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GJCST-A Classification : B.7.0



HARDWARE SYNTHESIS OF CHIP ENHANCEMENT TRANSFORMATIONS IN HARDWARE DESCRIPTION LANGUAGE ENVIRONMENT

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Hardware Synthesis of Chip Enhancement Transformations in Hardware Description Language Environment

Priyanka Saini ^α, Adesh Kumar ^σ, Neha Singh ^ρ & Dr. Anil Kumar Sharma ^ω

Abstract - Human analyze different sight in daily life images to perceive their environment. More than 99% of the activity of human brain is involved in processing images from the visual cortex. A visual image is rich in information and can save thousand words. Many real world images are acquired with low contrast and unsuitable for human eyes to read, such as industrial and medical X-ray images. Image enhancement is a classical problem in image processing and computer vision. The image enhancement is widely used for image processing and as a preprocessing step in texture synthesis, speech recognition, and many other image/video processing applications. The main challenge is to transpose the validated algorithms into a language as hardware description languages. It is also the need that the input and output data files should be reshaped to match the binary content permitted into the hardware simulators. Research focuses on Simulation, Design and Synthesis of 2D and 3D Image enhancement chip in Hardware description language (HDL) Environment. The chip implementation of image enhancement algorithm is done using Discrete Wavelet Transformation (DWT) and Inverse Modified Discrete Cosine Transformation (IMDCT). Hardware chip modeling and simulation is done in Xilinx 14.2 ISE Simulator. Synthesis environment is carried out on Diligent Spartan-3E FPGA. Image enhanced values are seen in the waveform editor of Modelsim software.

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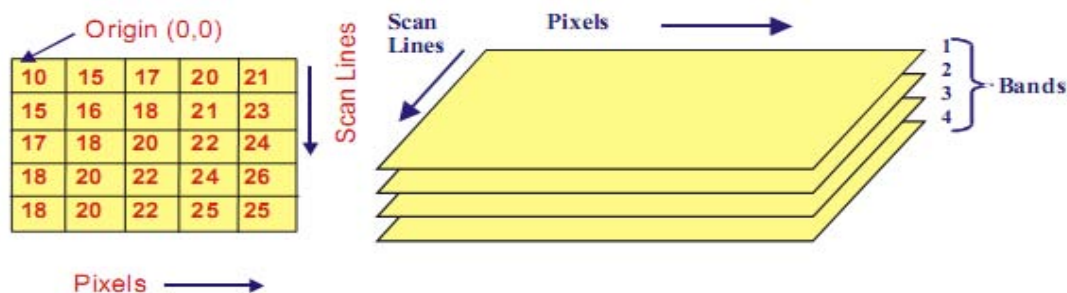


Figure 1 : Structure of a Digital Image and Multispectral Image [10]

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I. INTRODUCTION

Pictures are the most common and convenient means of conveying [4] or transmitting information. A picture is worth a thousand words [3] [7]. Pictures concisely convey information about positions, sizes and inter-relationships between objects. Human recognize the images as object which are represented in spatial information [1] that we can recognize as objects. Human innate [1] [5] visual and mental abilities are good at deriving information from such images, because of 75% of the information received by human is in pictorial form. A digital remotely sensed image is typically composed of picture elements or pixels [2] [6] are located at the intersection of each row i and column j in each K bands of imagery. Associated with each pixel is a number known as Digital Number (DN) [2] or Brightness Value (BV) [3] that depicts the average radiance [19] of a relatively small area within a scene as shown in figure 1. A smaller number indicates low average radiance [7] from the area and the high number is an indicator of high radiant properties of the area. The size of this area effects the reproduction of details within the scene. As pixel size is reduced, more scene detail is presented in digital representation.

Image enhancement methods [1] [2] [8] are basically improving the perception or interpretability of information in images for human viewers. The reason of it is to provide better input for other automated digital image processing techniques [21]. The main objective of image enhancement is to change or modify the attributes of an image [14] can be suitable for different task and a specific observer can identity it to fulfill his requirements. During image enhancement process,

[21] one or more attributes of an image are modified. A specific task may be the choice of attributes and the ways they are modified are specific to a given task. Choices of image enhancement methods are subjected to observer-specific factors such as the human visual system [11]. The choice of image enhancement methods also depends on observer's experience and it will introduce a great deal of subjectivity into choice of image enhancement methods [12]. Image enhancement is used in the following cases:- enhancement of dark image [7], removal of noise and distortion from image [7] [12], enhancement of dark image and highlight the edges of the objects [14] in an image. Different Transformations can be applied to perform these operations.

