HARDWARE IMPLEMENTATION OF 2D HAAR WAVELET TRANSFORM

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***ABSTRACT*— This paper proposes a system for iris pattern analysis by using a filter based architecture of Haar Wavelet Transform (HWT). Feature encoding and iris code matching are two main modules of this system. In spite of having many other methods 2D HWT is chosen because of its high speed and computational simplicity. Unrolled iris images are filtered using low pass and high pass HWT filters in feature extraction module. Filtering is required four times to generate corresponding coefficients so we developed architecture up to 4th decomposition level. Iris code matching is performed by calculating hamming distance in 2nd module. This design has been implemented using system-level modeling tool that facilitates FPGA hardware design. It extends Matlab Simulink in many ways to provide a modeling environment that is well suited to hardware design. In this paper Signal Processing is implemented as an application of bio-medical on Xilinx FPGA board–ML507. The ML507 board utilizes Xilinx Virtex 5 XC5VFX70T-FF1136 device.**

Index Terms— **HWT, System generator, Mallot algorithm, image compression, sub-band coding, iris reorganization.**

I. INTRODUCTION

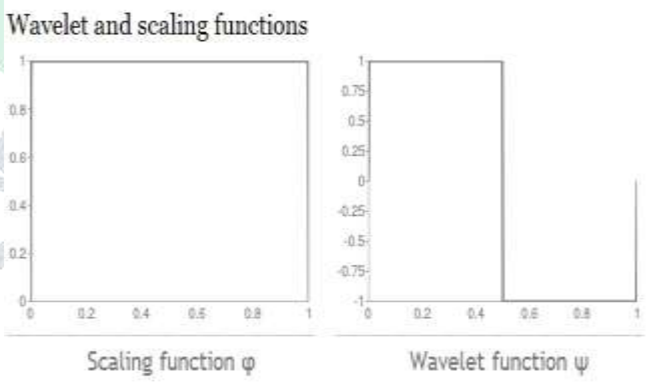
Recently, Wavelet Transform (WT) has gained very high attention in many fields and applications such as biomedical, physics, engineering, signal processing, applied mathematics and statistics. Advances in bio-medical imaging require efficient speed, high resolution and real-time memory optimization. Wavelet Transform (DWT) is widely used method for these bio-medical imaging systems because of perfect reconstruction property. DWT can decompose the signals into different sub bands with both time and frequency information and facilitate to arrive at high compression ratio. DWT architecture, in general, reduces the memory requirements and increases the speed of communication by breaking up the image into the blocks but use of HWT is really significant in biomedical field.

Iris pattern analysis has become a popular area of research in biomedical during past decade. It plays a major role in identifying and recognizing an individual given a huge database. There are a few challenges faced while developing an iris recognition system. Among them are the dynamic sized iris region that causes a direct match to be infeasible, and the invariant moment of the eye that caused by the angle of the head while the eye image is taken. Despite all these challenges, there are many automated iris recognition systems which have been commercialized over these years using different approaches. Haar decomposition extracts the iris features and converts them into 348-bits iris code to effectively recognize an individual. Besides its advantage in computational simplicity and speed, Haar wavelet decomposition is also less likely to be affected by environment factors as compared to Gabor wavelet. Due to the computational simplicity and high speed in matching binary strings, Haar wavelet decomposition and Hamming distance are adopted to perform iris feature extraction and iris code matching in our proposed system. To fasten the matching speed, a lower number of bits (348 bits) is used in composing the iris code, as compared to 2048 bits used in other methods.

In this paper, we have used HWT for feature extraction and image compression. This paper is organized as follows: In section II, mathematical formulation of 2D HWT computation necessary is presented. Section III, shows iris recognition methodology. In section IV, proposed architecture is implemented. In Sections V, results of proposed architecture are accessed. Section VI, presents conclusion and further improvement suggestions.

