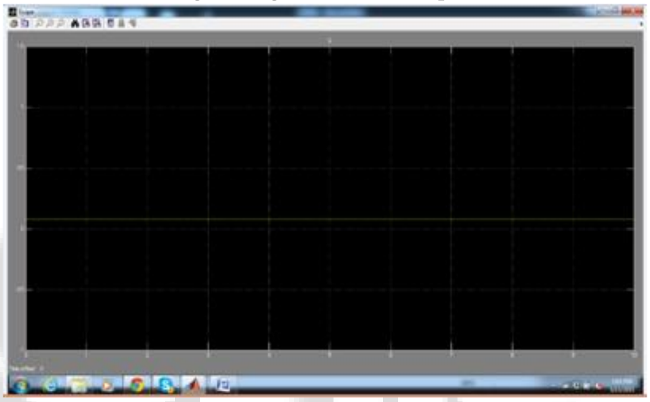

Fig.8: Green interpolator Output

Fig.9: RB_M1 interpolator Output

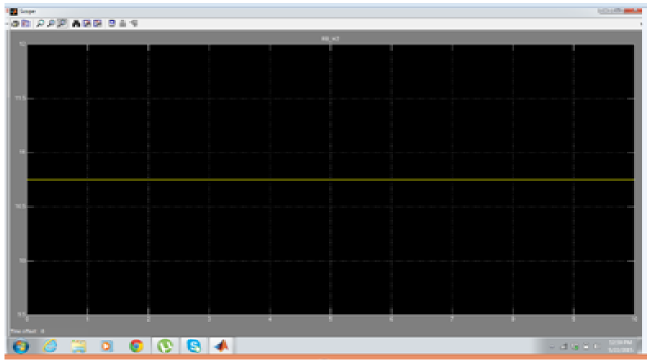

Fig. 10: RB_M2 interpolator Output

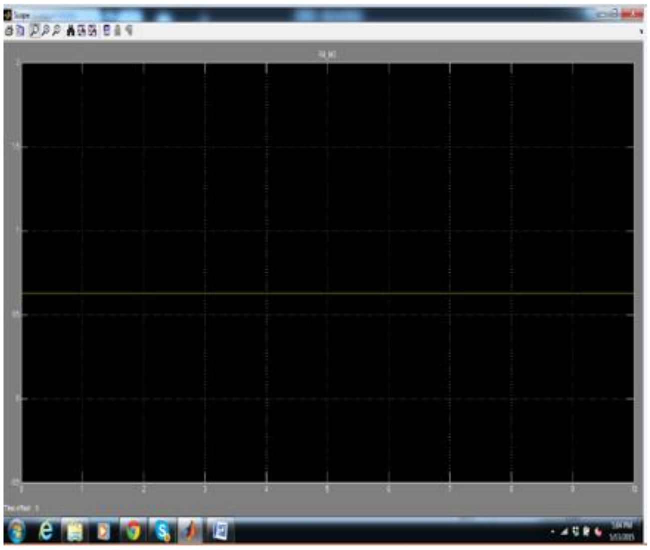

Fig.11: RB_M3 interpolator Output

Fig. 12: Color interpolator Output

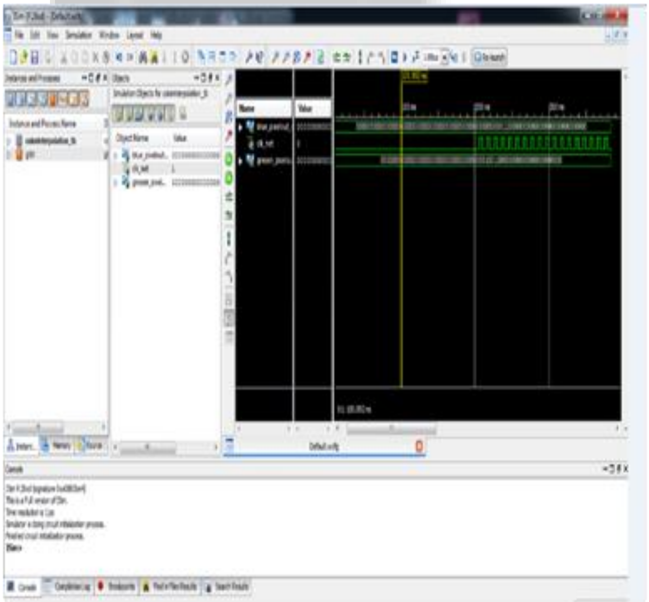

Fig. 13: Simulation result

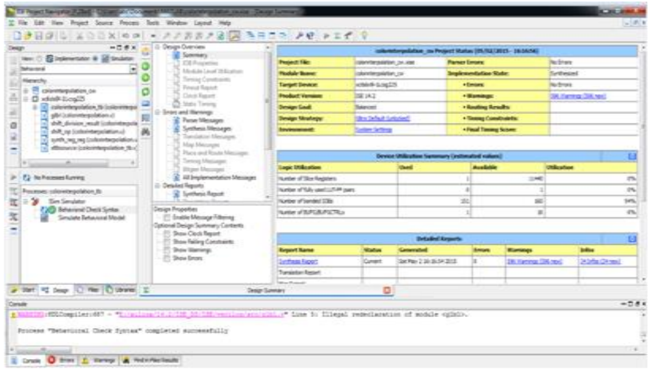

Fig. 14: Design Summary

IV. CONCLUSION

Most of the image interpolation processor techniques are aiming at the highly efficient algorithms which reduces the memory requirement, complexity of the design, power consumption and which gives the relatively high throughput. This project deals with the structure based design where each and every block is designed individually and the output of each and every block is checked. The main advantage if this project is the design and implementation using MATLAB Simulink® is very easy. It is easy to learn this tool. The main purpose of using this tool is it decreases the design complexity to the higher extent. This implementation procedure uses the less time and the code is generated automatically using Xilinx system generator which eliminates the human interventions.

From the results it is observed that the output of each block is clear and the entire thing is done with the use of pipelining. The throughput of the system is highly increased compared to the previous methods. The main motive of this projects is to design an optimized interpolation processor. Here this design is area efficient, user friendly with high throughput, reduces the time consumption and the economical. This is also adaptive. The power dissipation and the design utilities are very less. From the implementation point of view the gate count of the design is very less and the number of IOBs, buffer used are very less. This makes the design highly efficient. The above merits makes the above design efficient which is implemented using MATLAB Simulink® software.

ACKNOWLEDGEMENT

I would like to express my heartfelt gratitude to my Guide Mr. Naveen Kumar G. N, Assistant. Professor, Electronics and Communication Engineering, CMR Institute of Technology for his timely advice on the technical seminar and regular Assistance throughout the project work. I extend my sincere thanks to Dr.Indumathi.G Head of the Department, Electronics And Communication Engineering, CMR Institute of Technology, for her constant encouragement. I also extend my sense of gratitude and sincere thanks to all the faculty members of Electronics and Communication

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