Digital image processing can be implemented into digital chips. For example digital cameras [16] generally use dedicated digital image processing chips which are used to convert the raw data taken from image sensor into a colour image in a standard image file format. Further these images are used in digital cameras to improve their quality. A software program is used for the modification [16] in the image and can manipulate the images in different ways. Digital camera enable of viewing the histograms [12] [13] of images by which a photographer can understand rendered brightness range of each image shot more readily. Digital images play a very important role in our daily life applications such as satellite television, magnetic resonance imaging and computer tomography. An image is defined as an array [17], or a matrix, of square pixels [12] [17] arranged in rows and columns. These are also called picture elements. An image can be represented in 2D configuration for a 3 D scene [17]. An object can be represented by its numerical value by an image [15]. An image is said a 2D function that represents some characteristics such as intensity, colour and brightness [1] [16] of any scene. It can be defined as a two variable function $f(x,y)$ [17] projected in a plane where $f(x,y)$ defines the light intensity at particular point.

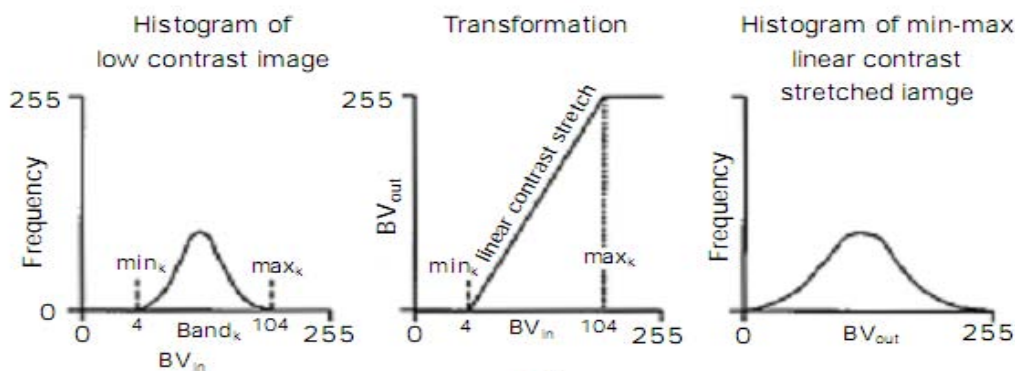
II. IMAGE ENHANCEMENT TRANSFORMATIONS

Image enhancement techniques [13] [14] improve the quality of an image as perceived by a human. These techniques are most useful because many satellite images [21] when examined on a color display give inadequate information for image interpretation. There is no conscious effort to improve the fidelity of the image with regard to some ideal form of the image. There exists a wide variety of techniques for improving image quality. The contrast stretch, edge enhancement, density slicing, and spatial filtering [3] are the more commonly used techniques. Image enhancement is attempted after the image is corrected for geometric and radiometric distortions [19]. Image enhancement methods are applied separately to each band of a multispectral image [17] [19]. Digital techniques [4] [12] have been found to be most satisfactory than the photographic technique for image enhancement, because of the precision and wide variety of digital processes. Image Enhancement Techniques are listed below:

- Contrast Enhancement Method
- Smoothing
- Brightening
- Intensity Transformation
- Discrete Wavelet Transformation
- IMDCT (Inverse Modified Discrete Cosine Transformation)

a) Contrast Enhancement Method

An Image is taken and its contrast is increased or decreased as per the enhancement requirements of the Image. The required contrast enhancement is achieved applying the Histogram Stretching [17] of the Image. There are two methods of image enhancement Linear and Nonlinear Contrast Stretch [15]. The grey values [4] in the original image and the modified image follow a linear relation in linear contrast method.



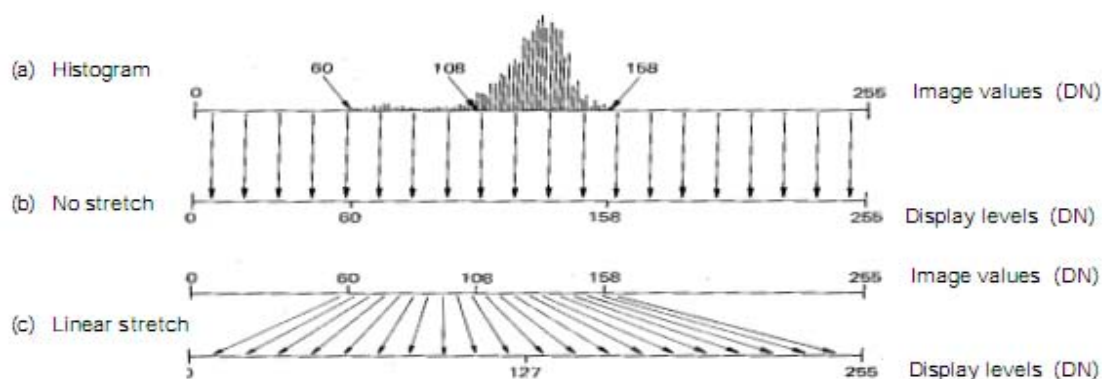


Figure 2: Linear Contrast Stretch [15]