II. FORMULATION FOR COMPUTATION OF HWT

In mathematics, the Haar wavelet is a certain sequence of rescaled "square-shaped" functions which together form a wavelet family or basis. Wavelet analysis is similar to Fourier analysis in that it allows a target function over an interval to be represented in terms of an orthonormal function basis. The Haar sequence is now recognized as the first known wavelet basis and extensively used as a teaching example in the theory of wavelets.



Scaling function φ Wavelet function ψ

Figure1. Wavelet and scaling functions of Haar

$$\phi(t) = \begin{cases} 1 & 0 \le t < 1, \\ 0 & \text{otherwise.} \end{cases} \quad (1)$$

This function is known as the scaling function of the wavelet. For the band-pass sequences the impulse responses converge holding the final difference equation which can be calculated as:

$$\psi(t) = \begin{cases} 1 & 0 \le t < 1/2, \\ -1 & 1/2 \le t < 1, \\ 0 & \text{otherwise.} \end{cases} \quad (2)$$

This is also called mother wavelet. If the scaling and Wavelet functions are separable; the summation can be decomposed into two stages. First step is along the x-axis and then calculate along the y-axis. For each axis, we can apply fast wavelet transform to accelerate the speed. Figures below shows the high pass and low pass coefficients of HWT.

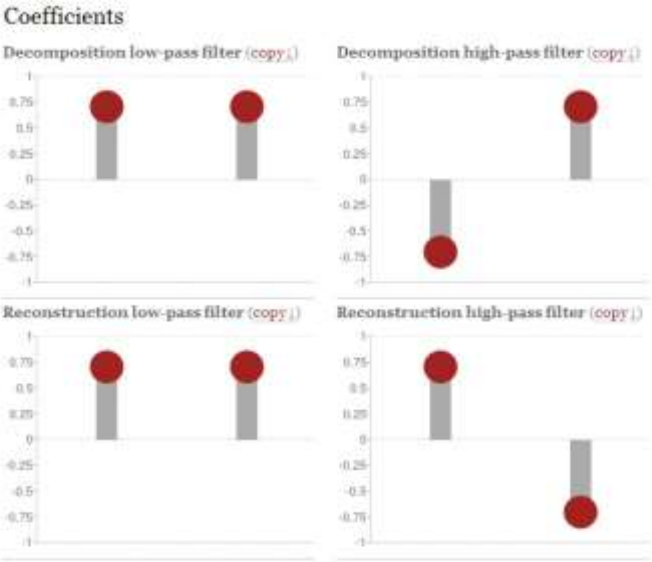


Figure 2. Low pass and High pass Haar coefficients

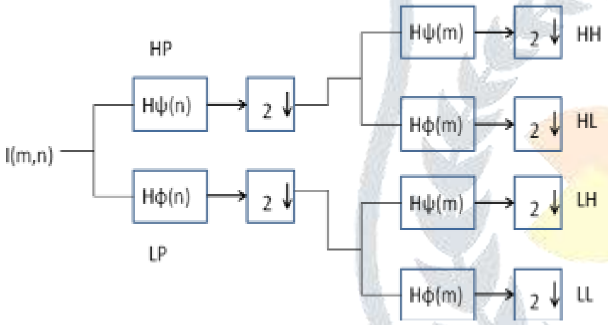


Figure 3. Block diagram of Haar wavelet one level decomposition

III. IRIS DETECTION METHODOLOGY

Our approach in this paper is using Haar wavelet decomposition to extract the iris features, and Hamming distance to measure the dissimilarity between the binary iris codes.

A. *IRIS FEATURE EXTRACTION PROCESS*

In the first module, an unrolled iris image contrast is enhanced using histogram to enable a better extraction of pattern by transforming the values in an intensity image, or the values in the color map of an indexed image, so that the histogram of the output image approximately matches a specified histogram. Figure 2 shows the effect of performing histogram equalization on an iris image. Histogram equalized iris region is then decomposed using Haar decomposition up to four levels of decomposition.