A density number in the low range of the original histogram is assigned to extremely black and a value at the high end is assigned to extremely white. The remaining pixel values are distributed linearly between these extremes. The features or details that were obscure on the original image will be clear in the contrast stretched image [3]. Linear contrast stretch operation can be represented graphically as shown in Figure 2. To provide optimal contrast and color variation in color composites the small range of grey values in each band is stretched to the full brightness range [11] of the output or display unit. In Non-Linear contrast enhancement [17], the input and output data values follow a non-linear transformation [15]. The general form of the non-linear contrast enhancement is defined by $y = f(x)$, where x is the input data value and y is the output data value. The non-linear contrast enhancement techniques have been found to be useful for enhancing the color contrast between nearly classes and subclasses of a main class. A type of non linear contrast stretch involves scaling the input data logarithmically.

b) Smoothing

A noisy Image is taken and the noise removal [3] is done by applying a smoothing technique. The noise removal is achieved by using a mask which enables neighborhood pixel processing [15]. The aim of image smoothing is to diminish the effects of camera noise, spurious pixel values, [14] missing pixel values etc. There are many different techniques for image smoothing; we will consider neighborhood averaging and edge-preserving smoothing [15]. Each point in the smoothed image, $\hat{F}(x,y)$ is obtained from the average pixel value in a neighborhood of (x,y) in the input image.

For example, if we use a 3 x 3 neighborhood around each pixel we would use the mask

$$\begin{matrix} 1/16 & 1/16 & 1/16 \\ 1/16 & 1/16 & 1/16 \\ 1/16 & 1/16 & 1/16 \end{matrix}$$

Each pixel value is multiplied by 1/16, summed, and then the result placed in the output image. This mask is successively moved across the image until every pixel has been covered.

Neighborhood averaging or Gaussian smoothing will tend to blur edges because the high frequencies in the image are attenuated. An alternative approach is to use median filtering [3]. Here we set the grey level to be the median of the pixel values in the neighborhood of that pixel. The median m of a set of values is such that half the values in the set are less than m and half are greater. For example, suppose the pixel values in a 3x3 neighborhood are (10, 20, 20, 15, 20, 20, 20, 25, 100). If we sort the values we get (10, 15, 20, 20, 20, 20, 25, 100) and the median here is 20. Figure 3 (a) & (b) shows an image before smoothing and after smoothing.



Figure 3: (a) Image before smoothing & (b) After smoothing

c) Brightening

Enhancement techniques expand the range of brightness [15] values in an image so that the image can be efficiently displayed in a manner desired by the analyst. The density values in a scene are literally pulled farther apart, that is, expanded over a greater range. The effect is to increase the visual contrast [14] between two areas of different uniform densities. This enables the analyst to discriminate [21] easily between areas initially

having a small difference in density. Brightened Image [13] developed from original image by increasing every

pixel with a constant. Figure 4 (a) & (b) shows an image before brightening and after brightening.

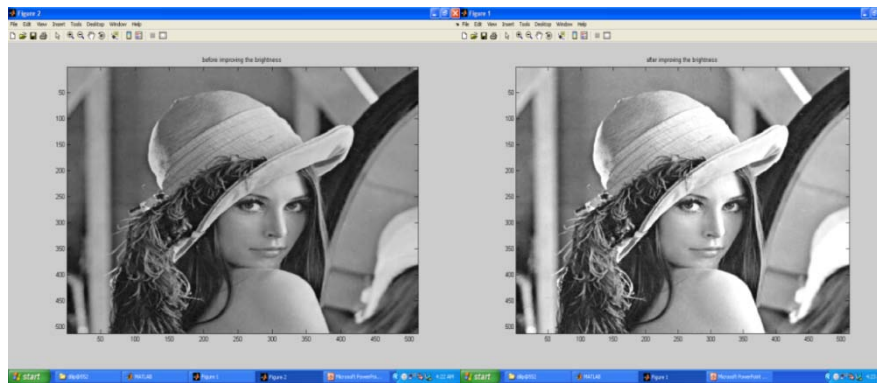


Figure 4 : (a) Image before bright and (b) After bright [15]

d) Intensity Transformation

The simplest form of the transformation T is when the neighborhood is $1 \times 1 \Rightarrow$ intensity transformation [13] [21]. Because they depend only on intensity values and not explicitly on the location of the pixel explicitly on the location of the pixel intensity, intensity transformation functions frequently are written as $s = T(r)$ where r denotes the intensity of f and s the intensity of g both at point (x, y) . for example, if $T(r)$ has the form in figure 5 (a), the effect of applying the transformation to every pixel of generate the corresponding pixels in g would be to produce an image

of higher contrast than the original by darkening the intensity levels below k and brightening the level above k . In this technique, sometimes called contrast stretching, values of r lower than k are compressed by the transformation function into a narrow range of s , toward black. The opposite is true for values of r higher than k . Otherwise how an intensity value r_0 is mapped to obtain the corresponding value s_0 . In the limiting case shown in figure 5 (b), $T(r)$ produces a two level image. A mapping of this type is called a Thresholding function [13]. By increasing the pixel size of any image we can enhance the image in x, y, z all the three directions.

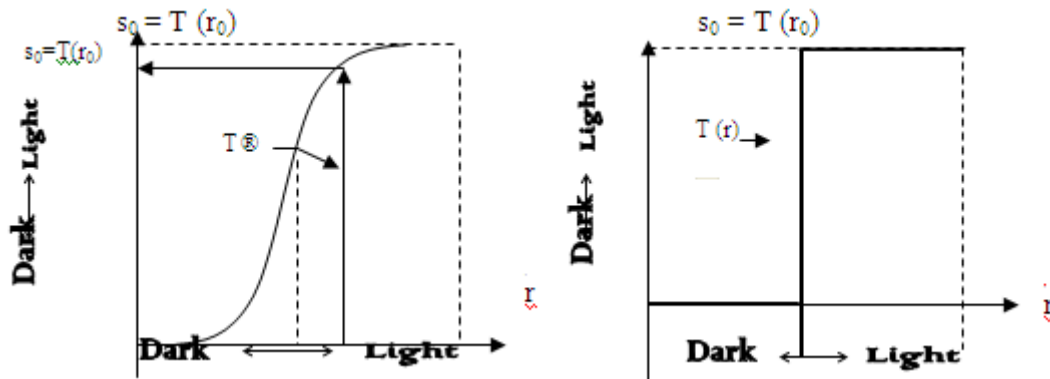


Figure 5 : Intensity Transformations (a). Contrast Stretching (b). Thresholding Function

e) Wavelet Transformation

The Discrete Wavelet Transform (DWT) [3] is a widely applicable image processing algorithm that is used in various applications. DWT decomposes an image by using scaled and shifted versions of a compact supported basis function called the mother wavelet, and provides a multi-resolution [18] representation of the image. Performing the DWT, modifying the transform coefficients, and performing the inverse transform (IDWT) [3] [19] of the modified coefficients is a promising method in signal and image

processing. It is based on the histogram equalization technique [19] to analyze the DWT and IDWT results.

f) IMDCT (Inverse Modified discrete cosine transform)

This transform is used for image compression and image enhancement [5]. It accepts 18 discrete values at one time. The 18-point IMDCT (block size 36) implementation is given by the following equation.

$$\widehat{x}_m = \frac{2}{N} \sum_{k=0}^{\left(\frac{N}{2}\right)-1} X_k \cdot \cos \left[\frac{\pi}{2N} (2k+1) \left(2m+1 + \frac{N}{2} \right) \right], \quad \text{with } m = 0, 1, 2, \dots, N-1$$

Generally, it is a lapped transform, the recovered data sequence $\{\widehat{x}_m\}$ does not correspond to the original data sequence $\{x_m\}$. To obtain the correct $\{x_m\}$ the outputs of consecutive transforms have to be combined. It can be seen that $N/2$ (non redundant) input values result in N output values (of course the MDCT [5] reads N input values and results in $N/2$ output values). Since it is not completely clear whether Equation 1

should be called an N -point IMDCT [5] or an $N/2$ -point IMDCT, in the following we shall identify these transforms given the number of inputs. Considering an 18-point IMDCT that delivers 36 output values, thus length N will be 36. Considering a case for $N=36$, we start from an 18 values input sequence: $\{X_0, X_1, \dots, X_{17}\}$. The output of rotational block is given by

$$a_n = X_n \cos \left[\frac{\pi}{2N} (2n+1) \right] + X_{N/2-1-n} \sin \left[\frac{\pi}{2N} (2n+1) \right]$$

$$b_n = X_n \sin \left[\frac{\pi}{2N} (2n+1) \right] - X_{N/2-1-n} \cos \left[\frac{\pi}{2N} (2n+1) \right]$$

$$\text{Here } n = 0, 1, 2, \dots, \frac{N}{4} - 1$$

The left most 'combine and shuffle'-block is thus nothing more than a reverse ordering of the second half of the input data.

III. DESIGN METHODOLOGY & FLOW

Figure 6 shows a flow chart over the design process when a design is implemented into an FPGA [13]. This flow was followed with all designs in this project and so became an important structure in the project plan. For those that is not familiar with these concepts a short description will follow. For more case specific see all the steps listed below at front end design. The Spartan 3E [23] [24] starter kit provides easy way to test the various programs in the FPGA itself, by dumping the 'bit' file of the designed program in Xilinx software into the FPGA and then observing the output. The Spartan 3E FPGA board comes built in with many peripherals that help in the proper working of the board and also in interfacing the various signals to the board itself. Some of the peripherals included in the Spartan 3E FPGA board include: 2-line, 16-character LCD screen used for display the output, PS/2 mouse [23] or keyboard port can be connected to the FPGA, VGA display port [24] used to display various encoded images via a screen.