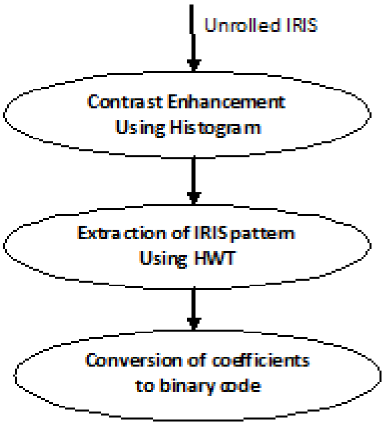


Figure 4. Iris Recognition Process

Since decomposing the iris region of 450 X 60 pixels will produce a very large number of coefficients, in our method, we only choose to take the fourth level of Haar decomposition to reduce the code length. Taking only the fourth level decomposition will produce 348 coefficients. These numbers are then converted to binary iris code simply by converting positive coefficients to 1 and negative coefficients to 0.

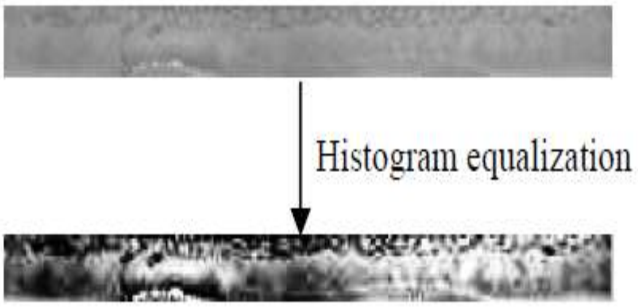


Figure 5. Unrolled iris image before contrast equalized and after equalized

B. *IRIS CODE MATCHING*

The iris codes in the database are used to find out which iris codes come from the same eye. Hamming distance is chosen because of its speed in calculating dissimilarity between binary codes. The formula is shown in Equation where *HD* is the Hamming distance between *jth X* and *Y* binary codes, and *N* is 348 in this case.