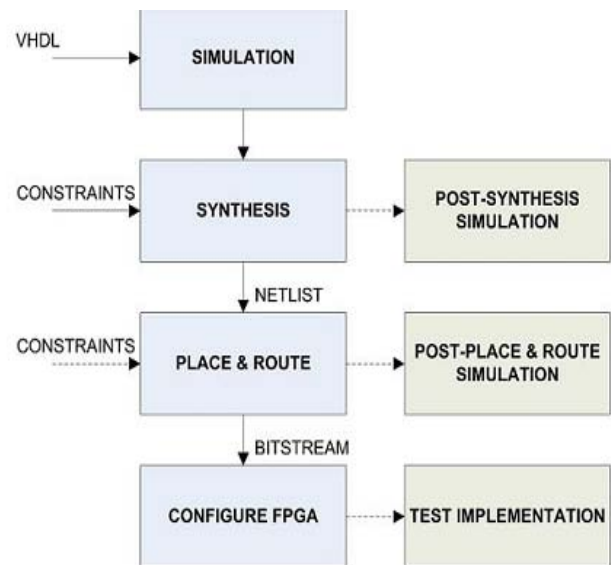


Figure 6 : FPGA Design Project Flow [22]

The image encoding would be done by the FPGA via the aid of the program and then the encoded image would be displayed on the screen. Two 9-pin RS-232 [23] ports help in the transmission of serial data to and from the FPGA board, 50 MHz clock oscillator is the system clock which helps in giving the clock signal to the various events taking place within the FPGA and the various programs that require clock for their working, A Digital clock manager [23] [24] can also be used to reduce the frequency of the system clock so that it is useful for various other purposes which need smaller clock frequency. On-board USB-based FPGA [24] download and debug interface is also in the Spartan-3E

kit in which the programmable file is dumped into the FPGA via the USB based download cable. Hence it is very much helpful in the testing of the programs whether they are working correctly or not, eight discrete LEDs can be interfaced to glow when a particular output becomes high. Hence the LEDs can be interfaced to show the output of a single bit. Four slide switches and four push-button switches are used to give the inputs to the FPGA board. They can also act as the reset switches for the various programs. Kit also has four-output, SPI-based on board Digital-to-Analog Converter (DAC) on board which is to be interfaced to give the analog output to the digital data values.

IV. SIMULATION RESULTS

Figure 7 (a) and (b) shows the snapshot results for image enhancement algorithm using DWT for 2D and 3D images respectively. Similarly, Figure 8 (a) and (b) shows the snapshot results for image enhancement algorithm using IMDCT for 2D and 3D images respectively. Simulation result is shown, considering 9 x 9 image sizes for 2D and 9 x 9 x 9 image for 3D.

Step Input 1 : reset =1, clk is applied for synchronization and then run.

Step Input 2 : reset =0, clk is applied for synchronization.

In the modelsim waveforms *image_in_x_axis*, *image_in_y_axis*, *image_in_z_axis* represents the integer value of image at discrete points at X, Y and Z axis respectively which is a matrix of 9 pixels vales. *Sample_x_axis*, *Sample_y_axis*, *image_z_axis* represents the integer value of image in discrete samples at X, Y and Z axis respectively by which image should be enhanced. It is also a matrix of 9 pixels vales corresponding to each input value of image. *image_out_x_axis*, *image_out_y_axis*, *image_out_z_axis* represents the corresponding results of image enhancement at X, Y and Z axis respectively within a matrix of 9 pixels vales. *P-state* and *n_state* are the present state and next state to develop the chip using Finite State Machine (FSM).

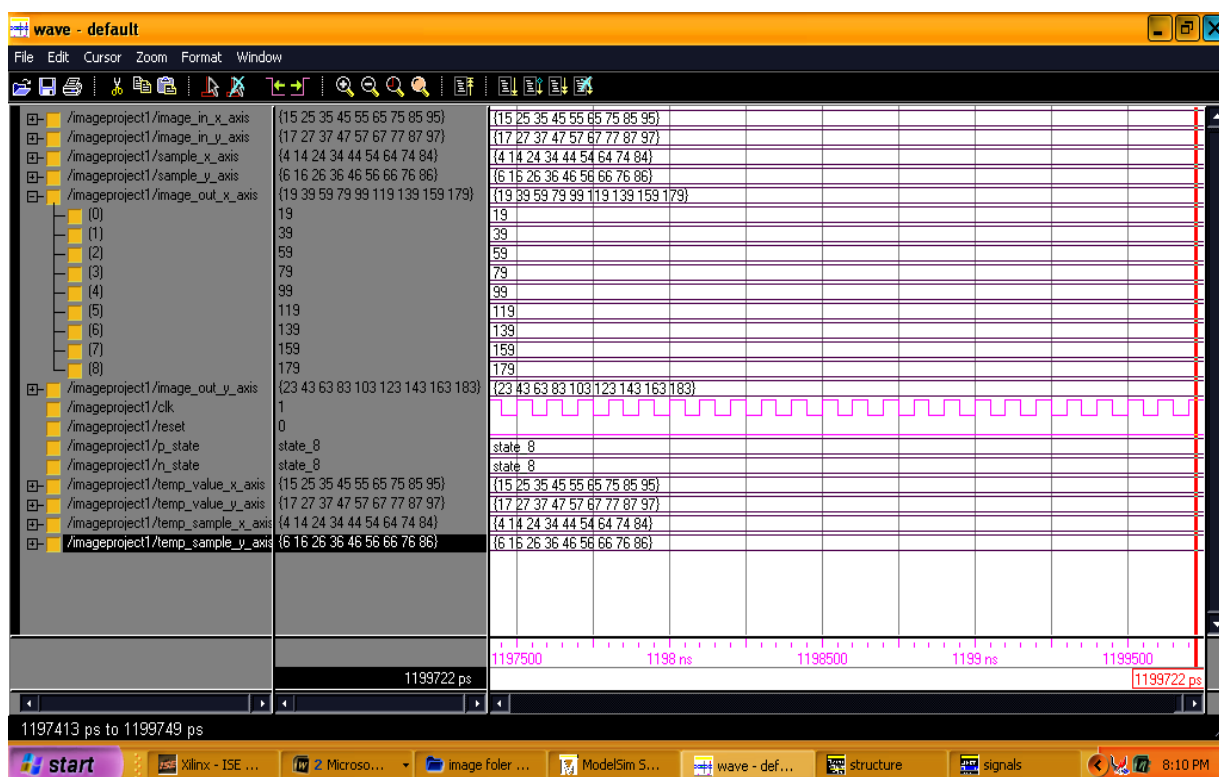


Figure 7 (a) : Modelsim waveform for 2D image enhancement chip using DWT

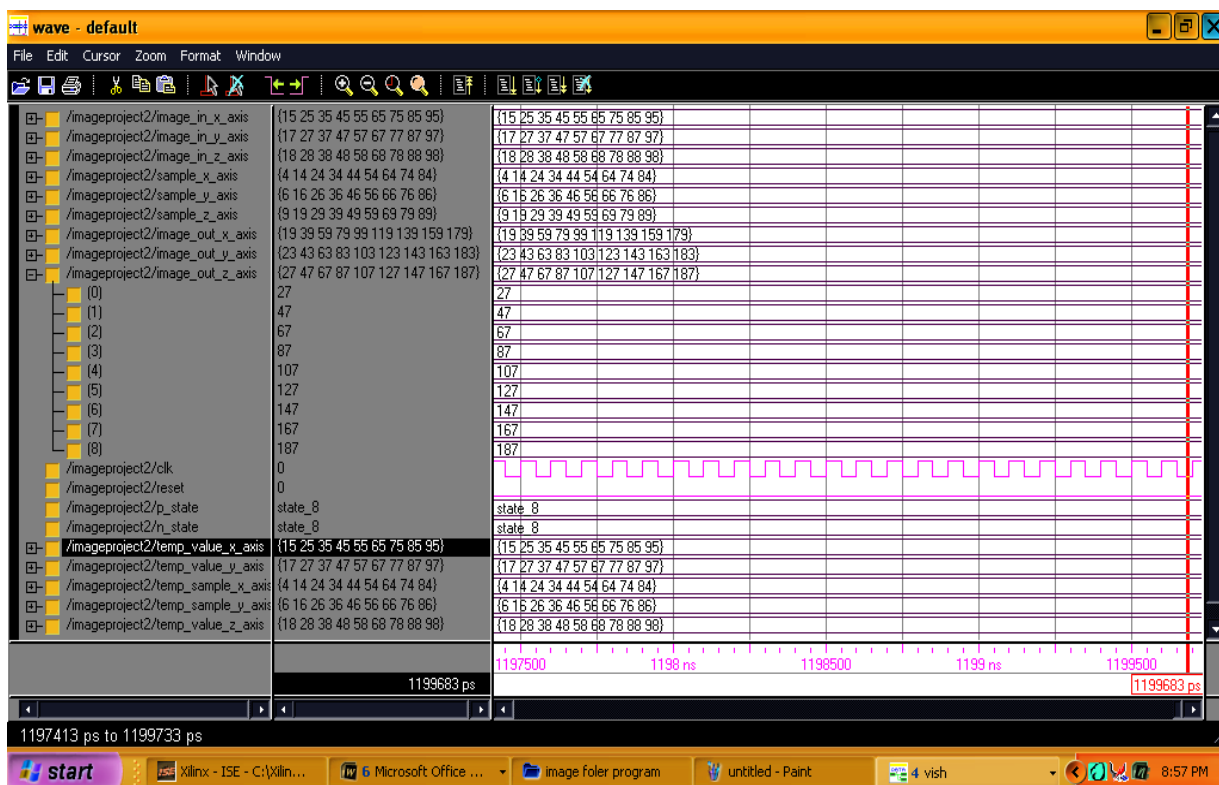


Figure 7 (b) : Modelsim waveform for 2D image enhancement chip using DWT

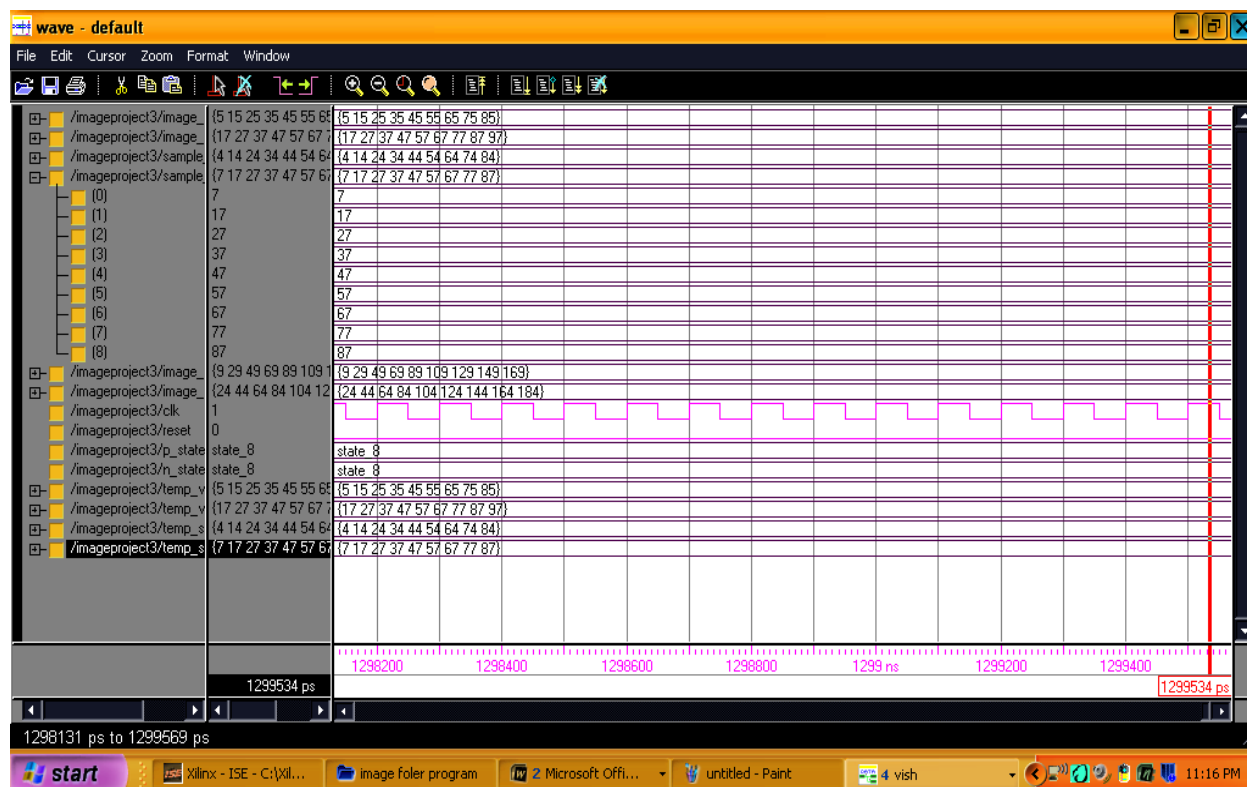


Figure 8 (a) : Modelsim waveform for 2D image enhancement chip using IMDCT

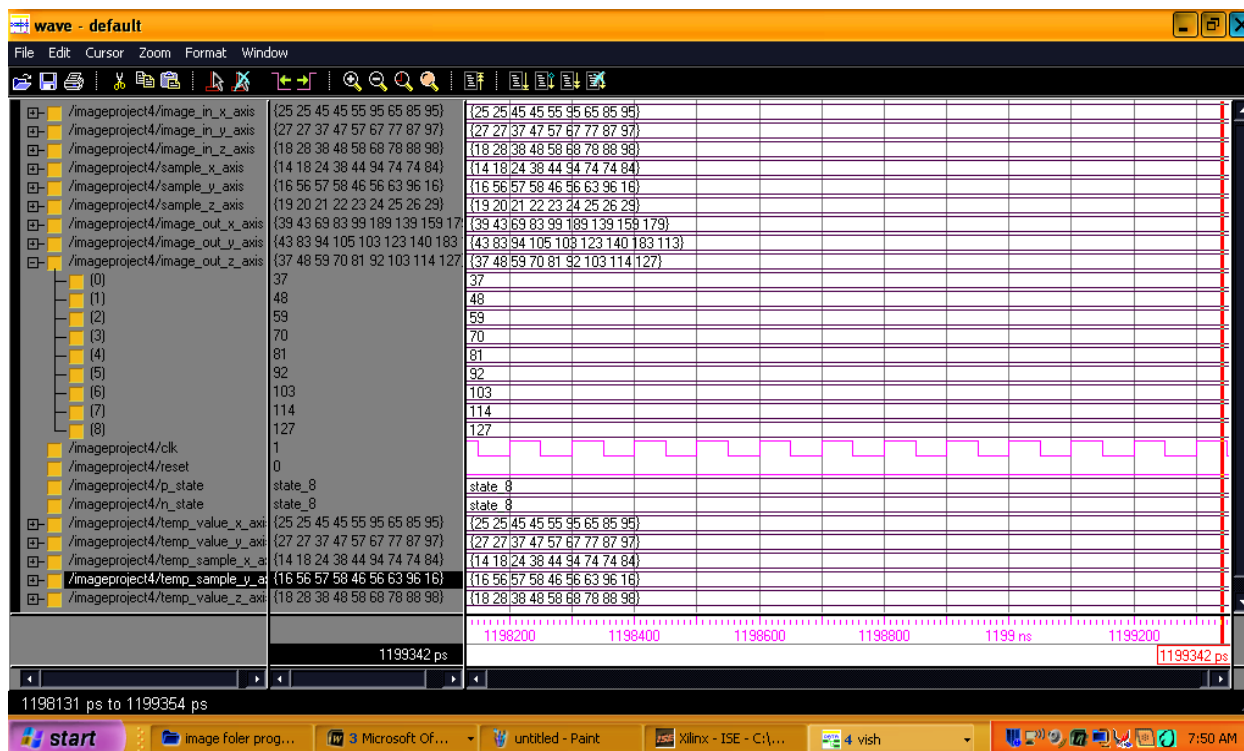


Figure 8 (b) : Modelsim waveform for 3D image enhancement chip using IMDCT

V. DEVICE UTILIZATION AND TIMING SUMMARY

Device utilization report is the report of used device hardware in the implementation of the chip and

timing report is the minimum and maximum time to reach the output. Table 1 and 2 shows the detail of device utilization for 2D and 3D images using DWT and IMDCT respectively.

Selected Device: xc3s250e-5pq208

Table 1 : Device utilization for 2D and 3D image using DWT

| Device Part | 2D Image (DWT) | | | 3D Image (DWT) | | |
|------------------------|----------------|-----------|-------------|----------------|-----------|-------------|
| | Used | Available | Utilization | Used | Available | Utilization |
| Number of Slices | 1294 | 2448 | 52 % | 1934 | 2448 | 79 % |
| Number of Flip Flops | 20 | 4896 | 0 % | 20 | 4896 | 0 % |
| Number of 4 input LUTs | 1164 | 4896 | 23 % | 1740 | 4896 | 35% |
| Number of bonded IOBs | 149 | 158 | 94 % | 149 | 154 | 97 % |
| Number of GCLKs | 8 | 24 | 33 % | 8 | 24 | 33 % |