$$HD = \frac{1}{N}\sum_{j=1}^{N}(X_j \oplus Y_j) \tag{4}$$

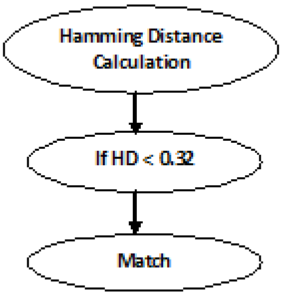


Figure 6. Iris Code Matching Process

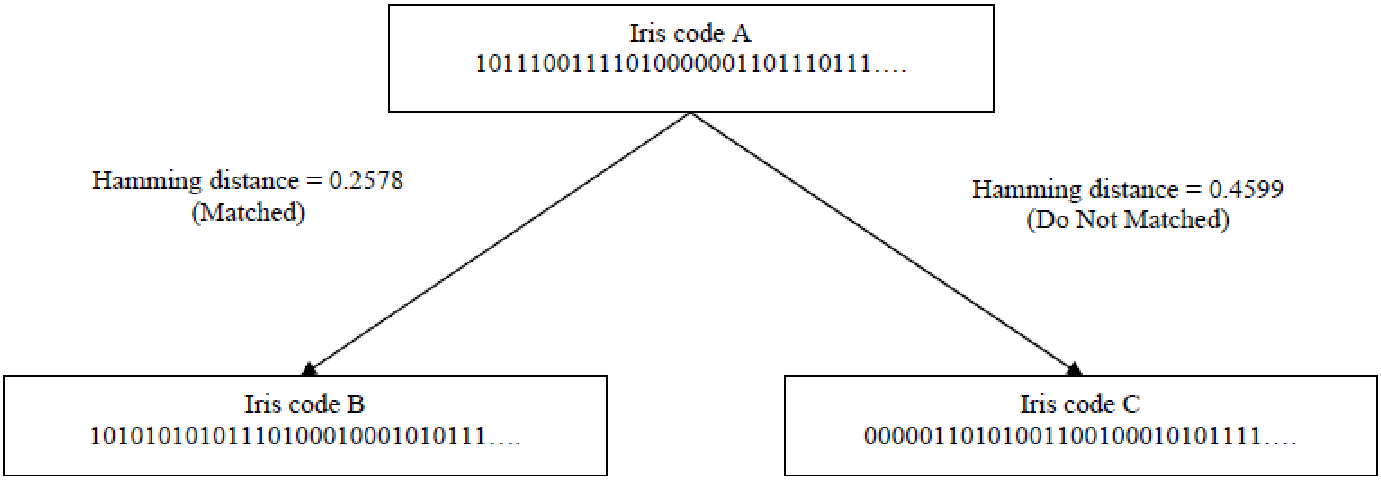


Figure 7. Iris code matching

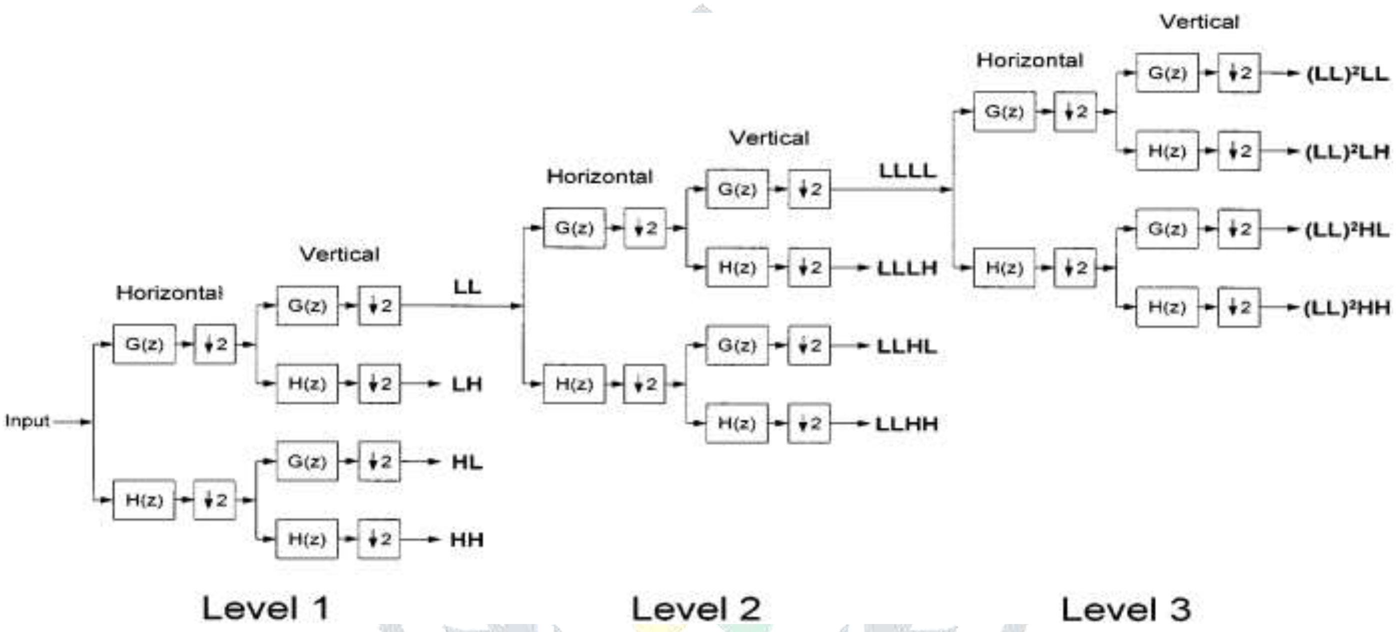


Figure 8. Haar three level decomposition

V. PROPOSED DESIGN

Video and image compression codecs such as MPEG or JPEG use block coding techniques where a biomedical image is typically divided into small blocks of 8x8 or 16x16 pixels and subsequently processed by frequency transform, motion compensation, quantization and entropy encoding procedure. Reduction of data rate for compression and loss of packets during transmission leads to several artifacts in the received video (image) such as blocking, blurring and ringing. Blocking artifacts appear as a regular pattern of visible block boundaries. This degradation is a direct result of the coarse quantization of the coefficients or loss of packets and the independent processing of the blocks which does not take into account the existing correlations among adjacent block pixels. System Generator allows designs to be composed from a variety of ingredients. Data flow models, traditional hardware design languages (VHDL, Verilog, and EDIF), and functions derived from the MATLAB programming language, can be used side-by-side, simulated together, and synthesized into working hardware. System Generator simulation results are bit and cycle-accurate. This means results seen in simulation exactly match the results that are seen in hardware. Here, we need not to perform quantization of wavelet coefficients. This tool provides