Table 2 : Device utilization for 2D and 3D image using IMDCT

| Device Part | 2D Image (IMDCT) | | | 3D Image (IMDCT) | | |
|------------------------|------------------|-----------|-------------|------------------|-----------|-------------|
| | Used | Available | Utilization | Used | Available | Utilization |
| Number of Slices | 1031 | 2448 | 42 % | 1541 | 2448 | 62 % |
| Number of Flip Flops | 20 | 4896 | 0 % | 20 | 4896 | 0 % |
| Number of 4 input LUTs | 705 | 4896 | 14 % | 1055 | 4896 | 21% |
| Number of bonded IOBs | 149 | 158 | 94 % | 149 | 154 | 97 % |
| Number of GCLKs | 8 | 24 | 33 % | 8 | 24 | 33 % |

Timing Summary

Speed Grade:- 5

Table 3 : Timing details for 2D and 3D image using DWT and IMDCT

| Parameters | Utilization | | | |
|--|-------------|-------------|-----------|-------------|
| | 2D Image | | 3D Image | |
| | Using DWT | Using IMDCT | Using DWT | Using IMDCT |
| Minimum Period | 2.2012 ns | 2.0071 ns | 2.2511 ns | 2.0978 ns |
| Maximum Frequency | 715 MHz | 715 MHz | 715 MHz | 715 MHz |
| Minimum input arrival time before clock | 6.115ns | 2.055ns | 6.363ns | 2.157ns |
| Maximum output required time after clock | 4.179ns | 4.179ns | 4.179ns | 4.179ns |
| Memory Utilization | 141048 kB | 142072 kB | 155384 kB | 156408 kB |