high-level abstractions that are automatically compiled into an FPGA at the push of a button. The tool also provides access to underlying FPGA resources through low-level abstractions, allowing the construction of highly efficient FPGA designs. In this paper, we are presenting 1st and 4th level decomposition image.

A. 1ST LEVEL DECOMPOSITION ARCHITECTURE

An unrolled iris image of size MxN as input is provided and M/2xN/2 image as output is produced after 1st level decomposition. Computation steps are given as:

[1] In first step image will go column by column to low pass and high pass filter of haar wavelet.
[2] Down sample the sequence by 2 at second step.
[3] Reconstruct the image (now image size will be (M, N/2)).
[4] Process the image row by row to Haar wavelet of low pass and high pass filter.

The figures below give the FIR Filter design for the Discrete Haar Wavelet Transform. These filters are required in order to carry out the Fast Wavelet Transformation. As shown in the figures we can see the filter coefficients being multiplied to the signal after the application of an appropriate delay.

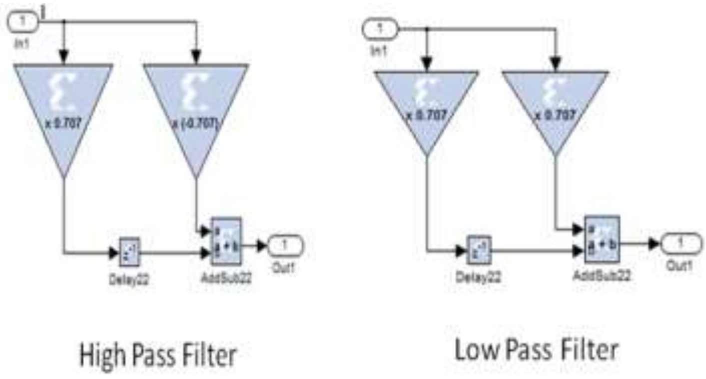


Figure 9. System generator LPF and HPF

We have to generate the delay of one row that is M so that images can be processed row by row and delay of N for processing image column by column. Following figure shows the 2D HWT architecture for 1st level decomposition.

B. 4th LEVEL DECOMPOSITION ARCHITECTURE

This architecture takes unrolled iris image of size MxN as input and produces M/8xN/8 image as output which is sufficient to produce the required corresponding coefficients.