Device utilization summary shows that number of slice utilization is reduced to 10 % in hardware chip design for 2D image using IMDCT, for 3D there is 16 % reduction in number of slices using IMDCT. There is a reduction of 9 % and 14 % in number of LUTs for 2D and 3D image chip using IMDCT respectively. Numbers of Flip Flops, bounded I/O, Number of GCLKs are same for both. Memory utilization shows an increment of 0.72 % for 2D and 0.65 % for 2D using IMDCT. Timing summary shows, there is 9 % reduction in minimum period for 2D and 7 % for 3D using IMDCT. There is great reeducation in Minimum input arrival time before clock which is 66 % change for 2D and 63 % for 3D using IMDCT method. The value of Maximum Frequency and Maximum output required time after clock are same.

VI. CONCLUSION

Image enhancement chip develop for 2D and 3D image is done using DWT and IMDCT transformations. Hardware parameter shows that there is 10 % reduction in number of slices in chip design for 2D image and 16 % reduction for 3D using IMDCT. There is great reeducation in Minimum input arrival time before clock which is 66 % change for 2D and 63 % for 3D using IMDCT method. Such applications are used in digital camera, satellite imaging, digital watermarking, X-rays, medical imaging, facial reorganization, Optical character reorganization and authenticity. This work is a significant effort towards total digitization of image processing and would surely prove a boon for VLSI design industry.

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