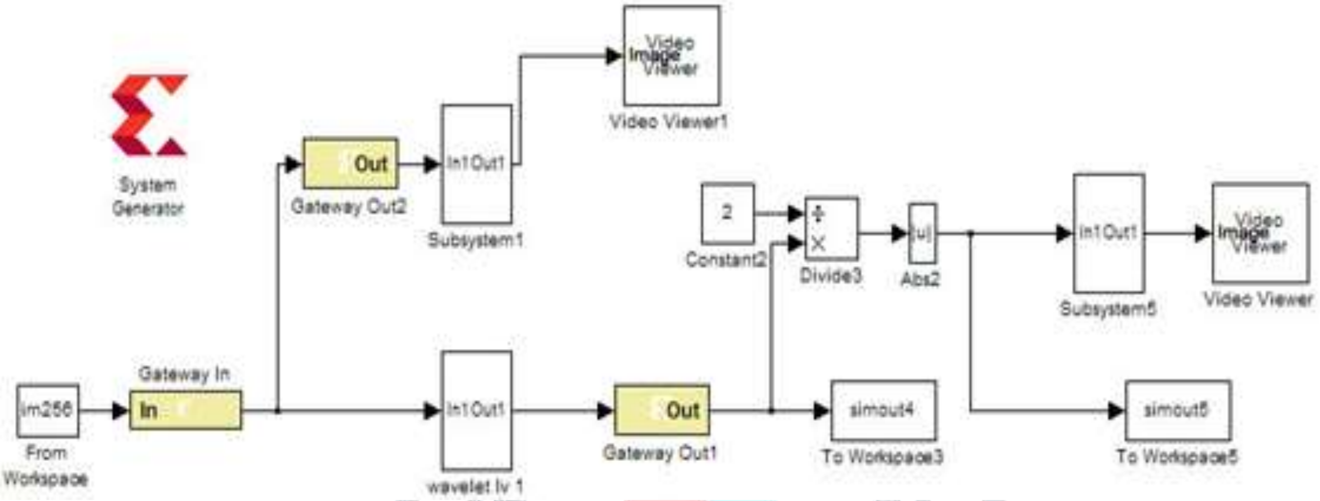


Figure 10. 1st HWT Decomposition Architecture

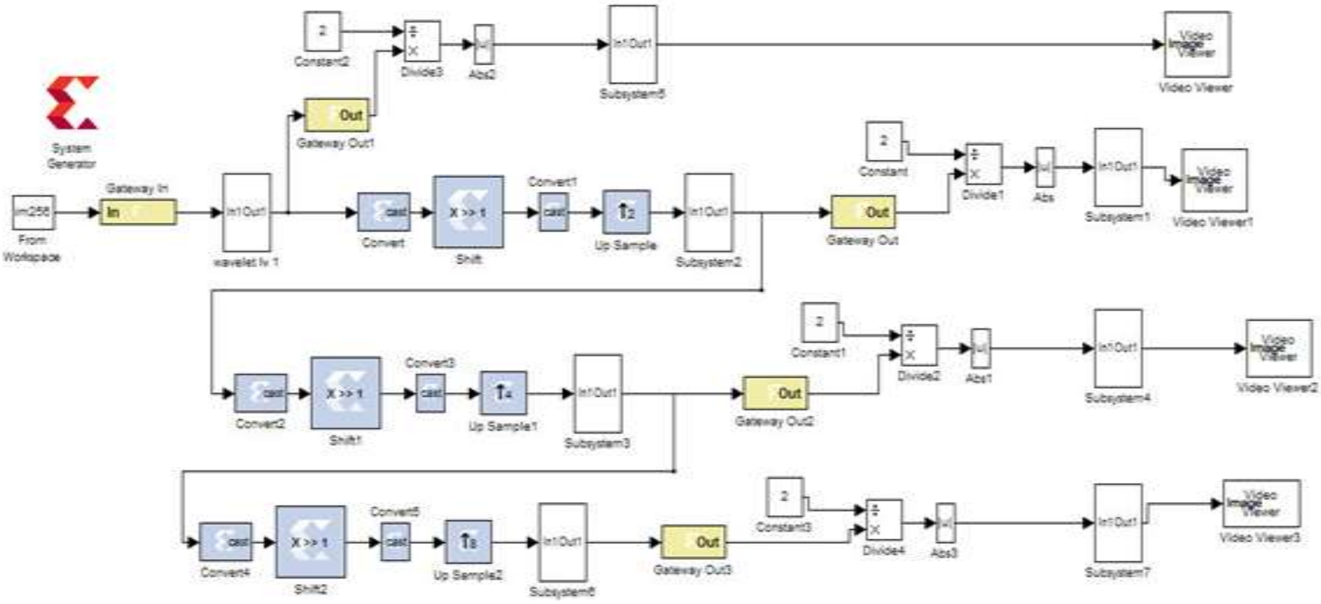
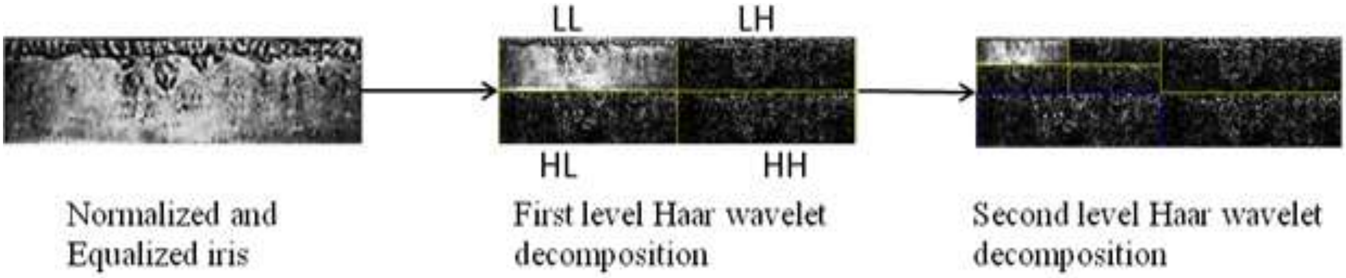
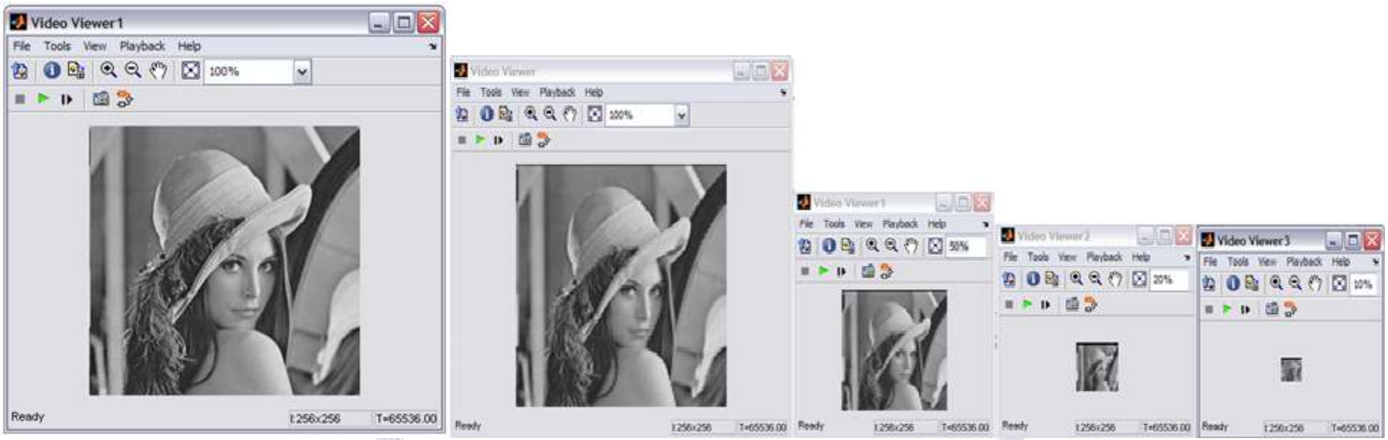


Figure 11. 4th HWT Decomposition Architecture

IV. Simulations

The architectures for HWT filter bank were implemented on system generator by performing co-simulation of the Xilinx 13.1 and matlab 2010a. The designs were tested with 256x256 Lena image and unrolled iris image. Figure displays the results of verification.





Input image

After 1st level Decomposition

After 2nd level Decomposition

After 3rd level Decomposition

After 4th level Decomposition

Figure 12. Decomposition Results

V. Conclusion

In this paper, Haar decomposition is used to extract the feature of the human iris and image compression. Hamming distance was calculated by converting the decomposition coefficients of iris into binary codes. Haar decomposition is rather simple compare to Gabor wavelet, because of its computational simplicity and lesser parameters are involved in determining the accuracy of the method. Despite the simplicity of Haar decomposition, this approach has achieved a high recognition rate up to 98.45%. An iris pair with Hamming distance above a threshold of 0.32 is matched against each other, whereas the rest are rejected. The main reason a perfect accuracy cannot be obtained is due to the quality of the test data and the iris regions are not segmented accurately due to noises like eye lashes and lighting effect.

Acknowledgement

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